Towards Round 3: Building the Offshore Wind Supply Chain

A review for The Crown Estate on how to improve delivery of UK offshore wind

BVG Associates

BVG Associates is a consultancy providing expertise in the design, technology and supply chain for fuel-less renewable electricity generation systems. The team probably has the best independent knowledge of the supply chain and market for wind turbines in the UK. BVG Associates has over 75 man years experience in the wind industry, many of these being 'hands on' with wind turbine manufacturers, leading RD&D, purchasing and production departments. BVG Associates has consistently delivered to customers in many areas of the wind energy sector, including:

- Market leaders and new entrants in wind turbine supply and UK and EU wind farm development.
- Market leaders and new entrants in wind farm component design and supply.
- New and established players within the wind industry of all sizes, in the UK and on most continents.
- Department of Energy and Climate Change (DECC), British Wind Energy Association (BWEA), Renewables East, Scottish Enterprise, Invest NI, One North East, NaREC and other similar enabling bodies.

Summary

Offshore wind has the potential to play a significant role in the European energy generation mix as the continent makes the transition to a sustainable energy future over the next 40 years. A key early impetus is the binding national targets for renewable energy generation by 2020 set by the European Union. The UK has furthest to go in meeting these targets and also the best wind resource. To date, the UK heads the world in terms of offshore wind installation and frameworks are in place to stimulate significant increases in capacity over the next 12 years.

Today, however, the economic viability of offshore wind is marginal and concerns about the sustainability of the industry are hampering delivery and investment in supply capability and next generation technology.

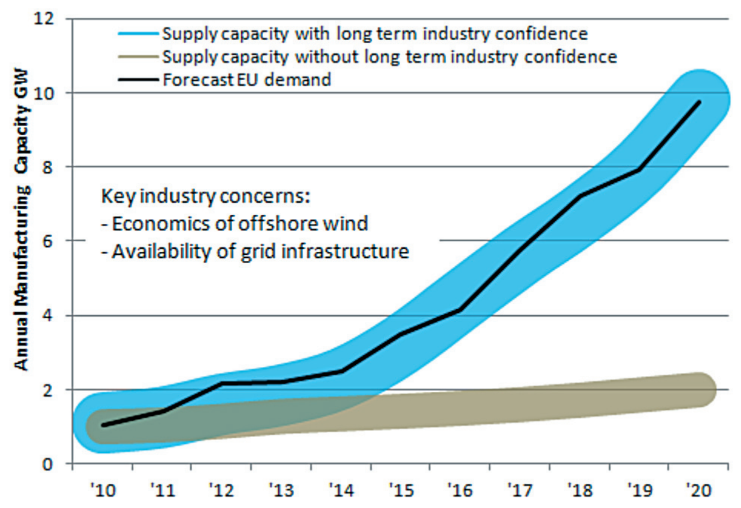
The Crown Estate wishes to play a leadership role in developing the industry. This report was commissioned by The Crown Estate in order to establish current supply chain status and to encourage positive action across the sector in order to deliver significant capacity in the UK by 2020. In addition to this report, BVG Associates has recommended to The Crown Estate a wide range of specific actions for consideration that are summarised under the following broad headings:

- Influence Government to improve economics, define deployment targets, remove barriers and facilitate wealth creation through UK industrialisation for offshore wind, thus establishing long-term **confidence** and increased **competition**.
- Use the granting of zone licences to consortia to encourage the industry to increase **collaboration** and work strategically to improve costs.
- Facilitate the growth of an industry characterised by good practice, strong communication and an excellent health and safety culture.
- Engage internationally to maximise long-term viability of a number of offshore wind markets and stimulate international cooperation, both in innovation and delivery.
- Invest in infrastructure around UK ports and technology demonstration in order to maximise deployment capability and the development of next generation technology.

We have undertaken a significant consultation with the industry to establish the capability of the supply chain to deliver significant capacity.

We conclude that given a favourable economic environment and necessary progress with grid infrastructure, then with the key ingredients of long-term **confidence**, **competition** and **collaboration**, current constraints will be addressed in time to deliver up to 33GW in the UK by 2020. Without these conditions, supply capacity will increase only slowly.

For the long-term success of the industry, we have to invest throughout the years up to the start of installation of Round 3 to make significant progress in developing technology, processes and industry culture.



" We've passed the point of no return for offshore wind - it will happen on a big scale."
UK UTILITY DEVELOPER

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1. Introduction

1.1. The Crown Estate and Offshore Wind

The Crown Estate owns most of the seabed out to the UK's 12 nautical mile territorial limit, including the rights to explore and utilise the natural resources of the UK continental shelf (excluding oil, gas and coal). More recently the Energy Act 2004 vested rights to The Crown Estate to license the generation of renewable energy on the continental shelf within the Renewable Energy Zone out to 200 nautical miles. It has made areas of seabed available for offshore wind development in three rounds, announced in December 2000, July 2003 and June 2008. Round 1 consisted of 18 demonstration projects in 13 locations, with total capacity of around 1GW. In Round 2, The Crown Estate made 15 sites available with a potential capacity of over 7GW. In Round 3, The Crown Estate offered 11 (now reduced to 9) zones with the potential for a further 25GW of offshore wind.

DECC published a Strategic Environmental Assessment (SEA) consultation paper in January 2009 which broadly confirmed the feasibility of the Round 3 potential. Already, exclusive rights to develop a further 6GW of sites within Scottish Territorial Waters have been awarded to 10 consortia. Further rounds are likely to expand significantly the UK's offshore wind capacity looking well beyond 2020, with many of these new sites likely to be in deeper water or further from shore.

1.2. Purpose of this Study

The Round 3 zones represent significant assets for The Crown Estate, with much of the best wind resource in Europe, and The Crown Estate recognizes that its role is broader than just to license areas for development of offshore wind. The Crown Estate has a key leadership role to play in enabling a young industry to establish, especially against a backdrop of tough binding national renewable energy targets agreed by the EU last year.

In order for The Crown Estate to show leadership in addressing key issues and constraints facing the industry, it needs to understand these better. At the heart of this study has been a significant process of listening to key players in the sector – their aspirations, concerns, needs and ideas. The Crown Estate understands that there are actions that it can implement to accelerate the development of a sustainable industry, and that there are actions best led by others, where The Crown Estate can influence decision making and facilitate progress.

This study considers all parts of the supply chain, interpreted in the broadest sense to cover not only the components and services needed to install and operate an offshore wind farm but also the infrastructure and broader landscape in which these investments are made. It presents the current landscape, supply chain and key issues. BVG Associates has made confidential recommendations to The Crown Estate to address each of these issues.

Although the focus of this work relates to the delivery of Round 3, the study also considers activity in both Rounds 1 and 2, Scottish Territorial Waters and also in the rest of Europe. Critical to the success of Round 3 is a vibrant industry learning much from the implementation of earlier projects in less demanding conditions. No consideration of supply chain would be complete without looking at the whole European picture, as for most key elements of supply, the market is that of European offshore wind, not just UK offshore wind – indeed, in a politically driven sector, the UK needs other vibrant national offshore wind markets in order to give sufficient confidence and market size to the supply chain to invest wholeheartedly.

Note that most dialogue with the wind industry was carried out before this year's Government Budget in late April. Further dialogue since the budget has been used in order to reflect most fully the latest views of the industry.

1.3. The UK's Targets

In order to meet its commitment to the EU target of 20% renewable energy by 2020, the UK will need to generate 30 to 35% of its electricity from renewable sources. The largest contribution will be from wind, both onshore and offshore. In order to help achieve this, The Crown Estate has declared intent to facilitate up to 33GW of offshore wind power generating capacity being brought on line in UK waters by 2020. Figure 1.3.1 below shows a forecast of installation, broken down by region. This forecast includes all Round 1 & Round 2 projects and assumes 25GW installed by 2020 from development in Scottish Territorial waters and Round 3 zones, with the remaining activity following after 2020. The forecast considers relative economic viability of zones by considering typical water depth and distance to shore, as well as area.

With a gradually growing average size for offshore wind turbines, it is relevant also to consider the number of turbines to be installed (see Figure 1.3.2).

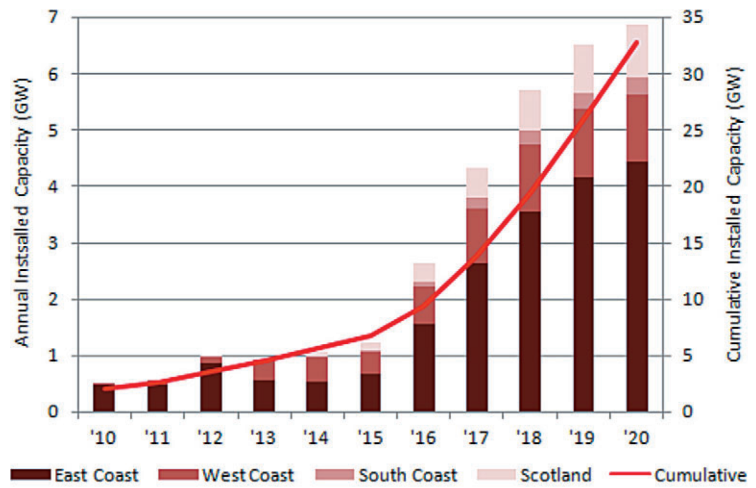

Figure 1.3.1. Projected annual and cumulative UK offshore installation to 2020 in GW. *The forecast assumes that installation in Scottish and Northern Irish territorial waters supplements Round 3 activity. The geographical split is based on Round 3 developments only.*

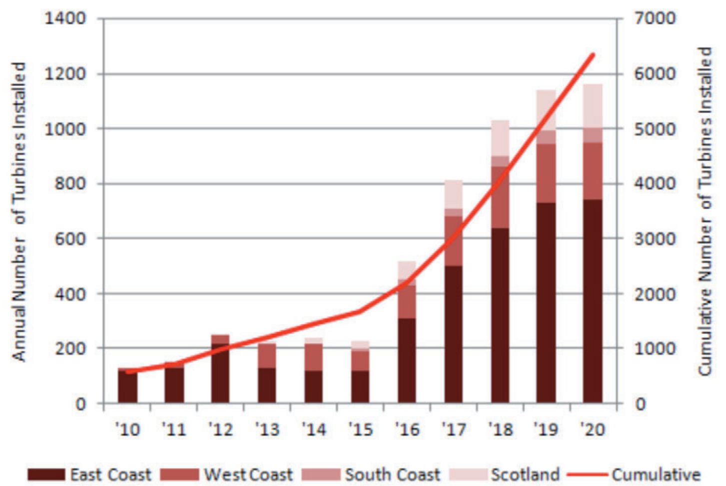

Figure 1.3.2. Projected number of turbines installed offshore UK to 2020. *The forecast assumes that installation in Scottish and Northern Irish territorial waters supplements Round 3 activity. It is anticipated that the average power rating of turbines to be installed each year will rise to just below 6MW by 2020.*

1.4. European Projections

It is important to consider the UK market in the context of the whole European offshore market, as most supply issues relate to the European market, not just the UK in isolation. The European picture is presented in Figure 1.4.1, using anticipated country-by country activity to 2015, combined with EWEA's estimate of total non-UK installation up to 2020. Key to note is that the levelling off followed by sudden increase anticipated in the UK between 2013 and 2016 is smoothed significantly when looking at the EU-wide picture. It is recognised that post 2020, offshore wind activity outside of Europe is likely to become an important consideration. Discussion with the supply chain has been in the context of this projection, recognizing that delivery of a full 33GW in the UK by 2020 required an impetus that had not been provided before this year's Budget.

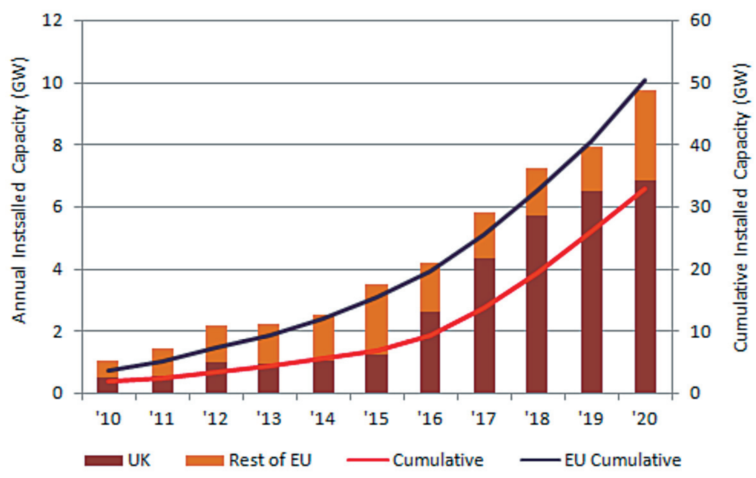

Figure 1.4.1. Projected annual and cumulative offshore installation to 2020 in MW in UK and rest of Europe.

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2. Industry Level Issues

There are a number of factors that contribute to the successful development of UK offshore wind, summarized in the sections below. Whilst the focus of this study is supply chain capability, insight is provided also in each of the other five areas.

- **Economic Viability**
- **Government Policy**
- **Infrastructure Provision**
- **Supply Chain Capability (focus of this report)**
- **Health and Safety**
- **Skills Availability**

2.1. Economic Viability

The considerable interest in Round 3 zones indicates that the industry believes that UK offshore wind has the potential to be a long-term viable investment.

2.1.1 Pre-Budget

Up until the Budget announcements in April 2009, feedback was that economics have worsened over the last two years for a number of reasons.

> *"Economics quite significantly worse than last year."*
> *UK UTILITY DEVELOPER*

- **Unfavourable exchange rate.** This has increased purchase costs in Sterling for most supply items by around 20% in the second half of 2008, currently with little opportunity for wind farm purchasers to balance exchange rate risks with UK supply. Buying wind farm components and services in Euros and selling power in Pounds is not currently an attractive combination.

> *"The exchange rate has caused a 20% increase in the cost of European imported components in the last 4 months; this has meant it's worth re-opening discussions about UK supply." SLP ENERGY*

- **Fall in electricity prices.** Electricity prices in UK have in recent times fallen due to decreases in fuel costs for conventional generation. In the short term, those negotiating power purchase contracts for offshore wind are not able to secure the same long-term contracts as two years ago. In the long run, offshore wind benefits from almost negligible fuel price impact once operational.
- **Increases in commodity prices.** The cost of energy from offshore wind is dominated by CAPEX which is impacted much more than conventional forms of generation by changes in commodity prices, especially steel and copper. After significant increases over the last few years, last year's Q4 falls should bring benefits for offshore wind. Some are however seeing forward prices for structural steel rising again as suppliers reduce output and close facilities quickly in response to falling demand, though the general expectation is of decreasing commodity prices in response to the global economic situation.
- **Supply limitations.** Supply of wind turbines and other key wind farm elements has for many been focussed on US and other dynamically growing onshore wind markets in the last 3 years. The latest plans announced by the US Administration may give another significant boost to their home market, just at a point where new manufacturing facilities in the US were starting to provide around 50% of demand. This could once again take focus away from offshore wind, though there is evidence that investment into new facilities in the US has weakened in recent times. Likewise, an upturn in oil and gas work connected with last year's $100+/barrel prices will for a while continue to draw in resources that could otherwise have been focussed towards offshore wind.
- **Technical difficulty.** There has been much learning about working in relatively shallow coastal waters and adapting methods used in other sectors for multiple-repeat use in offshore wind farms. The result of this is that in a number of areas, costs of delivery of robust solutions have risen. Cable installation, major

component reliability, maintainability and access for maintenance are some of the key areas where learning has been significant.

- **Lack of availability of finance.** Though much utility investment is balance-sheet financed, some wind farms and much investment in new equipment relies on the availability of suitably priced finance. Since Q3 last year, this has been severely reduced and there is clear evidence that this has slowed progress in the industry and decreased competitiveness.

> *"Today, economics do not really add up… with economics resolved, much more will follow"* DONG

Economics was the dominant issue when considering delivery of new capacity for most offshore wind players consulted. Visible signs of this include the delay in the construction of the 250MW Lincs project, where we are advised that a range of suppliers have been working 'at risk' and are likely to be more circumspect with regard to other upcoming projects. Such delays threatened a return towards the conditions three years ago where some sub-suppliers asked for payment to quote, so often had they used valuable design resource to help shape wind farm projects that had then not progressed.

Universal feedback from developers was that economics were worsening, though some reported that it was still possible to justify construction of Round 1 and 2 projects (for example, the sanctioning of construction of 315MW Sheringham Shoal at the beginning of April 2009) and others reported that turbine costs were no longer rising and negotiation on terms and conditions had become possible, due to the global easing of supply limitations.

It was recognised that straight economic intervention would enable key Round 2 projects to move through to build and operation, thus re-establishing momentum, and that it would take separate intervention to enable significant industrialization in the UK in order to meet the manufacturing needs of the industry. This industrialisation is discussed further in Section 2.2.

The banding of the Renewables Obligation and its extension beyond 2027, finally law at the beginning of April, were welcomed by the industry. Though there was a strong view that there was an urgent need for the Government to make offshore wind more economically viable, there was a general recognition of the significant value in stability of market structures and that risk sharing or guaranteeing a minimum value of ROC-type revenue may be preferable to further adjustment of the ROC multiple through legislation. The consistent message received was that some intervention relating to economic viability was needed soon, before momentum and fragile confidence was lost.

It was recognised that the issue of economics of offshore wind could be solved quickly, given the right intent within Government. Similarly, it is recognised that the industry has an important role to play in helping itself, by constructive collaboration to improve costs through rational sharing of risk and development of new commercial and technical solutions as the industry matures and moves to work on larger projects further from shore and in deeper water. Again, the driver for investment in these areas is long-term confidence in the market.

Pre-Budget, two scenarios relating to long-term economic viability existed:

- **Poor/uncertain economic viability.** Some projects will continue to be built but supply chain confidence and hence investment in next generation technology and supply capability will be low. This means that over time, costs will not drop significantly, leading to a high overall cost of delivery of 2020 targets. This is where the industry saw itself. Despite EU targets, the general view is that we will install of the order of only 6-10GW in the UK by 2020 unless an impetus was provided.

- **Improved economic viability.** All good projects will be built and confidence in a long-term sustainable sector will grow, leading to strong investment in new technology and supply capability. This investment will help decrease costs, leading to an overall lower cost of delivery to 2020 and beyond. The industry expects that if an impetus is provided that improves viability, then at least 20GW will be delivered in the UK.

> *"The biggest bottleneck for Round 3 is ideas - we need to come up with cheaper ways to do things."* FARM ENERGY

Under the first scenario the underlying cost of energy will only improve by less than 10% by 2020, whereas the second scenario will lead to improvements of the order of 25%. We need to ensure that sufficient time and confidence is given to invest to enable costs to come down before the bulk of Round 3 activity begins, or else we will find ourselves repeating the same discussion regarding economic viability in 10 years time.

2.1.2 Post-Budget 2009

In the Budget, a number of new measures were set out, including plans for additional ROCs for projects reaching financial close before the end of the

2010/11 tax year and £4bn of new capital from the European Investment Bank for energy projects. Since then, the London Array consortium has announced investment in the first 630MW phase of its eventual 1GW wind farm, DONG has confirmed its commitment to build both phases of its Walney project in the North West and RWE npower has announced an acceleration of activity for the 750MW Gwynt y Mor project.

The general feedback from the development community is that the intervention is sufficient for construction of all 'good' projects that can be contracted whilst the additional incentive is in place – and that this applies to all live Round 1 development projects and all but 2-3GW of Round 2 projects.

This will produce a 'rush' of contracting activity, though other constraints are likely to smooth installation activity. It means that over the next 5 years, progress in delivering projects is likely to be good. With the additional costs associated with the majority of Round 3 projects, it is recognised however that the economic viability of these projects remains uncertain at a ROC multiple of 1.5 and this is likely to limit investment in the next-generation technology and thinking required in the years before Round 3 installation begins.

There is a fundamental dynamic between EU Governments (now with binding 2020 renewable energy targets to meet) and utilities tasked with delivering new renewable energy generating capacity that will continue to be played out over the next years. Some see that it is generally in the utilities' interest to delay large spends and hold out for further support, though the UK system does encourage early-movers through the sharing of ROC buyout revenue between those that have been awarded ROCs. In Germany likewise, the feed-in tariff is structured to provide extra revenue for early offshore wind projects.

It is beyond the scope of this work to quantify the current economic viability of projects. Such calculation is made difficult by the uncertainties present with any quota-based support mechanism, accentuated today by the lack of clarity in the forward value of ROCs.

Today, we see an industry hungry to develop and improve costs over time, which has received support for projects to be built using today's technology but perhaps without providing much additional confidence of long-term viability beyond these projects. We will show later that there are no critical barriers to delivery of large quantities of offshore wind power as long as the supply chain has the confidence to invest. Currently, it does not; it acts to provide what is needed now without in many cases investing wholeheartedly in the future.

2.2. Government Policy

Energy security and climate change are matters of Government policy. Generally, feedback is that the use of policy levers and Government influence to address barriers to deployment of offshore wind are having a positive impact, though there is more to do. The Strategic Environmental Assessment process and measures to streamline consenting via the Infrastructure Planning Commission are generally seen as positive by the wind industry.

In general, the wind industry also welcomes the creation of the Department of Energy and Climate Change in October 2008, though delays in the establishment of the new Office for Renewable Energy Deployment are unsettling. There remain concerns in the supply chain, also, that too often plans are diluted or delayed, leading to a sense that Government is not yet fully committed, making minor adjustments rather than addressing the needed fundamental changes. An example of this criticism is around the Transmission Access Review where for some considerable time, many have provided feedback that the proposed structures will not deliver what the industry needs in order to progress most efficiently.

> *"For Government to convince supply chain of the market, it will need to behave quite differently from up to now…"*
> ***SIEMENS T&D (pre-budget)***

Pre-budget, there was a growing view within the wind industry that the UK Government probably was indeed strongly committed to offshore wind, but with many still wanting to see real evidence. Certainly, there had been a strong increase in high-level contact between key industry players and central Government which was welcomed. Post-budget, the view is that decisive action relating to economics short term has been taken but the Government's position on industrialisation is not yet clear – strong progress is needed to confirm Government intent.

> *"UK is still THE market."*
> ***VESTAS***

> *"UK is Siemens' no. 1 market offshore, and is growing tremendously."* ***SIEMENS WIND POWER***

Feedback received is that the industry still views the UK as the number one offshore wind market. With German contracts starting to progress, however, there is an expectation of a "beauty contest" between UK and German markets and incentives in the lead-up to 2020, where both Governments are vying to meet stretching renewable energy targets with limited supply available.

Some people raise concern about political risks relating to a change of UK

Government. Conservative leadership is strongly supportive of offshore wind but its appetite for onshore wind is perceived as low. There are also concerns relating to the position of the Infrastructure Planning Commission under a Conservative government.

2.2.1 Targets
An area of almost universal concern for the wind industry is the level of perceived inconsistency over UK offshore wind aspirations. The Renewable Energy Strategy consultation initiated in summer 2008 proposed a forward view of renewable generation, with offshore wind contributing around 15GW of installed capacity by 2020. Government communications have however referred to a potential 33GW by 2020. Firm percentage ROC obligations do not go beyond 2015 and clarity on the expected technology split for the delivery of renewable energy targets has not yet been provided. Some clarity is anticipated with the publication of the Renewable Energy Strategy this summer. Further substance will be provided when the UK submits its National Renewable Energy Action Plan to the EU next year.

"Danes, Germans etc. have a national plan and stick to it, rather than having market approach. This continental approach is more likely to give confidence and hence deliver." **SIEMENS T&D**

The industry is concerned that lack of clarity now as to what the industry should/will deliver in the next 12 years or so is affecting confidence and hampering investment. Although the UK is unusual in operating a quota system to promote renewable energy generation in a relatively technology-neutral way, and therefore has only indirect policy levers, the industry would value greater consistency in the figures quoted by the Government and in Government-sponsored reports. To have a benefit, harmonisation needs to be around figures that make sense to the industry.

"Useful to have a shared installation target – otherwise there is no context for investors"
RWE NPOWER

There are a range of views within the industry as to the total capacity that will be installed in UK waters by 2020, from less than 10GW right up to the headline 33GW quoted by The Crown Estate, but with a modal value of around 20GW. Part of the reason for variation is because of significant installation rates anticipated around 2020 (i.e. 5-10GW per year offshore in Europe), which means that small changes in the installation schedule of projects can have a significant impact on the capacity installed by the end of 2020. The wind industry recognises that The Crown Estate's Round 3 process is a paradigm-changing initiative and that is having a valuable "stretch" effect. We suggest that a vision from The Crown Estate of 20-22GW by 2020 would keep that 'stretch' but would be more rational and allow a more industry cohesion around a common expectation. We set out the justification for this in the paragraphs below.

The key considerations in setting such a vision are:

- **Renewable energy targets.** 20-22GW fits with the likely need that the UK has from offshore wind, based on an evolving understanding of what technologies can indeed supply into the renewable energy mix required across electricity, heat and transport by 2020. The 15GW from offshore wind suggested by BERR last summer is seen as low by wind industry players who advise that the anticipated contribution from other renewable energy sources now looks optimistic – hence offshore wind will have a larger role to play.

- **Deliverability.** Although there are no critical supply chain constraints to the delivery of more than 30GW of offshore wind in the UK by 2020, risks associated with deployment at such rates are significant for a young industry. These relate to the suitability of technology still in development for offshore use and risks of one part of the supply chain not delivering in a rapidly evolving market-driven approach. Non-delivery of any one area (for example in grid infrastructure or installation vessels) jeopardises investment made in many other elements of the supply chain and the faster the growth, the more efficient the market and communication needs to be in order to deliver all links in the chain. 20-22GW is seen by the industry as a tough demand, but one that is achievable without excessive risk as long as long-term stability is provided and investment and communication are well enabled. Higher totals are achievable but only with an acceptance of some level of increased inefficiency.

- **Long-term sustainability.** In considering activity and investment in offshore wind, it is important also to look beyond 2020. If rates of installation leading up to the delivery of 2020 targets exceed activity post-2020, then such activity will be inherently inefficient, with resources that had been focussed on offshore wind needing to be re-deployed elsewhere. In looking beyond 2020, it is important to consider the long-term business provided by repowering offshore wind farms, rather than solely initial build. In Germany, we are just starting to see significant repowering of onshore wind farms. 20-22GW in UK by 2020 fits with an eventual capacity of the order of the order of 150GW in Northern Europe, whereas 33GW by 2020 fits with an eventual total of at least 180GW. The European Wind Energy Association forecasts 120GW of offshore wind operating by 2030, which in turn fits well with an eventual capacity of 150W, in line with EU energy strategy looking to 2050, where EU electricity demand is anticipated to be 4000TWh and where 60% will be supplied by renewables and (say) 40% of this by wind.

- **Maximising UK wealth benefit.** It is important to remember that beyond the benefit of meeting EU targets, offshore wind offers a considerable opportunity for UK to create wealth through provision of manufacturing and services in offshore wind. Should significant offshore wind development occur in the UK before other markets (as is currently anticipated to be the case) and should the UK positively choose to capture long-term benefit in terms of wealth creation though manufacturing, then there may be sense in setting higher expectations in order to make more obvious the case to invest in UK manufacturing rather than elsewhere around the North Sea. An approach that targets 30+ GW of installation by 2020 but that shows agnosticism about manufacturing location risks missing a supply opportunity not seen since North Sea oil and gas.

To deliver 22GW in UK by 2020, along with anticipated activity in the rest of Europe requires a peak installation rate for offshore wind of 6-8 GW per year across the EU. Considering repowering of projects, an indicative EU-wide scenario of ongoing installation up to 2050 is presented in Figure 2.2.1.1. Here, timing of development is optimized to give a smooth installation rate, with a scheduling of repowering assumed, whereby 20% is repowered before design life, 60% at end of design life and 20% after an extended life, adjusted for each UK Round to reflect the likely long-term viability of technology used. The split between Round 4 activity and EU non-UK activity is arbitrary. The cumulative capacity is the total net installed base, taking into account both the annual installed capacity and decommissioned capacity.

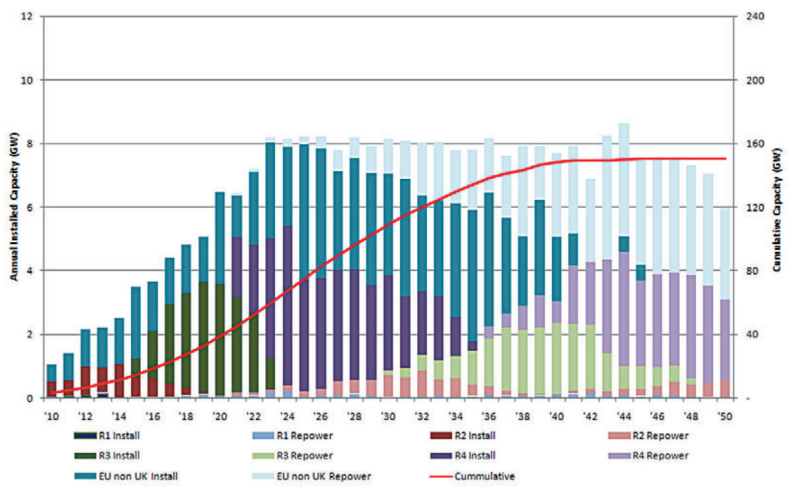


Figure 2.2.1.1. Indicative annual and cumulative offshore installation in UK and Europe to 2050, including anticipated Round 4 (BVG Associates indicative suggestion only) and repowering, based on target of 22GW in UK by 2020 and with ongoing installation across EU at 6-8GW per year.

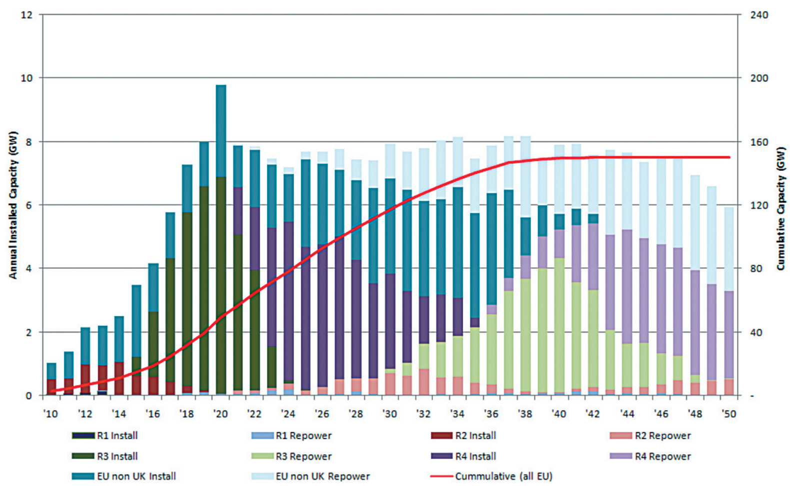


Figure 2.2.1.2. Indicative annual and cumulative offshore installation in UK and Europe to 2050, including anticipated Round 4 (BVG Associates indicative suggestion only) and repowering, based on target of 33GW in UK by 2020 and with ongoing installation across EU returning to 6-8GW per year.

If instead, a UK total of 33GW by 2020 is assumed, Figure 2.2.1.2 shows a significant peak in installation around 2020. If the long-term expectation is of capacity of the order of 150GW, then this would require inefficient short-term investment, for example in of the order of five extra installation vessels just to cope with the extra demand in 2020 than would be needed in either 2019 and 2021, coupled with a much more rapid acceleration in activity between 2016 and 2018.

Alternatively, should installation continue at around 10GW per year, the installed base will be of the order of 180GW or more (see Figure 2.2.1.3). The relevance of thinking about eventual capacity in planning activity to 2020 is evident. It is recognised that the average 20 year operating life for offshore wind projects used here (increasing to 25 years for later projects) may increase further once the pace of technology development slows. This will impact required repowering capacity post 2035.

Industry is more likely to develop efficiently in an environment where long-term stable activity is established. If UK takes the bulk of this up to 2020 (shown nearing 60% for 22GW case, nearing 70% for 33GW case), then it will have a strong chance to establish the supply chain and then likely to be well placed to export as other nations catch up. If UK activity drives a peak demand much higher than the long-term average, then the investment in the UK sector is likely to be quite inefficient. For this and other reasons, it is argued that gaining a cross-stakeholder industry consensus on a UK installation expectation to 2020 is very important. This common vision needs to be challenging but achievable and fit with a long-term view of the sector and short-term needs in terms of renewable energy targets.

It may be more helpful for the industry to aim for annual offshore installation rates (of say 7-8GW in EU; 3-4GW in UK), rather than time-bound cumulative targets. Figure 2.2.1.4 summarises our suggestion, equating to 20-22GW installed in the UK by 2020.

Notwithstanding this suggestion, consideration of supply chain capability in Section 3 is provided within the context of installation of 33GW of offshore wind in the UK by the end of

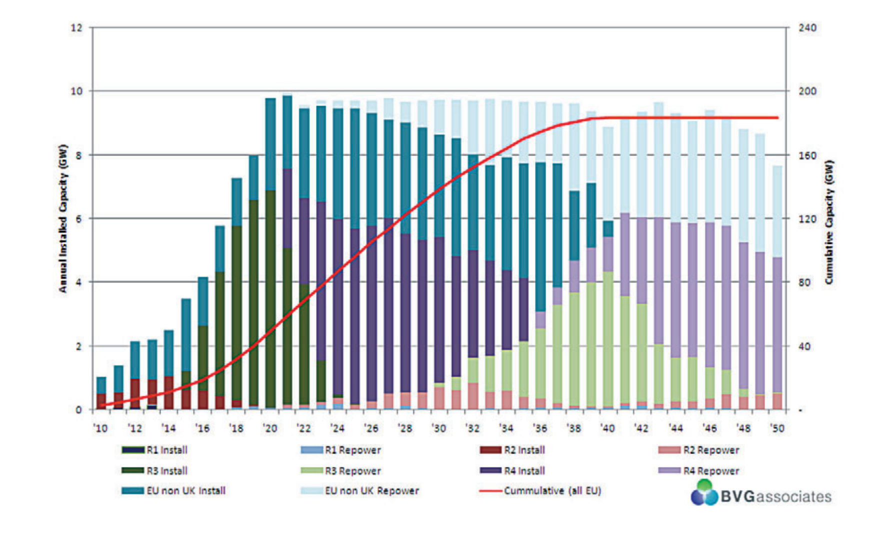


Figure 2.2.1.3. Indicative annual and cumulative offshore installation in UK and Europe to 2050, including anticipated Round 4 (BVG Associates indicative suggestion only) and repowering, based on target of 33GW in UK by 2020 and with ongoing installation across EU at around 10GW per year.

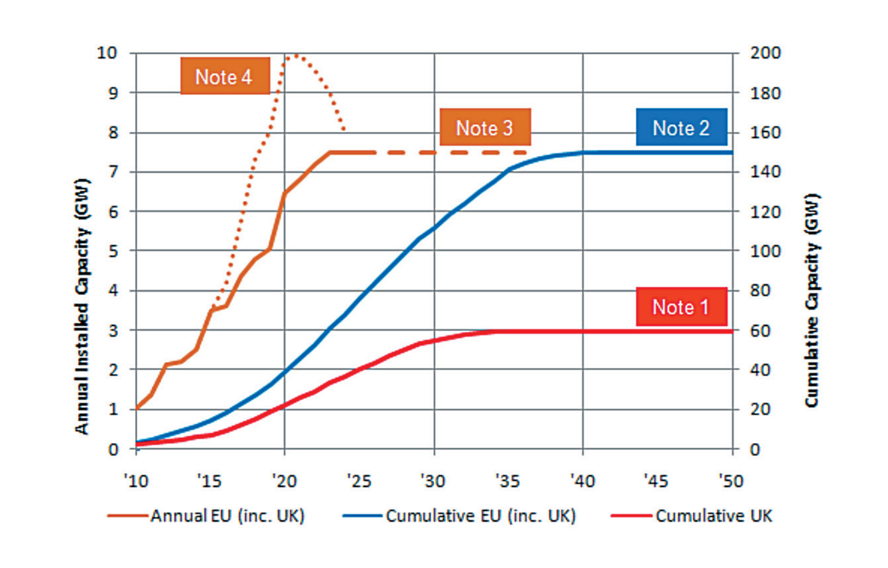


Figure 2.2.1.4 Projected EU installation to 2050, showing key considerations relating to installation up to 2020.

Note 1 – Cumulative UK Capacity
- *Sufficient to help meet UK 2020 renewable energy targets*
- *Believed achievable by industry*
- *Sufficient to stimulate UK industrial-isation with government support*

Note 2 – Cumulative EU capacity
- *Fits EWEA forecasts to 2030*
- *Fits EU renewable energy expectations to 2050*

Note 3 – Annual EU capacity
- *Significant sustainable business*
- *Large enough for good competition and investment*

Note 4 – Annual EU capacity (very high growth)
- *Higher peak artificial to achieve 33GW in UK*
- *Very high growth introduces more risk and inefficiency*
- *Only sustainable if eventual EU market size is of the order of 200GW.*

2020, coupled with just less than 20GW in the rest of Europe.

The experience in Spain, China and elsewhere is that given the right environment, the wind industry, working collaboratively with enabling bodies, has repeatedly reached rational targets early.

2.2.2 Industrialisation
There a number of drivers for Industrialisation of offshore wind in the UK.

- **Dominant home market.** We have the dominant market in offshore wind. Significant new manufacturing capacity is needed somewhere around the North Sea and both logistical considerations and the wish to minimise exchange rate risk point to increased manufacturing in the UK.

> *"We are looking hard at improving logistics – we see logistics as a key differentiating factor."*
> *MAJOR OFFSHORE DEVELOPER*

- **Wealth creation.** The UK has globally recognised expertise in offshore engineering, a deep knowledge of North Sea conditions and a strong manufacturing and innovation pedigree. It has a strong chance of creating significant wealth through manufacturing for offshore wind in the way that Denmark has for onshore wind.

- **International competition for resources to meet targets**. In a resource-limited sector with a number of EU countries relying on offshore wind in large part to deliver 2020 renewable energy targets, the UK today is at risk because the supply chain to offshore wind is predominantly controlled by Germany and Denmark. Even in a free market, we see that national support for continental players is strong. In straight competition between markets showing similar economics, we can expect (for example) German supply to go to German projects, as there are likely always to be motivations and inducements to support a home market in preference to an overseas one.

Currently, the UK supply chain is limited with respect to wind turbine components, balance of plant and services – there are far more large vessel providers active in offshore wind that are registered in Netherlands than in UK, for example. We also hear of the difficulties new UK suppliers face breaking into continental supply chains to continental customers. There are however examples of strong UK competence and indeed manufacturing for the wind industry. Converteam continue to turn over of the order of £100m a year in supplying power converters and generators to the sector. Welcon/Skycon and BiFab are manufacturing towers and offshore support structures in the UK and a range of wind turbine manufacturers are looking at UK coastal sites for their next generation manufacturing facilities. As an island nation with a strong pool of oil and gas excellence and the bulk of the continent's offshore wind resource, a strategic focus on industrialisation in offshore wind makes good sense.

It is important to recognise that any industrialisation will be in competition with activity in other EU countries, especially those bordering the North Sea. There is clear evidence of how other governments have supported the growth of home supply of components and services over the last decade and the UK Government needs to address the opportunity with a full understanding of the European perspective.

In the 1990s, the Danish Government stimulated a home market for wind turbines built around long-term stability. It also provided strong support for industrialisation and export which led to the wind industry being the nation's largest industrial exporter. The result is that Denmark is home to two of the largest wind turbine manufacturers in the world and a strong and dynamic associated supply chain. Denmark also is seen as the global home of wind turbine technology, still very much at the forefront of research and innovation. In 2008, UK overtook Denmark in terms of both onshore and offshore wind capacity, but does not come close yet in terms of supply chain and technology leadership. The difference between the two countries is in the timing of wind farm development (Denmark acted first) and the type of government support offered.

Budget announcements in April 2009 included allocation of financial support to develop infrastructure suitable for facilitating industrialisation of offshore wind. Coupled with positive messages from a number of English RDAs and other enabling bodies, conditions look as bright as they ever have done for establishing new UK manufacturing for the wind industry within the next few years. Key now is to grown momentum through real commitments.

2.3. Infrastructure Provision

In the course of our consultation with the industry, grid infrastructure (both onshore and offshore) was raised by many as an area of significant concern (after economics), certainly the most important 'big picture' issue. For many, it is of greater concern as so much design work, consenting activity and site work (hence elapsed time) is needed to actually deliver connections within any arrangement finally agreed. Issues relating to ports infrastructure and physical delivery and installation of subsea cables are covered under supply chain capability, below.

> *"Grid is probably the largest big-picture concern, as it takes a lot of activity to deliver."* *RWE NPOWER*

Four main wishes regarding grid infrastructure were raised by industry players in our discussions:

- There should be a more strategic approach to both the onshore and offshore elements of transmission. This will give the cheapest long-term solution (as discussed in the recent BERR Electricity Networks Strategy Group output). Suppliers advised of instances where choices regarding early Round 2 grid connections may well add significant extra cost to later Round 2 activity and for Round 3, where the current arrangements are seen to drive decisions towards the least immediate cost connections which will provide non-optimal flow within onshore distribution networks.

- Each zone should be serviced by a single transmission network provider, to allow a long-term relationship to develop between developer and offtaker.

- Developers should be given the freedom to choose whether to act as connection provider for their zone or to place the connection within the regulation process for others to bid build and operate.

- There was support for some level of socialisation of grid costs as a way to improve economics, in line with the German approach to grid access.

It was commonly suggested that The Crown Estate should seek to influence such arrangements, with recognition also of the significant industry consultation facilitated by DECC and Ofgem.

2.4. Supply Chain Capability

The issues affecting the capability of the supply chain to deliver UK offshore wind farms are the primary focus of this study and in the sections below a detailed analysis of each area of the supply chain is provided. There are a number of issues that are relevant across the supply chain, however, and these are addressed here, along with a summary of key supply chain constraints.

2.4.1 Confidence in the Offshore Wind Industry

Market

To date, the offshore wind sector has achieved a maximum annual installation rate of 5-10% of what is anticipated by The Crown Estate in 2020. Over the next 12 years, an average annual growth rate of 20% is required, a figure well below the 28% average annual growth rate seen in the onshore wind sector over the last 12 years. Leaders in the wind industry are used to growth rates like this – past growth has been achieved through activity in a range of markets and with a strong, confident attitude to ongoing investment and growth.

Today, that same confidence is not yet there in offshore wind. We will show later that we anticipate availability of turbines increasing at over 25% year-on-year for the foreseeable future. Almost all input that we have received from the supply chain reflects the view that certainly up to the anticipated needs presented in Section 1, given reasonable customer commitment and notice, whatever is needed can be provided. The challenge is that unlike in onshore wind, there is not yet the confidence in the supply chain to invest prior to customer commitment. In turn, customer confidence is low due to the uncertain economic viability and concerns relating to availability of grid infrastructure and supply chain.
This low confidence has two effects. First, it limits investment in new capacity, raising concerns about lack of supply chain capability to deliver. The second effect is just as significant – it limits investment in development and demonstration of technologies and processes that will help bring down lifetime costs of Round 3 projects, as discussed in Section 2.2.

Overall, most who expressed a view saw the future of UK offshore wind as positive; indeed a number expressed that in terms of order books or plans, there hadn't been a healthier time in the industry than now, but much of the positive view is about what is likely to come, not what is here today – that is not sufficient to move focus from other markets, whether that be oil and gas for some or onshore wind for others.

> *"Recent times are as positive as seen so far in terms of firm booking."* **A2SEA**

For wind turbine manufacturers, a viable UK onshore sector is also important, as any manufacturing facility will probably also service the onshore market. Though the economics of onshore wind are somewhat better than offshore, other constraints still limit this market in a way that is not helpful also for UK offshore wind.

Technology

Confidence also relates to technology. Well-publicised issues relating to Vestas V90-3MW turbines led to a moratorium on sales of this turbine for around a year. The recent announcement of a second gearbox swap for all Horns Rev turbines reminds us that turbine technology is still developing. It is a concern for each member of the supply chain that the industry may not progress as fast as wanted due to technical concerns outside of their control.

The same argument is also applies regarding potential constraints in supply, highlighted in the past by turbine manufacturers stating that there is no point in preparing to supply more wind turbines to the offshore market because there would not be enough vessels to install them. We see that such attitudes have softened considerably in recent times and we see that it is one role of The Crown Estate to facilitate improved communication to address such issues.

2.4.2 Impact of Round 3

A positive feature of The Crown Estate's Round 3 process for many is that it is significant enough to cause a rethink in terms of delivery of offshore wind projects, both in consideration of scale of activity but also of technical solutions due to increased distance from shore, water depth, wind farm and likely turbine size. Turbine suppliers advise that in a number of cases, Round 3 has successfully got the attention of their supply chain also. A number of players also recognise the strengths and weaknesses of utilities, arguing also that the Round 3 process drives innovation but squeezes out smaller wind farm developers who may be best at delivering that innovation. Utilities are not generally seen as the first to embrace change; however the Round 3 process is built around change.

> *"The Round 3 process has galvanised attention in developers, us and our supply chain – it is working as a method of getting attention."*
> *WIND TURBINE MANUFACTURER*

We see a difference in response to the changed challenges of Round 3: some would seem to be following a business as usual scenario, seeing Round 3 as merely a larger Round 2; others are embracing the new challenges and thinking strategically about how best to address them.

Where the need for innovation is being addressed, it is key that the correct focus and base data are available to maximise the benefit of new thinking. Again, we see that The Crown Estate has a key role to play in facilitating provision of this.

Though there is an overall positive response to the Round 3 initiative, a number of players seek earlier activity via extension of Round 1 and 2 projects, in order to facilitate ongoing ramp-up of UK activity and avoid a "slow" to "go go go" cycle through each stage of activity as Round 3 work starts. This may be achieved for some through early delivery of projects within Scottish territorial waters.

2.4.3 Summary of Key Supply Chain Constraints

Figure 2.4.3.1 presents known planned capacity increases against demand for the top three supply chain constraints raised by the wind industry, taken from the analysis in Section 3. Dashed lines represent achievable ramp-up capacity should investment decisions be made when highlighted by the diamonds. For vessels, that investment required is in 2009. Each of the top constraints is then discussed below, followed by commentary on other key constraints.

- **Offshore wind turbines.** Though often quoted as the key constraint, the supply situation continues to improve and no investment beyond plans already in place (though not necessarily signed off) are needed to meet demand. The development of technology that will meet the demands of Round 3, in terms of reliability and maintainability, remains a key challenge.
- **Installation vessels.** Our forecast of vessel capacity shows that further investment is needed now in order to meet the industry's needs in 2012. This investment may have been made without visibility to us. If not, then we may see sub-optimal solutions adopted in 2012 and 2013. Ramp-up rates for vessel supply (as shown by the dashed line) could be quite high due to the global availability of shipbuilding capability and the number of designs that are 'ready to order'.
- **Export cables.** The supply of subsea export cables is specialist and investment decisions to increase current growth plans will be needed in 2011 to enable supply to meet demand, especially as projects

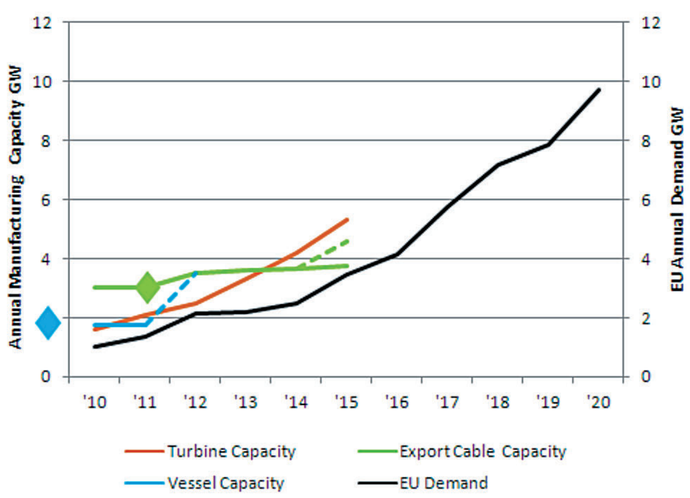


Figure 2.4.3.1 Projected capacity against European demand to 2020 for key potential offshore wind supply constraints.

go further offshore from 2015. As shown by the dashed line, ramp-up in supply is anticipated to be lower than for vessels.

- **Cable installation.** Although the provision of cable installation services is not delaying projects, it continues to be a high-risk process where processes and quality needs to improve.

- **Other areas.** There are many other areas where existing supply cannot meet anticipated demand, but we believe that normal market dynamics will deliver, in that lead times for new facilities and barriers to entry are unlikely to limit supply. Substation transformers, large bearings for wind turbines and skills are the areas of greatest concern.

2.5. Health and Safety

The significant increase in installation activity planned for Round 3 and the much increased distances from shore raise new health and safety issues that should be addressed in a non-competitive environment. The Crown Estate has the chance to play a pivotal role in developing health and safety culture within the offshore wind industry at both a national and international level. Correctly, health and safety has a significant weighting in The Crown Estate's assessment methodology for Round 3 bids.

It is beyond the scope of this document to provide a robust review of health and safety issues relating to Round 3. Rather, this section summarises perspectives received during interviews.

Helicopter Use
Some are anticipating significantly increased use of helicopters for accessing individual turbines on a regular basis. Others are moving away from their use. One developer that has operated turbines with helicopter access advised of a policy decision taken not to continue using helicopters on future projects, citing health and safety risk assessments as the driver for change, due mainly to the large number of anticipated journeys. They advised that this fits with a move to limit helicopter use also in the oil and gas sector. On-land noise issues also were raised with respect to helicopter use.

Distance from Shore
It is recognised that with an increase in the distance from wind farms to emergency medical care from 10s to 100s of kilometres, changes in protocols and facilities are needed right from the very first activities during offshore wind farm construction in order to protect construction staff. This may include the early use of fully equipped offshore fixed or floating 'hotels'.

2.6. Skills Availability

There have been a number of recent studies conducted to quantify the skills gap and opportunity in the offshore wind industry, both at a UK and a European level.

EWEA's Wind at Work report, published in January 2009 concluded that:

- 15.1 jobs (for a year) are created in the EU for every MW installed (per year).

- 0.4 jobs are created (long-term) per MW of cumulative capacity in operations and maintenance and other activities.

- Of the 108,000 people directly employed in the European wind industry in 2007, 37% are employed by wind turbine manufacturers and a further 22% by component suppliers.

- Almost 80% of the direct jobs are in Spain, Germany and Denmark.

- There are an estimated further 42,000 indirect jobs as a result of the wind industry, making the industry responsible for 150,000 jobs in total.

- This figure will more than double by 2020 (based on total installed base of 180GW). By then, half of the jobs will be offshore related.

The BWEA published two studies in 2008. A report by Bain found that:

- Around 5,000 are employed now in the UK wind industry.

- Under a dynamic growth scenario (34GW installed offshore and onshore by 2020), employment in the UK wind industry rises to 57,000.

> *"Our limit? The number of technical experts needed to design projects."*
> **SIEMENS T&D**

An SQW report published alongside the Bain study maps key skills required and the organisations seeking to address the needs. Professionals required by the wind industry include:

- Electrical and electronic engineers.

- Structural and marine engineers.

- Health and safety specialists.

- Construction project managers.

- Maintenance workers.

The report goes on to discuss key methods to address needs.

We recognise the work underway in this key area and the considerable extra focus required but it is outside scope to provide a detailed view.

3. Wind Farm Level Issues

3.1. Approach

This section features a series of tables, one for each of the supply chain areas described below. Each is broken down into key elements, which is given a headline traffic-light label. The tables are designed to give an overview, with further detail provided for elements classed as areas of concern. The definitions are:

G **Green.**
Not currently an area of concern. Where problems have been identified, there are reasons to believe that these will be rectified by market pressures. A watching brief should be maintained.

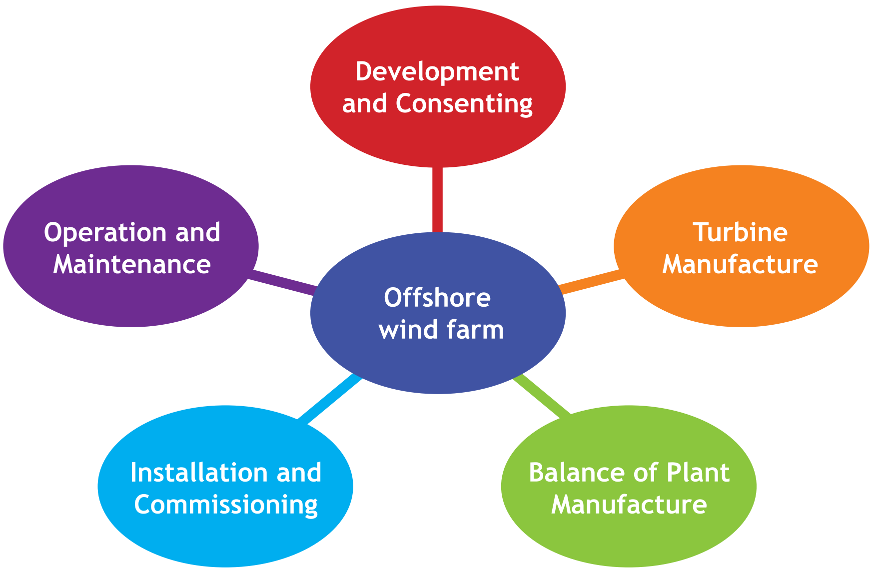
A **Amber.**
An area of concern. Some proactive intervention is required in order to address market disconnect.

R **Red.**
An area of significant concern. The issue demands further analysis and strategic action.

The supply chain can be divided into five areas, as shown below. The pie chart alongside gives an indication of their typical contribution to the cost of energy based on 20 years of wind farm operation.

The areas have been chosen as to reflect, as far as possible, discrete activities undertaken by different suppliers. Combined, they cover the bulk of the cost of energy generation from a given wind farm.

- **Development and consenting.** This covers wind farm design and consenting activities undertaken before installation, excluding R&D, design and manufacture of components. These are therefore primarily costs to the developer.
- **Turbine manufacture.** This covers the activity by wind turbine manufacturers and their suppliers, i.e. nacelle component manufacture and assembly, blades and towers.
- **Balance of plant manufacture.** This covers the manufacture of all other wind farm components, such as foundations and electrical infrastructure. These items



Typical contribution to total cost of energy from each element shown are procured by developers or contractors on their behalf.

- **Installation and commissioning.** This covers installing foundations, final assembly of turbines at ports, installation of turbines on site, laying cables and installing substations. Again, these activities are procured by developers or contractors on their behalf.

- **Operation and maintenance.** This covers all the activities undertaken once the wind farm is operational. These are undertaken by asset owners or contractors, frequently with a significant role for the wind turbine manufacturer.

Each of these areas is broken down into smaller elements in the following sections. In analysing each element, we identified significant suppliers in each area category, defining their status as follows:

- **Proven capability.** For example, wind turbine manufacturers that have installed a significant level of offshore capacity, or suppliers with strong onshore pedigree that is immediately relevant to offshore applications.

- **Likely future capability.** New entrants or players with onshore experience that is not sufficient to give high confidence of success offshore.

The lists of suppliers are not intended to be exhaustive – named companies are examples only. It is recognised that for a study of this sort in a dynamic international sector, there may be omissions or incorrect designations of companies with significant capabilities.

For the purpose of the rest of the analysis, it is assumed that economic, infrastructure and political risks are mitigated, hence delivery depends on issues relating to the physical delivery of wind farms in an environment where the external factors do not impact negatively. Requirements are based on the market forecast set out in Figure 1.4.1.

3.2. Development and Consenting

This section is broken down into the following areas.

- **Finance.** This covers the provision of capital and related services to finance wind farms.

- **Development and environmental.** This covers both pre- and post-consent activities from initial prospecting through to start of construction.

- **Statutory consultation.** This covers all activities undertaken by stakeholders in order for consent to be granted for a given wind farm development.

3.2.1 Finance

Landscape
Though much utility investment is balance-sheet financed, some wind farms and much investment in new equipment relies on the availability of suitably priced finance. With the scale of Round 3 activity, even utilities may look to access external finance.

The Dutch 120MW Q7 offshore wind farm was the first financed through non-recourse loans, where the three banks involved are relying solely on the project to generate the revenues needed to service the interest costs and principal repayment with very limited additional sponsoring support. Technology used was Vestas V80-2MW on monopiles, considered lowest risk of the technology available at the time.

The second project, stage 1 of the Thornton Bank project was again arranged by Dexia. Using six REpower 5M turbines on innovative concrete foundations, the technology risk is generally seen as higher.

It is anticipated that in time, project finance will be become as commonplace in offshore wind as it is onshore. In addition to concerns about economic viability, the key barriers today relate to illiquidity of the markets and concern about syndication. The more experience and understanding banks and all other parties involved get, the easier it will become to raise cost-effective finance.

Issues
Lack of finance available. This in line with the global financial situation.

3.2.2 Statutory Consultation

Landscape
The current consenting process applicable to Round 1 and 2 sites requires developers to obtain three consents, one from DECC (Section 36) and two from DEFRA (FEPA and CPA). The overall process is coordinated by DECC.

From April 2010 Round 3 wind farms above 100 MW will be subject to a single new Infrastructure Planning Commission (IPC) consenting process. The IPC will have sole authority to grant the necessary consents.

The current average lead time for obtaining consent is two years. The IPC has a target of granting consents of 12 months. To facilitate this, is expected that the IPC will have more authority to enforce deadlines on statutory consultees than DECC currently has.

DEVELOPMENT AND CONSENTING			
Proven capability (examples only)	**Utilities** Centrica DONG RWE **Finance Arrangers** Dexia **Banks** Fortis Bank **Investment Vehicles** Masdar **Insurers and advisors** Delta Lloyd G-Cube JLT Marsh	ABPmer, ERM, EMU, Garrad Hassan, Faber Maunsell, Fugro Seacore, Metoc, Noble Denton, Mott MacDonald, Natural Power, Oceanear, ODE, PMSS, RES, RPS Group, Searoc, Sgurr, SKM, Titan, TNEI, various non-UK players	CAA DCLG DfT JNCC MFA MOD etc.
Likely future capability (examples only)	Various	Many – from parallel sectors	
Component	**Finance (including insurance)**	**Development and Environmental**	**Statutory Consultation**
Market Concentration	Low	Low	Not a market
Issues	• Lack of finance available • (Economics marginal and getting worse)	• Ramp-up in demand is sharper than for wind farm hardware	• Limited statutory consultee resources • Conflicts of Interest within individual consultees • IPC not yet established and consenting processes yet to be defined
Actions	• Engage with DECC's city liaison team and others regarding availability of finance • Facilitate increased investor understanding of the industry	• Raise awareness of anticipated offshore need. • Ensure consenting processes are as clearly defined and communicated as possible	• Influence resourcing and training within statutory consultees • Ensure clarity about processes for all stakeholders • Share early dialogue with IPC and facilitate relationship building between IPC and consortia • Facilitate planning of consent submissions to maximize effectiveness of consultees
Traffic light rating (see 3.1)	A	G	R

The IPC planning process can be broken down into five key stages:

- Pre-application consultation.
- Application.
- Acceptance of the application by the IPC.
- Examination of the application.
- Decision.

Currently, submissions often do not contain the full information that statutory consultees are looking for which introduces additional delay in the consultation process. The new IPC pre-consultation process is designed to resolve this by asking the consultees to define the information they require up-front, so that this can be included on submission.

Issues

Limited statutory consultee resources. Feedback is that there are not enough resources within the statutory bodies to deal with the volume of activity today. Unless addressed, the delays introduced by the process will get worse.

Conflicts of interest within individual consultees. Awareness and policies continue to develop which lead to uncertainty within the process. In many cases, guidance notes to underpin activity are not yet established.

The IPC is not yet established and the consenting processes yet to be defined. The IPC will not be established until April 2010. There are risks as to its early effectiveness. In addition, various processes are yet to be defined; for example, DECC has not announced whether consents will be granted at zone level or individual wind farm.

3.3. Turbine Manufacture

Turbine supply is widely identified by those at the heart of project planning as a significant issue, partly due to component supply limitations and partly due to market dynamics with respect to onshore wind. The current economic conditions are inevitably having an impact. There is a trend towards vertical integration of component supply, especially for offshore wind players keen to hold a full technical understanding of their technology and quality, at a time that the industry is expanding rapidly.

Turbine supply is subdivided into the following areas:

- **Offshore wind turbines.** Complete supply, including all of the items below.
- **Blades.** Blades form a significant element of the turbine cost (around 20%). Almost all blades for offshore wind turbines are currently manufactured in-house by wind turbine suppliers. As the final assembly of blades to the turbine only happens close to the site and the transport of blades is a significant consideration, it is relevant to consider blade manufacture as distinct from turbine nacelle assembly and other main component manufacture – it can be carried out efficiently at a separate coastal location.
- **Castings and forgings.** These items include the hub, main shaft (where used), main frame (in some cases), gearbox castings (where used) and bearing forged rings. For very large offshore turbines, minimising transport of these items will start to become an important issue.
- **Gearboxes and large bearings.** All offshore players in the market today use gearboxes. Siemens Wind Power is testing a preliminary design of a direct-drive, permanent magnet generator and Multibrid uses a low-ratio gearbox and mid-speed generator. Bearings are critical supply items for incorporation into the gearbox as well into nacelle and hub sub-assemblies.
- **Towers.** As for blades, towers need not meet other turbine components until they reach the site, so they can be sourced separately from turbine nacelles. Again, logistics of transport become critical for very large offshore designs, requiring a move to coastal manufacture. In some onshore markets, towers have been procured by the developer (to the turbine manufacturer’s design), but the pattern offshore is for the wind turbine manufacturer to source.

3.3.1 Offshore Wind Turbines

Landscape

Wind turbine supply remains a critical path item for most developers and one least within the UK’s sphere of influence as no wind turbine suppliers have headquarters in the UK and currently no wind turbines are assembled from key components in the UK. Lead times for turbines have until the recent global economic downturn been up to 2-3 years and the offshore sector continues to be squeezed by the significant success of the global onshore wind market in response to the rapidly growing demand for sustainably produced low-carbon energy. All developers interviewed put turbines within their top two supply concerns.

The anticipated number of offshore turbines required in Europe and associated spend is presented in Figure 3.3.1.1, based on an increase in average turbine size installed increasing to just under 6MW in 2020.

TURBINE MANUFACTURE

Proven capability (examples only)	Siemens Vestas Repower	Siemens Vestas LM Glasfiber	**Castings** Felguera Melt, Fonderia Vigevanese, Metso, MeuselWitz, Rolls Royce, Sakana, Siempelkamp, Vestas **Forgings** Brück, Euskal, Skoda, Thyssen, non-EU players	**Gearboxes** Bosch Rexroth, Eickhoff, Hansen (Suzlon), Moventas, Winergy (Siemens) **Large Bearings** FAG, IMO, Liebherr, NSK, NTN, Rollix, Rothe Erde, SKF, Timken	Ambau, BiFab, Bladt, SIAG, Vestas, Welcon Various metal fabricators
Likely future capability (examples only)	Bard, Clipper, Darwind, Mitsubishi, Multibrid, other existing WTMs, other newcomers	A&R Rotec (SGL), GBT, SSP, non-EU players	Various non-EU players	Various existing smaller players, non-EU players and global non-wind players	
Component	**Offshore Wind Turbines**	**Blades**	**Castings and Forgings**	**Gearboxes and Large Bearings**	**Towers**
Market concentration	High – few with offshore pedigree	High – majority of manufacture in house and/or use LM Glasfiber	Medium – large global supply base but few with capability to manufacture large items	High – few with capability to manufacture large items	Medium
Issues	• Limited supply of turbines • Few turbines specifically designed for offshore operation • Significant technical development still needed – reliability • Qualified commitment to market by suppliers • Lack of coastal turbine assembly and large component manufacture	• Need new coastal facilities. • Test rigs for large blades needed • Little 'independent' competition	• Limited supply, especially at large size • Lack of UK supply capability discourages wind turbine manufacture in UK	• Limited supply, especially at large size • Poor operational reliability	• Need new coastal facilities
Actions	• Support manufacturers focused on UK offshore • Facilitate development of test rigs • Invest in ports where relevant • Invest in test turbines where appropriate	• Support development of optimally located UK supply	• Raise awareness of anticipated offshore need • Support development of optimally located UK supply	• Raise awareness of anticipated supply • Support development of optimally located UK/ European supply • Facilitate development of bench test facilities.	• Raise awareness of anticipated offshore need • Support development of optimally located UK supply
Traffic light rating (see 3.1)	R	G	A	A	G

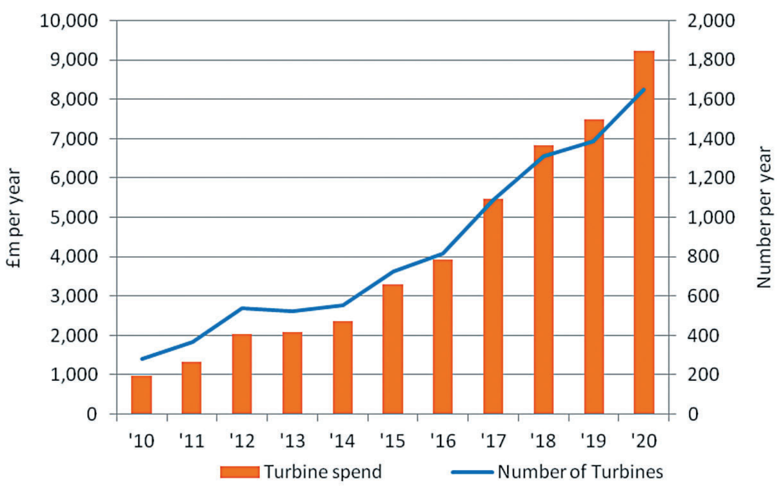


Figure 3.3.1.1. Projected spend and number of offshore turbines required in Europe to 2020.

Market share
Market shares (in terms of total installed capacity at the end of 2008) for the top four players in terms of installed capacity are presented in Figure 3.3.1.2, showing that the dominance of Vestas and Siemens in UK and the rest of Europe.

Supply Forecast
To date, only Siemens and Vestas have built a pedigree in offshore wind, (defined here by having 200MW turbines operating offshore). With so little choice, this means that in the short term, the turbine market is not functioning as a competitive system. This is a concern to a range of developers, both for technical and commercial reasons.

The forecast of turbine supply in Figure 3.3.1.3 was derived from interviews with wind turbine suppliers and a process of moderation based on an understanding of the views of developers about purchasing either new or proven technology and the capabilities and expectations of the wind turbine suppliers, whether large or small. Also applied is an efficiency factor – it is seen that not all available supply is installed each year due to relationships between particular players and suitability of specific turbines for given sites. Also incorporated is a forecast of the development of the number of wind turbine suppliers in the market with offshore pedigree. Note that the white bars show forecast availablity as presented in BWEA's UK Offshore Wind: moving up a gear, published 18 months ago. It shows an improvement in the availability of turbines which reflects the changing attitude of suppliers to the market.

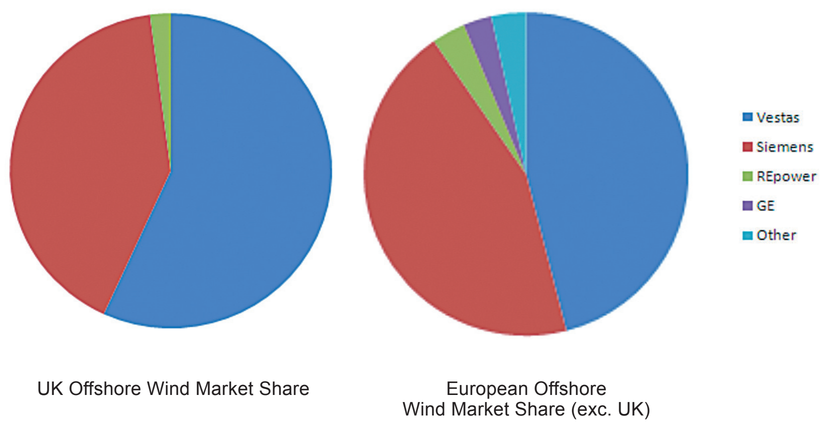


Figure 3.3.1.2. UK and EU non-UK offshore market share.

> *"There is no allotment of turbines for onshore or offshore wind within Vestas... Should an offshore project meet the acceptance criteria it will have priority over onshore and get the turbines."*
> *VESTAS*

> *"Siemens intends to remain #1 in the offshore wind market... We are willing to provide more turbines now than last year."*
> *SIEMENS WIND POWER*

Splitting capability into four pools of wind turbine manufacturers, the following players are anticipated to have this pedigree in due course (with current size of offshore turbines shown):

- Pool 1 (pedigree established now): Siemens Wind Power (3.6MW) and Vestas (3MW).
- Pool 2 (pedigree established by end 2011, latest): Bard (5MW+), Repower (5/6MW) and Multibrid (5MW).
- Pool 3 (pedigree established by end 2015, latest): Three suppliers from a pool of six including (at least) new players DarwinD (5MW), Clipper Windpower (10MW), 2-B Energy (6MW) and existing big players Acciona, Enercon, Gamesa, GE Wind Energy, Mitsubishi and Nordex.
- Pool 4 (pedigree established after 2015): Others currently developing technology, including new players Blue-H, vertical axis players Nova and VertAx and other existing players (including Chinese manufacturers; Goldwind already has a 1.5MW turbine installed offshore).

Supply forecasts are limited by different factors for different turbine suppliers, including combinations of:

- Offshore pedigree and financial strength (as viewed by customers);
- Management of risk (as viewed by the wind turbine supplier);
- Availability of contracts with suitable terms (compared to onshore opportunities);
- Component supply availability; and
- Resources needed to develop and support wind turbine technology suited to offshore use.

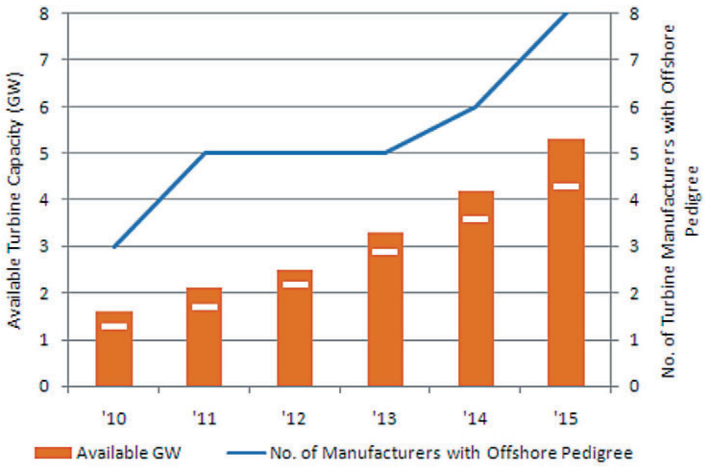


Figure 3.3.1.3. Projected wind turbines supply availability for the global offshore market and number of wind turbine manufacturers with offshore pedigree.

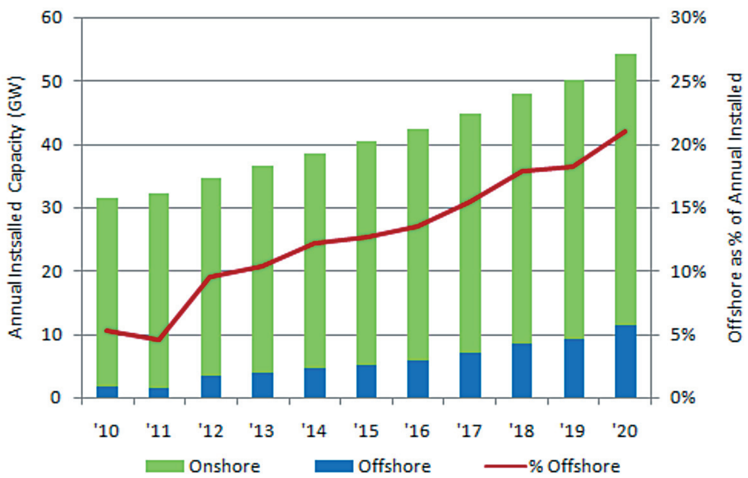


Figure 3.3.1.4. Projected global installation to 2020 showing relative onshore and offshore contribution.

"Our limit is the availability of project teams, not number of MW." VESTAS

Looking further ahead, in response to global onshore wind demand, a significant number of new entrants are developing onshore technology. Many of these players are located in growing markets which also are low-cost manufacturing locations. Their entry is likely to squeeze the established European turbine suppliers at the same time as the European offshore wind sector grows from providing a negligible (though high-risk) contribution to total wind turbine sales to providing a significant fraction, as shown in Figure 3.3.1.4.

a segment share of 10-20% of EU turbine installations, physically being able to supply turbines to the offshore market is not likely to be the limiting issue. More important is whether turbines of the desired size are made available by wind turbine suppliers at a cost and under terms that projects can bear.

New Technology
The rate of growth of turbine size (rated MW capacity) entering the global onshore market continues to slow due to transport and other physical constraints. Existing suppliers of offshore turbines generally expect that variants of today's turbines will remain core products dominating sales into 2012/13, with next-generation, larger technology only taking over towards 2015. This means that for some time, the market will be dominated by technology adapted for offshore use, rather than fundamentally designed for offshore use. Effort will continue to be put in to improve both reliability and maintainability but significant strides in terms of lifetime cost of energy improvement are likely to come only in next generation products.

Key reliability issues remain:

- Gearbox failures (especially bearings).
- Generator failures (especially bearings and cable connections to generator).
- Subsea cable damage.
- Operator access limitations.

Much learning can be derived from the existing UK and European experience of constructing and operating offshore wind farms. More feedback into design of both turbine concepts and individual components and sub-systems is required. Lack of relevant operational and reliability data is also limiting the effectiveness of innovators, especially those from outside of the wind industry.

In addition to improving reliability, removal of some of the constraints affecting onshore wind, especially in northern Europe, provides a significant opportunity for innovation. These include efforts to minimise noise and visual impact. Unlike for onshore wind, there are fewer barriers to increasing turbine size. In response, we are seeing a reconsideration of design concepts, including a return to development of 2-bladed turbines and vertical axis turbines, both with potential technical advantages at the largest scale which are not likely to be seen onshore.

Issues
Limited supply of turbines.
Turbines generally remain one of the longest lead items in offshore wind procurement. Feedback from developers is that due to the current global financial situation, turbine prices have stopped increasing and terms and conditions are now more negotiable. Indeed, the feedback from suppliers is that they are willing to provide more turbines for offshore now than last year – reflected for example by REpower's recent framework contract with RWE and Siemens's with DONG. Two years ago, we advised the change in the perspective of developers towards offshore wind from obligation to opportunity. We see that now for at least some turbine manufacturers, there has been a similar change in perspective about supplying the sector from reluctance to ambition.

This easing in supply situation is shown in Figure 3.3.5 (dashed lines summarise output from *BWEA's UK Offshore Wind: moving up a gear,* published 18 months ago). Then, there was a period between 2010 and 2012 when developer demand exceeded supply. This is no longer the case, although its worth noting that developer demand is based on an inherent understanding of supply, so is naturally moderated.

Few turbines specifically designed for offshore operation. It is a concern of all developers that there is insufficient choice of turbines available for offshore use. This increases both the technical and commercial risk, as typified by Vestas's temporary withdrawal of the V90-3MW from the market two years ago. Further, few developers feel that they have available to them turbines that have been designed specifically with the offshore market in mind.

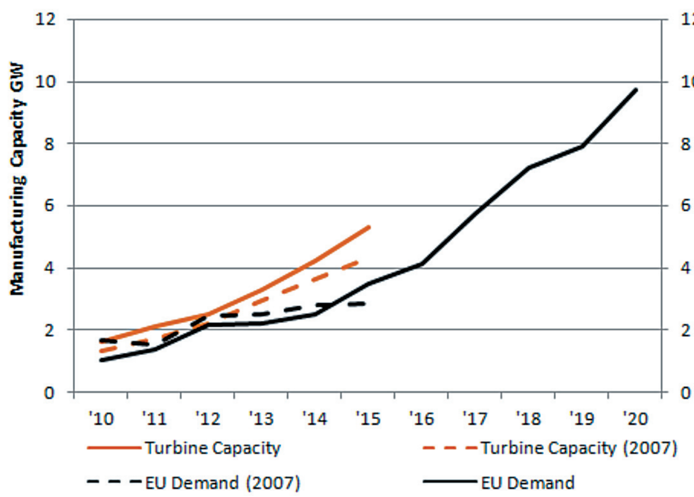


Figure 3.3.1.5. Projected offshore wind turbine manufacturing capacity and European demand to 2020.

It is anticipated, therefore, that

Significant technical development still needed. Activity is required at concept and component (reliability) level, both by wind turbine manufacturers and key members of their supply chain. The limited resources in the technology departments at turbine manufacturers are generally focussed on onshore issues rather than offshore. With the relative scale of the two sectors, this makes a fair degree of commercial sense, but it is limiting the speed of development of offshore-specific technology, to the detriment of the sector. There is discussion about the sense in designing (at least some) wind farm components for 40 (or even 60) year life. There is scepticism that the turbine development projects funded by Energy Technologies Institute will have an impact on the market by 2020, due to the distance of the innovators from the practicalities of the offshore wind sector. One interviewee suggested funding would be better spent through existing players in the development of their next generation products.

Qualified commitment to offshore market by suppliers. At least one wind turbine supplier cites instability in the UK onshore wind market as an increasing concern in the development of the offshore market. It is important for the offshore sector that the UK onshore market is vibrant. Considering the bigger picture, it remains the case also, that the focus on offshore wind is reduced by the ongoing success of the onshore market, once again showing trend-exceeding growth of almost 30% last year. With increased risks and lower overall returns for offshore wind projects, commitment to the offshore wind market is likely to remain qualified for wind players active globally.

Lack of coastal turbine assembly and large component manufacture. Today, hardly any turbines are being assembled at locations with direct access to coastal load-out facilities. The same is true for blades and towers. New coastal assembly and manufacturing facilities are needed in locations better suited to supply to the offshore wind sector. Such facilities will need to be well established as the anticipated ramp-up in demand due to Round 3 commences. Typically, large manufacturers think in terms of facilities for nacelles and blades that produce multiples of 1GW per year, needing to see a robust expectation of orders at above this rate for at least 5 years in a given geographically or technically separate market in order to consider investment. In time, this factory size will continue to grow, so the market and any support provided needs to be of a scale such that any individual player is enabled to invest for growth.

3.3.2 Castings and Forgings

Landscape

Castings (SG iron) are used in the following components:

- Hub.
- Nacelle bedpate (some suppliers; others use steel fabrications).
- Main bearing housings (if present).
- Gearbox housings and support components (if present).

These castings are produced by large foundries which serve customers in many different industries. In order to secure their supply chain, wind turbine manufacturers have entered into long-term framework agreements with specialist foundries and in some cases have acquired suppliers or established their own facilities in order to be able to in-source components. The market forecast for large castings (i.e. 8 tonnes+) for the wind industry is expected to consume 50% of the estimated total global capacity of established suppliers of suitable sized castings by 2012. Recent tightness in supply has been easing as existing players expand their capacity and new companies enter the market, especially in India, China and US.

Forgings have greater strength and ductility than cast materials. They are used in the following components:

- Bearings – both slewing rings (blade and yaw bearings) and main shaft / gearbox bearings.
- Shafts.
- Gears wheels.
- Tower section flanges.

The anticipated demand and spend profile for castings and flanges for European offshore wind is shown in Figure 3.3.2.1. This is based on a usage of approximately 16 tonnes of castings and 8 tonnes of forgings per MW for 2MW-scale turbines, rising to 30 tonnes of castings and 15 tonnes of forgings per MW for 5MW-scale turbines to match current industry patterns.

Issues

- **Limited supply, especially at large size.** Supply of very large castings (20 tonnes+ for offshore wind) in significant quantities close to point of use is insufficient to meet the anticipated demand. With an increase in supply of castings from Asia, European players may be encouraged to concentrate on offshore supply, but not many are well-located for this at present. Likewise, there is a less urgent need for new European large forging capacity.
- **Lack of UK supply capability discourages wind turbine manufacture in UK.** Feedback from some turbine manufacturers is that assembly of turbines in a given market will follow the supply of key components from that market. One

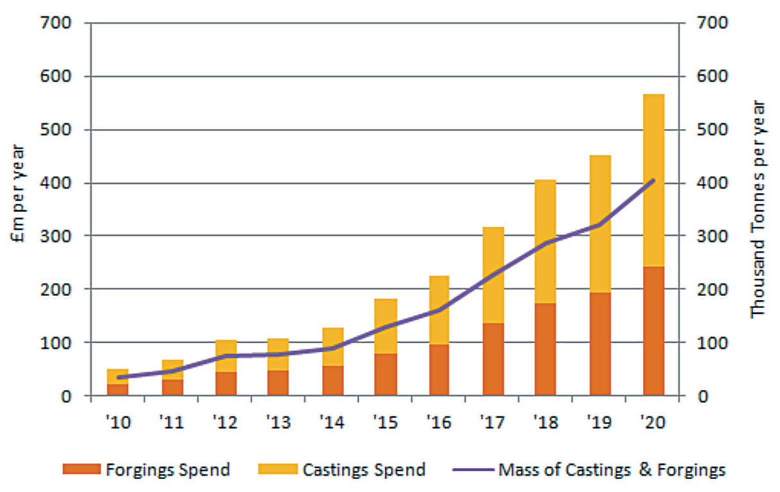


Figure 3.3.2.1. Projected spend and production for castings and forgings for European offshore wind to 2020.

key set of components are the large castings and forgings, especially critical because of high transport costs. Other turbine manufacturers would expect their existing supply chain to follow to new manufacturing locations, so availability of relevant skills is more of a need than existing established suppliers. The UK has in the past manufactured very large iron castings and mid-quality steel forgings and still has some strong relevant skills. There is now interest in re-establishing such facilities.

3.3.3 Gearboxes and Large Bearings

Landscape

The supply of gearboxes for the wind industry has been an area of concern for some time. Again, investment in new capacity has been significant and supply is currently reported to be enough to meet demand. It is anticipated that this situation will ease further in 2009 due to some level of downturn of demand due to the current state of the financial markets along with a significant increase in production capacity.

Large bearings are also an area of significant concern, including gearbox, generator and main shaft bearings in the nacelle and also blade bearings. The constraint arises from the small number of companies capable of supplying these large bearings. The tightness of gearbox supply is mainly attributed to bearing supply issues which in turn are significantly affected by the availability of high-quality steel forgings.

There is a considerable amount of work underway to improve bearing lifetime, especially with respect to steel quality, optimisation of contact angle and the development of oils and greases that protect bearings over the whole range of conditions seen during a wind turbine's lifetime. For generator bearings, work continues to improve electrical insulation.

Key reasons for the tightness of supply include:

- Large increase in demand in wind industry also coupled with demand in other industries (eg. mining and ship building);
- High entry barriers including industry-specific know-how to provide a reliable product;
- The high cost of production and test hardware; and
- Constraints on supply of key components, including specialist steels and large castings and forgings.

Issues

- **Limited supply, especially at large size.** There has been a significant expansion of supply capability in recent years, both from established players and newcomers to wind that are located within key growth markets, especially China and US. So far, these newcomers have not supplied the offshore market where risks are greatest and gearboxes are at the largest end of the ranges supplied. The presence of newcomers in the onshore market has however decreased pressure on some of the existing mainstream players such as Winergy and Hansen. Even some significant players such as Moventas are not pursuing the offshore market due to concerns about increased risks; rather focussing on establishing manufacturing in the US, for example.

- **Poor operational reliability.** Gearbox reliability has been a key issue for the wind industry for many years. High-profile problems with Vestas's offshore V80-2MW and V90-3MW turbines have raised considerable concerns, especially due to the high costs of replacement. If Siemens were to have a significant type fault with its offshore gearboxes, then the choice of install turbines offshore at this stage in the development of the industry might be severely limited.

3.4. Balance of Plant Manufacture

Issues relating to balance of plant manufacturer are considered under the following headings.

- **Subsea cables.** These include subsea inter-array and export cables. Inter-array subsea cables connect turbines to local substations (typically offshore for large wind farms) at medium voltage (typically at 33kV today; this could rise to 66kV). Export cables connect offshore substations to shore. Limited supply of the latter especially is generally recognized as of concern.
- **Foundations.** Steel monopile foundations currently dominate the market but as offshore technologies develop, particularly in deeper water, other designs will be used increasingly. Another key material for offshore foundations is concrete. Since the issues that relate to steel and concrete manufacture are distinct, these are considered separately.
- **Electrics.** Covers substations and transformers. Again, since issue that relate to offshore and onshore electrics are different, these are considered separately.

3.4.1 Subsea Cables

Export Cables

Landscape
Capacity for manufacturing high voltage (HV) subsea cables is limited, with only three established players in the offshore wind market: Nexans, Prysmian (ex Siemens) and ABB. Recently NKT has entered the market, winning their first contract to supply HV cable to the Baltic 1 offshore wind farm and committing to build a new factory in Cologne, Germany. Feedback from these suppliers is that that in the past, bottlenecks have been forecast but projects have then been held up by consenting delays or (more recently) economic problems, not cable issues. There is a consensus that if Round 3 construction does indeed begin in 2015, there will be a significant shortage of high voltage cables unless further investment happens well in advance. Most suppliers have expansion plans in place but are unwilling to invest without a firm indication from the market that the projects will proceed.

Based on existing capacity and that currently being built, the existing suppliers will be able to provide around 2000km extrusion; hence 1000km run of HVDC (2-core) or 700km HVAC (3-phase) cable by 2015. A single extrusion line can produce around 200km of core per year (this equates to around 40cm per minute). Bringing a completely new line on stream in a new location can take up to four years, although it takes less time to extend existing capability. It takes 2 years to test and type certificate a new cable and risk is attached to early supply from a new facility/supplier so purchasers do not expect to see a rapid ramp-up in supply. Cables that will be installed subsea need to be loaded onto an installation vessel from the factory, which limits the number of sites where additional capacity can be built. Some existing suppliers with the potential for additional capacity in their factories asserted that it would be possible to expand production within 12-18 months and felt that this would be sufficient time given the other timescales inherent in the construction of offshore wind farms.

It is anticipated that much of Round 3 and German offshore installation will have grid connection via HVDC links. To date a range of HVDC links are operating (including subsea) though no offshore wind farms have yet used HVDC technology, which is offered primarily by ABB and Siemens. For distances greater than 80km (this tipping point is dropping over time) HVDC seems to have a cost advantage over HVAC. HVDC technology provides a more efficient use of cable with 2 cores rather than 3. The maximum power transmission per connection also is higher (now over 1GW as compared to 400MW for HVAC) and technological

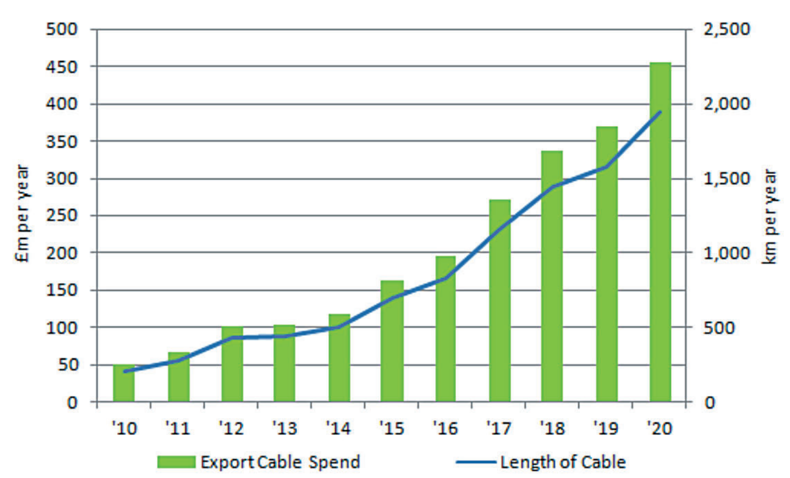


Figure 3.4.1.1. Projected spend and production for export cable for European offshore wind to 2020.

BALANCE OF PLANT MANUFACTURE					
Proven capability (examples only)	ABB, Nexans, Prysmian	**Manufacture** Aarsleff, NCC Construction **Design** Aarsleff, Carl Bro	**Manufacture** BiFab, Bladt, SIF/ Smulder **Design** MT Højgaard, Rambøll, LICEngineering, SLP	**Substation electrical** ArevaT&D, EDF, Siemens T&D **Transformer** ArevaT&D, Siemens, Tironi	Areva T&D EDF
Likely future capability (examples only)	Draka, General Cable / NSW, JDR, NKT, Parker / Scanrope	Gifford, SLP, various (continent)	SLP	Pauwels	Siemens T&D
Component	**Subsea Cables** **(especially export cables)**	**Concrete Foundations**	**Steel Foundations**	**Offshore Electrics**	**Onshore Electrics**
Market Concentration	Medium	High –few players with suitable coastal locations	High –few players with suitable coastal locations	High	High
Issues	• Limited supply of export cables • Lack of focus on grid • Frequent damage during / after installation	• Innovative solutions not proven– applications mainly shallow water to date	• Limited supply • Volatile steel price • Installation tooling restricts monopile sizes • Innovative solutions not proven	• Limited supply of substation transformers • High degree of bespoke activity • Raise awareness of anticipated offshore need	• Consenting delays • Lack of availability of skilled power engineers • Dialogue through BWEA to address skills concerns.
Actions	• Facilitate ongoing dialogue with the key suppliers, in order to maximize investment • Ensure a clear market need is kept up to date • Encourage convergence on standards around cable design and supply	• Enable demonstration of innovative solutions • Invest in infrastructure and shore-side access for new facilities where relevant	• Facilitate effective dialogue regarding in order to help focus innovation • Enable demonstration of innovative solutions • Invest in infrastructure and shore-side access for new facilities where relevant	• Facilitate dialogue around standardisation of specifications and designs of offshore substations	
Traffic light rating (see 3.1)	R	G	A	A	A

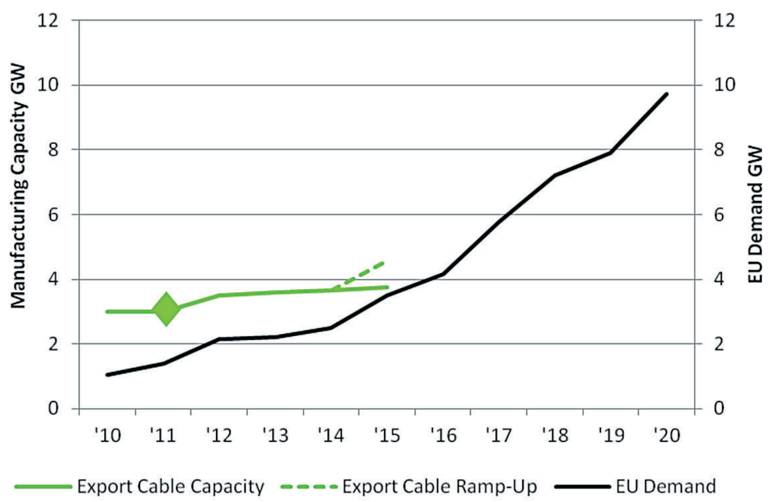


Figure 3.4.1.2. Projected export cable cable capacity and European offshore demand to 2020.

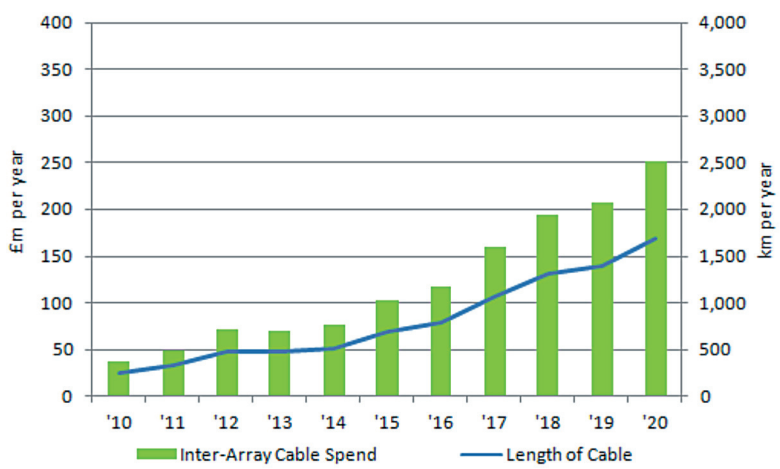


Figure 3.4.1.3. Projected spend and production for inter-array cable for European offshore wind to 2020.

improvements mean that the advantage is likely to increase. The voltage ratings on HVAC cables are also rising, from the standard 132kV used in current wind farms up to 170kV and 245kV.

According to The Crown Estate's Round 3 Connection Study, the total requirement for cable for Round 3 projects is approximately 7700 km (3000km HVAC and 4700 HVDC). The forecast European demand for export cables is shown in Figure 3.4.1.1. Note that from 2015, the amount of cable per GW installed in the UK increases significantly due to increased distance to landfall for typical projects

Our forecasts show that the European demand for HV export cables will exceed supply by 2015 without investment in production capacity, especially in HVDC cables. Between now and 2020, European and other countries will invest significantly in electricity interconnectors also. This will also increase the demand for HVDC cable, as will the UK onshore grid strengthening work which is expected to take place in the next five years.

The anticipated supply capacity is plotted against demand in Figure 3.4.1.2. This shows that until 2015, sufficient capacity is available. The relatively slow ramp-up rate achievable (indicative gradient of ramp-up is shown for one year only) is due to the limited number of players in the market and the timescales and investment needed to bring new lines in. We anticipate that new investment (on top of existing plans to ramp up supply) will be needed by 2011 (2012 using most optimistic response) if we are to have sufficient supply looking forward to 2015.

Inter-Array Cables

There are more manufacturers of medium voltage inter-array cable than for high voltage export cable and the barriers to new entrants and establishing new lines of production are lower, so the industry does not expect inter-array cables to constrain project delivery. Most purchasers believe that the market will deal reasonably effectively with supply issues around these cables, though new investment certainly will be needed. One UK supplier has already made a significant investment and is willing to expand further if the demand materializes, quoting current lead times of 40 weeks for 33kV export cable and a ramp-up time to increase supply of only 6-8 months.

The anticipated demand and value of inter-array cables for the European offshore wind market is shown in Figure 3.4.1.3. The total demand of approximately 9000km is equivalent to the distance from London to Mexico

City and total spend is of the order of £1.3 bn. This forecast is based on an assumption of gradually decreasing cable use per MW installed, following the trend seen in wind farms installed to date due to the use of larger turbines. There have been suggestions that due to the increased size of wind farms there may be benefit in increasing the inter-array voltage from 33kV to 66kV. So far, customers have not shown interest in 66kV arrangements.

Issues

Limited supply. With a highly concentrated market (three established players and one new entrant) and limited manufacturing capacity, long-term concerns remain about the availability of high-voltage export cables.

Lack of focus on grid. Manufacturers have expressed concern that due to lack of focus on grid and technical understanding, supply decisions may be poorly timed, leading to delays.

Frequent damage during and after installation. To date, cables have been the largest source of insurance claims relating to offshore wind farms. Technical, commercial and consenting issues need to be addressed in order to reduce the lifetime cost of subsea cables, including export cables.

3.4.2 Steel Foundations

To date, the majority of offshore foundations have been manufactured from steel and the vast majority of these have been monopiles. As water depth and turbine size increases (leading to greater tower-top mass and decreased aerodynamic loading frequencies), it is anticipated that there will be a significant move towards alternative designs of foundations, including jackets, tripods and suction buckets. In deeper water, other concepts will be used, including tension-leg and other floating designs.

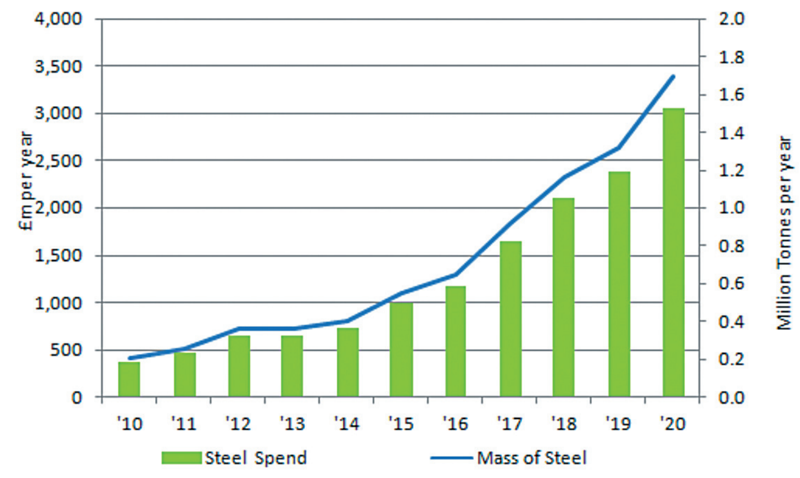


Figure 3.4.2.1. Projected spend and production for steel foundations for European offshore wind to 2020.

The anticipated demand and value of steel foundations for the European offshore wind market is shown in Figure 3.4.2.1. The total spend is of the order of £5.9 bn. This forecast is based on an assumption of constant percentage use of steel foundations (as opposed to concrete foundations) from 2012 and with foundation mass being a strong function of water depth and turbine size, assuming a move to non-monopile structures as they become the most cost-effective for a given site, following the trend seen in wind farms contracted to date.

Although existing supply is well below eventual demand and few players currently service the market, ramp-up times are relatively short (less than 2 years) and a good number of players (including those manufacturing wind turbine towers currently at inland locations) could locate new businesses coastally to supply. Steel foundation manufacture indeed offers significant opportunities for UK business. The current dominant market leader in monopile supply, SIF/Smulders, has current supply capability of the order of 0.1 million tonnes per year. By 2020, demand will be over ten times this capacity. Developers did not show much concern about supply of foundations, with more attention being given to design innovation. Such innovation, though needed, may raise new supply concerns as it takes time to bring through suitable manufacturing technology efficiently to produce the latest designs. Investment is needed not simply in increasing the number of manufacturing lines but also for example in increasing mechanisation in the manufacturing process for jackets and in fewer-pass welding for really thick joints, for example by using TWI's electron beam technology.

Issues

Limited supply. With few players and limited manufacturing capacity, significant investment will be needed in the medium term.

Volatile steel price. As foundations form significant element of wind farm CAPEX and cost is dominated by global steel prices, the choice of optimum foundation is a function of volatile commodity markets. Opportunities may exist for the use of recycled steel from ships and oil and gas facilities.

Installation tooling restricts monopile sizes. There are technical reasons why large diameter monopiles (5.5 m and above) often are not the most cost-effective solution. There are also limits in the current availability of installation tooling (anvils etc.) which affect the choice of foundation technology.

Innovative solutions not proven. New designs are under consideration but are often hampered by incomplete design inputs due to the need for iterative feedback from a wind turbine manufacturer.

3.4.3 Offshore Electrics

Landscape

The feedback from the industry is that offshore substation transformers remain the greatest area of concern relating to offshore electrical hardware, though the general view is that though tight, they are not expected to become critical. The offshore wind demand is a fairly small fraction of global demand for transformers of this size, so it is anticipated that sufficient supply will be available. Lead times generally are between 2 and 2 ½ years because of the nature of typical infrastructure projects.

"Inter-turbine subsea cables and substation transformers will be tight but are not expected to become critical path."
SIEMENS T&D

Global players are increasing capacity at the moment, but with six factories closing around five years ago (two in UK), expansion is likely to be through the addition of new bays rather than establishing new facilities (in EU at least). Large transformers are quite bespoke and not many customers like to be the first to buy from a new facility or supplier.

Much of Round 3 will be connected via HVDC links. Currently, it takes typically 3 years from contract award to energisation of HVDC converter stations of grid transformers, plus a 9 month procurement process, giving a total 3½ to 4-year programme from starting procurement to grid connection.

Another concern about transformers is the risk of damage during operation with a consequent long outage and resulting lost revenue. Already, the substation transformer at Nysted offshore wind farm in Denmark has been replaced, with downtime of 6 months or so.

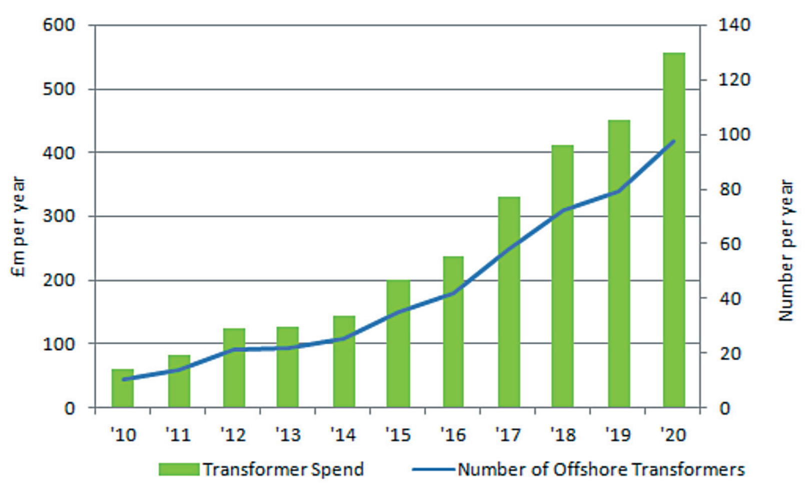


Figure 3.4.3.1. Projected spend and production for substation transformers for European offshore wind to 2020.

Issues

Limited supply of substation transformers. Though lead times are long, not too much concern is raised at being able to secure supply within normal procurement timescales for projects.

High degree of bespoke activity. In order to enable modular build, address spares concerns and improve costs, it is recognized that a higher degree of standardization in specification and design and would be beneficial. It also allows a more flexible procurement route for transformers.

3.4.4 Onshore Electrics

Landscape

Apart from the grid connection itself, none of the players we spoke to anticipated particular concerns within the onshore electrics, though obtaining planning consent for onshore facilities has proven to be challenging at times and lead times for main components are long. A substation for a major offshore wind farm such as London Array is a significant size, covering a total area of 20 acres including landscaping.

Issues

Consenting delays. Projects have been held up by consenting for onshore electrical works. As offshore wind farms grow in size, onshore issues need to be carefully managed.

Lack of availability of skilled power engineers. ABB, Siemens T&D and others expressed concern over the lack of available experienced power engineers, partly due to high demand from other sectors. At the moment, postgraduates frequently are recruited from overseas as there are not enough with suitable skills coming out of UK universities.

INSTALLATION AND COMMISSIONING				
Proven capability (examples only)	Belfast, Esbjerg, Ijmuiden, Mostyn, Vlissingen	A2Sea, Ballast Nedam, Geosea, Jack-Up Barge, Marine Construct International, MPI Offshore, Scaldis Salvage and Marine	CNS Subsea, Global Marine, Mika, MPI, Nexans, Peter Madsen Rederi, Prysmian, Subocean	Ballast Needam, CB&I, Hochtief, Flour, KBR, MT Højgaard, SLP, Van Oord, various supporting consultancies
Likely future capability (examples only)	Bremerhaven, various (UK)	BARD, Beluga, GAOH, Hochtief, SeaJacks, Seaway Heavy Lifting, Seawind, Smit, Wind Carrier		Aquaterra Energy, Bilfinger Berger, oil and gas players
Component	**Construction Ports**	**Turbine and Foundation Installation**	**Cable Installation**	**Civil Engineering / Construction Management**
Market concentration	High – few ports have space/capability	High	High – few experienced players	Medium
Issues	• Lack of suitable construction ports currently available	• Limited supply of suitable vessels available	• High risk of damage	• Limited experienced skills base
Actions	• Engage early with Zone consortia and interested investors about developing ports infrastructure • Invest in infrastructure and shore-side access for new facilities where relevant	• Facilitate aggregation and dissemination of clear picture of installation needs • Assist in early pre-commitment of vessels for Round 3 zones	• Facilitate dialogue on how to improve learning and reduce number of issues arising with subsea cables	• Challenge consortia on project management capability • Maximise sharing of experience and good practice • Develop links between UK and continental trainers
Traffic light rating (see 3.1)	A	R	R	A

3.5. Installation and Commissioning

Installation and commissioning covers work on all balance of plant as well as turbines. It is broken down further into the following areas:

- **Construction Ports.** Several UK ports have been used to date for offshore construction; however, the scale of Round 3 developments will require more ports with larger lay-down areas.
- **Foundation and Turbine Installation.** This includes transport from to the site and installation, including scour protection, transition piece installation, J-tubes and ancillaries, then later installation of turbines.
- **Cable Installation.** This includes both inter-array and export cables and their termination at the foundations.
- **Civil Engineering / Construction Management.** This includes delivery of specific supply contracts within an EPC or multi-contract environment.

Onshore electrical installation and grid connection, covering substations and cable-laying is not considered a likely area of concern, employing widely used resources from across the power industry.

3.5.1 Construction Ports

Landscape

The wind industry's requirements for construction ports are starting to be better understood by UK port owners. There are a number of scenarios for port usage in offshore wind construction. It is likely that the use of ports for storage and marshalling will decrease in the North Sea but may well be maintained in areas that are less well served by manufacturing facilities.

> *"All new vessels in discussion are fast jackups. This pushes towards the model of ignoring UK East Coast construction ports. Hardware only touches UK if manufactured/ assembled there."* **A2SEA**

The anticipated demand for ports is shown in Figure 3.5.1.1, based on the assumption that the construction port may also house turbine assembly and other major component manufacture (non-construction costs and space is not included below and would increase figures significantly). A typical port here is considered to have 8 hectares available seasonally, plus 200-300 m quay length, water access to accommodate vessels up to 140m length, 45m beam and 8m draft with no tidal restrictions and no overhead restrictions below 100m.It is assumed that each such port can install 100 turbines per year. In reality, instead of having 20 or so similar-sized ports, it is envisaged that a core of 4-5 very large hubs plus a range of smaller ports of the size described will be used. The total value to European ports of wind farm construction (excluding wind turbine manufacture) in the period to 2020 is of the order of £1.2bn.

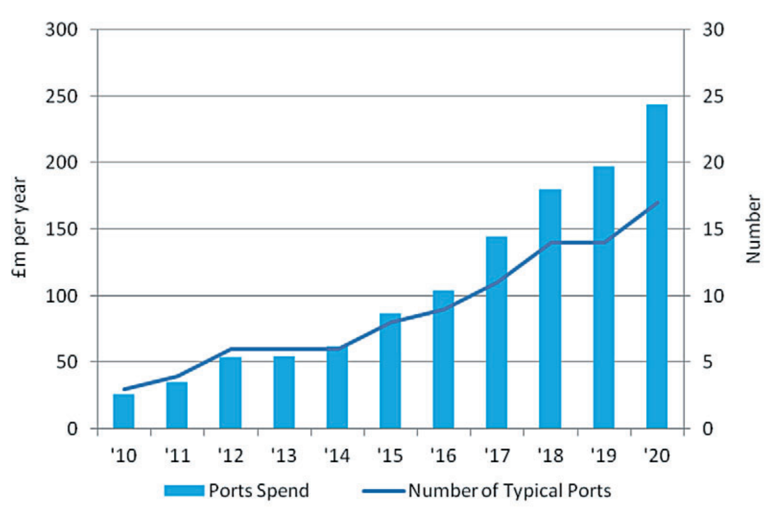


Figure 3.5.1.1. Projected spend and number of typical construction ports for European offshore wind to 2020.

Issues

Lack of suitable construction ports currently available. Currently, no wind turbine supplier assembles turbines at a coastal location with 24-hour direct water access. In order to improve efficiency of delivery of offshore wind, this situation will change. Port facilities exist in UK, as well as on the continent, for construction as well as large-scale manufacture. It is important for UK offshore wind that the UK retains some capability in this area.

3.5.2 Turbine and Foundation Installation

Landscape

Vessels remain a key constraint in the eyes of most developers and turbine manufacturers. Typical lead times from the date of investment decision to a new vessel entering the market have been given as nine months for modification of an existing vessel and between 2 and 2½ years for a new build of a "typical" jack up barge or self-propelled installation vessel. In general, vessels on the drawing

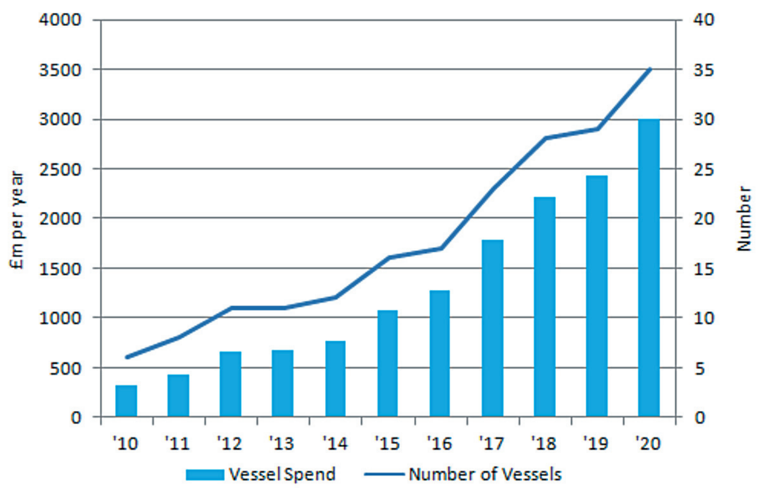


Figure 3.5.2.1. Projected charter spend and number of installation vessels for European offshore wind to 2020.

board or in construction are fast, self-propelled crane ships, rather than towed platforms.

Other developers are less concerned, advising that there are plenty of vessels that could be used and new ones are ready on the drawing board to be built should the commitment be provided. Generally the limiting operation is turbine installation, rather than foundation installation. Today, a number of vessels are used for both activities. It may be that Fluor's innovative methods for monopile installation at Greater Gabbard will change the playing field with respect to monopile installation, also enabling alternative vessels to enter the market.

> *"Vessels will limit installation within 5 years unless we see new ways of investing in vessels soon"*
> *VESSEL OPERATOR*

Either way, new investment is being seen and more is needed, especially as some existing vessels are not suitable for installing larger turbines in deeper water and in harsher conditions. Three examples of vessels committed to in the second half of 2008 are the MPI Adventure and Discovery (due to be available in 2011) and GeoSea's Sea-2000. Others have prepared designs of vessels in order to be able to progress to manufacturing quickly. Manufacture of vessels, though time consuming, is not a limiting factor – there are a range of suitable shipbuilders and though propulsion systems, jack-up systems and cranes are specialist products, each can be sourced given sufficient planning and time. Predictions of the number of vessels required to be operating depend on different construction scenarios, vessel sizes and levels of conservatism about weather. Our forecast is provided in Figure 3.5.2.1, along with charter spend on vessels (rather than build cost for new vessels). Total European spend to 2020 is of the order of £15bn.

Another related consideration is the provision of monopile installation equipment, specifically large diameter anvils (each designed for a specific monopile diameter). Two main players, IHC and Menk, have provided tooling for most offshore wind monopile installations to date where driving has been chosen and new anvils will be required as larger monopiles are produced. Significant investment and lead time is required to produce these new anvils. Most developers understand that they need to secure the use of such tooling before monopiles are manufactured. One way to reduce the size of anvils required for some ground conditions is to use conical-topped monopiles, but this introduces additional monopile manufacturing complexity and cost.

It is anticipated that we will see innovation in a number of areas of installation and a widening in the number of approaches before any future harmonization on preferred methods. This will include:

- Speeding up the standard processes;
- Reducing the transit time for crane vessels by using floating/jackup feeder vessels, possibly with Ampelmann or equivalent technology; and
- Using dynamic positioning (DP) vessels for foundation installation.

One caveat is that new foundation technology or installation methods may drive the need for new vessel solutions, superseding existing vessels. As an example, installation methods and vessels for gravity base foundations are completely different to those for monopiles.

The availability of heavy-lift vessels for the installation of gravity base foundations is not yet considered to be of concern. Fewer vessels still are suitable for substation installation.

Issues

Limited supply of suitable vessels available. In general, there is agreement that vessels will limit installation within 5 years unless we see a new way of investing in new vessels. In the first half of 2008, it was possible to finance a new vessel based

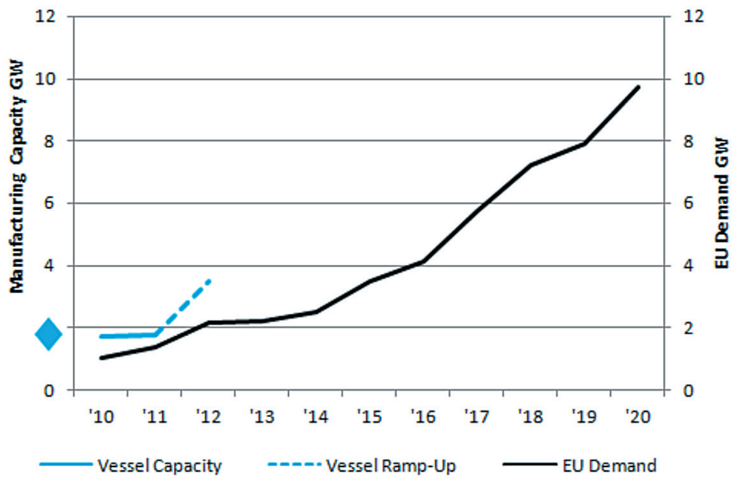


Figure 3.5.2.2. Projected installation vessel capacity and European demand to 2020.

on a long-term charter. Now, it may be that developers or others would need to provide a significant equity stake in any new vessel. This may not look so unattractive given the relatively low discount offered for long-term compared with short-term charter.

> *"6 months ago, vessel owners could have financed a new vessel on the promise of 5-year charter, but not now."*
> *RWE NPOWER*

It is anticipated that Round 3 licence holders will need to consider carefully such commitments pre-consent in order to be sure of securing supply. Other sources of finance may well also be available by then. Our forecast of vessel capacity (Figure 3.5.2.2) shows that further investment is needed now in order to meet 2012 needs. It may be that this investment has been made without visibility. If not, then we may see non-optimal solutions adopted in 2012 and 2013.

3.5.3 Cable Installation

Landscape

There is increased concern in the market about cable-laying and it is listed as one of the top or upcoming constraints by a number of people. The incidence of cable damage during or after installation, coupled with commercial difficulties of various players, has alerted a number of stakeholders to the issue. More experienced players generally have been priced out of the market, with the result that installation has been carried out by less experienced players and has been of insufficient quality. Whether the wind industry can get the quality that it needs at the prices it has been paying is yet to be seen. Sufficient vessels are available as they work also in other sectors.

> *"Next bottleneck is quite likely to be cable installation - need more companies with hardware and muscle to deliver large contracts. It seems as although we have had cables on the seabed for decades, it is still not a mature market... Few suppliers have sufficient credibility to be chosen by a utility developer."*
> *RWE NPOWER*

Some of the cable manufacturers own their own installation vessels and can install their own cables. Nexans has a marked preference for installation by water jetting installation, arguing that this is less likely to damage cables during installation. Deep burial (to 3m depth), as demanded for Round 1 projects, has certainly been the cause of some damage. Shallow burial coupled with routine condition checks is seen as a preferable method under many circumstances. Dialogue between cable suppliers and installation contractors could increase the compatibility of design and installation methodology. The oil and gas industry has a standards group under the Umbilical Manufacturers' Federation, which meets to review standards and best practice for umbilical cable installation and a similar group would be likely to benefit offshore wind.

Issues

High risk of damage. Cable laying is seen has the highest risk/value ratio of any offshore wind contract. The quality of work to date generally has been insufficient.

3.5.4 Civil Engineering / Construction Management

Landscape

In early projects, often the wind turbine manufacturer took management responsibility for construction activities under an engineering, procurement and commissioning (EPC) contract. As the market has matured, developers have chosen to use multiple supplier contracts (MSC) where they project-manage the process, placing multiple supply or EPC contracts, sometimes using specialist construction management providers to work alongside them. For Greater Gabbard, Airtricity has once again followed the EPC contracting route, this time using long-term project partner Fluor, a construction management provider to deliver the full project. Whether EPC, MSC or using combinations of both with framework supply agreements and some more collaborative arrangements, significant construction management resource is needed in all projects and in offshore wind this is in relatively short supply. There are a number of highly competent players especially from oil and gas and other infrastructure supply that are yet to manage offshore wind farm construction and it is likely that we will see these enter the market in due course, though there is concern about the cost of oil and gas teams.

For many projects, front-end engineering design (FEED) activities are becoming more detailed. Such studies enable more focussed procurement, reduce project contingencies and post-consent timescales and can facilitate innovation on a range of levels.

Issues

Limited experienced skills base. There are few people with long-term experience in offshore wind construction, but there are possibilities to draw in skilled people from other sectors. The challenges of effective delivery of offshore wind projects with a fair degree of repeated process are similar but different from oil and gas and other infrastructure work dominated by single, high value activities.

3.6. Operations and Maintenance

Issues relating to operations and maintenance are considered under the following headings:

- **Maintenance.** Maintenance can be broken down into planned activities (much of which could be classed as inspection, but also includes routine exchanges of worn parts and planned replacement of major components in response to failure investigations) and unplanned maintenance in response to faults. Unplanned maintenance often requires spares and vessels at short notice. Both activities are dependent on good access to turbines, often under difficult environmental conditions.

- **Operation.** This includes monitoring of wind farm performance and management of maintenance.

- **Onshore facilities.** Maintenance needs to be supported by onshore facilities, used for administration, refurbishment and storage of spares.

- **Transport and offshore accommodation.** There is a move away from helicopter access for some asset managers, following a trend in the oil and gas industry, and further thinking is underway regarding offshore accommodation for wind farms far from the coast and those close to other wind farms where facilities could be shared.

3.6.1 Maintenance

Landscape

Currently, almost all commercial offshore wind turbines are either in warranty or maintained under long-term service agreement by the turbine manufacturer. UK asset managers are starting to address the issue of increasing numbers of onshore turbines coming out of warranty, prompting them to develop maintenance and support strategies. The three main options for maintenance are:

- Continue to purchase from the turbine manufacturer;
- Move to using a 3rd party service provider; and
- Establish in-house maintenance expertise.

> *"O&M is really important as that's where money is made or lost..."* ***INDEPENDENT OFFSHORE DEVELOPER***

A number of utilities advise a strategy of using in-house expertise from their other power generation support functions for maintaining onshore wind turbines and using specialist third party service providers (such as blade and gearbox specialists) where necessary.

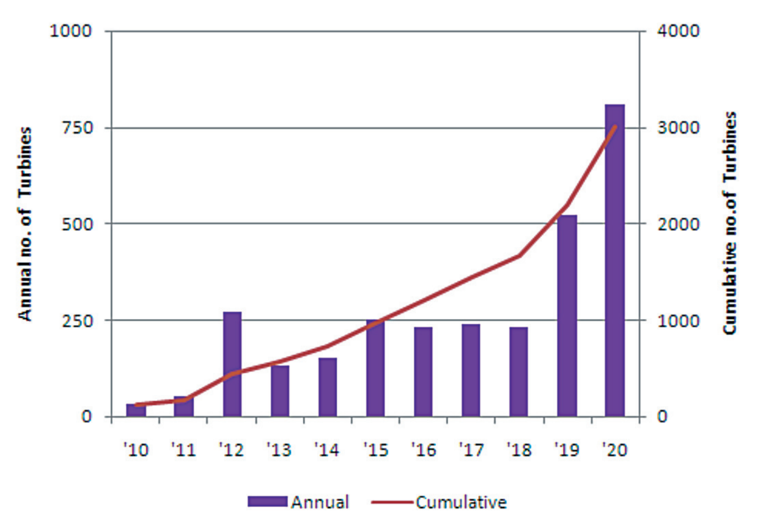


Figure 3.6.1.1. Projected UK offshore turbines leaving warranty to 2020.

OPERATION AND MAINTENANCE				
Proven capability (examples only)	Turbine manufacturers	Wind turbine manufacturers, wind farm asset managers	Various UK	Alnmaritec, Bond Air Services, Izax, Offshore Wind Power Marine Services
Likely future capability (examples only)	Onshore wind O&M player s that may extend to offshore, offshore and oil and gas contractors	Offshore / O&G contractors, operations teams from parallel sectors	Various UK	Various others, especially from O&G
Component	**Maintenance (planned and unplanned)**	**Operation**	**Onshore Facilities**	**Transport & Accommodation**
Market concentration	High	High	Medium – limited port space may be available in nearest suitable location for given wind farm.	Medium – oil & gas capabilities could engage quickly
Issues	• Dependence on wind turbine manufacturers • Limited sharing of operational experiences • Lack of skilled resource • (Significant technology development still needed - reliability)	• Complexity increases with number of assets/variety of OEMs	• Few facilities currently established	• Turbine access • Health and safety • Impact of new strategies
Actions	• Raise awareness of anticipated offshore skills needs • Support technical college courses • Maximise sharing of maintenance learning	• Maximise sharing of operational data and learning	• Invest in ports where relevant	• Raise awareness of anticipated offshore skills needs • Facilitate dialogue on transport and accommodation with special reference to health and safety
Traffic light rating (see 3.1)	A	G	G	A

It is anticipated that more asset managers will continue to purchase offshore maintenance from the turbine manufacturer given the additional level of risk associated with the technology. We suggest that those asset managers with stronger technical teams (such as DONG, for example) have a better chance of securing a relationship with their O&M provider that leads to long-term reliable turbines. Third party providers are likely to provide specialist access and repair/retrofit support to wind turbine manufacturer staff.

The expected number of UK offshore turbines coming out of warranty is shown in Figure 3.6.1.1, based on a long-term assumption of a 3 year warranty.

Issues

Dependence on wind turbine manufacturers. Currently asset managers advise against over-reliance on wind turbine manufacturers for support of turbines, both in and out of the warranty period. During the warranty period, more third party technical expertise is needed to provide independent advice. Asset managers with turbines out of warranty are also seeking additional third party technical capability for component inspections, repairs and refurbishment, particularly for gearboxes and blades, where again they are over-reliant on the original equipment manufacturer. Currently there are few players in the UK offering even onshore maintenance services.

Limited sharing of operational experiences. We understand that operators are starting to share experiences and technical information to enable them to maximise the performance of their assets, though such activity is limited by a lack of resource.

Lack of skilled resource. Turbine manufacturers, asset managers and third party maintenance service providers are all stating that acquiring skilled resources is a big issue. Siemens UK, B9 Energy and others have both teamed up with further education institutes to develop a turbine technician course to help address their resource limitations.

3.6.2 Transport and Accommodation

Landscape

Round 1 and 2 wind farms are being maintained from a base at a nearby port. The maintenance base houses crew areas and spare parts as well as the transport vessels. The relatively short distances to port makes transportation by small vessels a viable solution. As the distance and size of wind farms increase, such vessels no longer become the optimal transportation solution. Siemens have stated that they will be using helicopters for personnel transportation for Greater Gabbard, for example.

For even larger and more distant Round 3 wind farms, it is expected that the offshore wind industry will follow the trend of the oil and gas industry with the use of founded or floating hotels rather than solely using helicopters. Personnel will stay away from land for many weeks, using smaller vessels or helicopters to transfer to individual turbines. Horns Rev 2 is the first offshore wind farm to have some level of offshore accommodation.

Issues

Turbine access. Currently access between the vessel and turbine is limited due to sea conditions. In the oil & gas industry more innovative solutions have been deployed to minimise the lost time of not being able to get personnel on to the rig. Similar innovation is required for offshore turbines.

Health and safety. Key concerns relate to helicopter access and greater distance from shore for Round 3 projects.

Impact of new strategies. In response to the significant changes in operating conditions, new strategies for maintenance and staffing will be required. In some cases, these may impact design of turbines and installation methods, so consideration needs to be given to this area at an early stage.

4. Methodology

The methodology followed that of BWEA's *UK Offshore Wind: moving up a gear*, whereby an initial installation forecast and understanding of key industry constraints was presented to selected industry players (including at an early stage, BWEA's Offshore Wind Delivery Group, where final conclusions were also discussed). Interim results were presented at the European Wind Energy Conference in Marseille in March 2009. The principal method of collecting the information was by confidential interview with a range of offshore wind players. Factual input, company and personal views were received and presented back in writing to interviewees for approval under a number of different levels of confidentiality, including:

- Input may be published and be attributed / will not be attributed / may be passed to The Crown Estate but will not be published directly / will not be passed on or published.

BVG Associates is grateful to the many people who contributed through formal interviews and informal discussions. Further feedback is always welcome.