renewableUK
The voice of wind & marine energy

THE CROWN ESTATE

BUILDING AN INDUSTRY

UPDATED SCENARIOS FOR INDUSTRIAL DEVELOPMENT

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BVG Associates is an independent consultancy with a global outlook, specialising in the technology, delivery and economics of wind and marine energy generation systems. We specialise in market analysis, supply chain development, technical innovation and project implementation enhanced by our hands-on experience and deep understanding of technology. Our team has the best objective knowledge of the market and supply chain for wind turbines in the UK, derived from over 130 combined years of experience. Our sole purpose is to help clients establish renewable energy generation as a major, responsible and cost-effective part of a sustainable global energy mix.

Authors

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Disclaimer

Foreword by RenewableUK

2013 is a year of consequence for the offshore wind sector. It is first and foremost a year of delivery. Half way through the year we have over 3GW in operation. Already we have seen Greater Gabbard – at 504MW – claim the title of world's largest offshore wind farm, before passing on that honour to London Array with its 630MW. The UK has, by a country mile, the world's most successful and ambitious offshore wind programme.

Alongside these operational projects, we have construction work around UK waters which will add a further 1.5GW of capacity, with ports in areas such as Barrow, Belfast, Lowestoft, Merseyside, Grimsby, Teesside and Mostyn busy as installation and operating bases for existing projects and the next tranche of offshore wind capacity.

The supply chain supporting this infrastructure programme is a substantial one, and the benefits accruing to UK industry right now are real and significant.

However, it is important that we pause and consider the next phase of growth, and take stock of what further opportunities could come to the UK, given that we expect to dominate the international league table for ambition in offshore wind for some time to come. This need to take stock and plan for the future is what makes 2013 important for a number of other reasons.

2013 will see the publication of the Government's Industrial Strategy for Offshore Wind, as well as its draft and final delivery plans within Electricity Market Reform. These documents will define what happens in the next phase of this offshore wind programme. Most critical will be the UK's ability to secure a greater share of economic benefit available from this infrastructure programme.

This updated *Building an Industry* report sets out the size of the opportunity at hand. It shows that the overall scale of ambition in the UK matters, and sets out the views of industry about likely scales of delivery. Importantly, this applies not just to the scale of our offshore programme out to 2020 and whether we see 13GW or 18GW delivered, but what happens across the next decade. For an industry which is making long-term decisions about manufacturing capacity, whether the UK is content with current offshore deployment plans or wants to press ahead at scale further out to 2030 matters greatly.

Irrespective of the scale, the supply chain opportunities are considerable, but our report also shows that Government needs to take care to play its hand intelligently. We know Government is all too aware that a UK supply chain will not form of its own accord, but will require Government to be an active player and supporter of this market.

Government's actions are crucial, as this important research shows that in the race to land UK manufacturing – around which a supply chain can more easily coalesce – we are in competition with other European nations also seeking to secure such benefits. Our advantage is the potential scale of our programme. The challenge is the need to secure significant inward investment from first tier manufacturers to build upon the limited manufacturing base that we already have. This is in contrast to our competitors who already have established supply chains built from onshore wind or earlier offshore projects. Alongside this, industry has also had the challenge of managing investor uncertainty, while delays in consenting are leading to gaps in the build out programme which impact on order books for the manufacturers.

It is clear that stakes are high, but much can be gained from developers, manufacturers, port operators and government working effectively together. There is a shared interest in a healthy industry build out that increases the sector's ability to reduce costs, while providing confidence to manufacturers to invest in UK sites. Everyone therefore needs to take seriously the need to deliver on both cost and economic benefit, and be aware of the risks of not putting in place a programme capable of delivering this.

2013 therefore marks a fork in the road. We can look back and see the achievements in what is a world leading sector. And we can look forwards and work out how we best build on this. This means the UK avoiding the road less travelled. Unlike in Robert Frost's poem *The Road Not Taken* it is clear right now which is the path to tread. The UK needs to step confidently onto the busier, faster road: down this route lays hustle and bustle, risks and rewards. Also down this road lays continued UK market leadership, cost reduction and clear UK economic benefit.

But Government and all parts of the industry need to commit to travel down this path together rather than standing at the roadside waiting for another to make the first step. The 2013 Industrial Strategy represents the moment where industry and government sign up to the task at hand and agree how to grasp the prize. The contribution of this report, "Building an Industry", is to set out in clear terms the scale of this prize, the supply chain needed for the key elements of turbines, substations, foundations and cable, as well as the technical challenges faced in growing this supply chain in the face of international competition. With confident steps, 2013 could be the year when we cement the UK's place at the head of this global shift to a low carbon economy; a strategic business sector delivering vital low carbon electricity as the end product of a healthy UK supply chain.

Maf Smith
Deputy Chief Executive
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Executive summary

The UK is at the forefront of offshore wind development and the global leader in installed capacity. Despite this pedigree, and the fact that there is a significant pipeline of projects in planning, investment in manufacturing and installation infrastructure in this country has not yet followed at any significant scale.

Defining a healthy industry

The UK has a once-in-a-generation opportunity to benefit from its world-leading position by stimulating investment in manufacturing and installation infrastructure that can serve its domestic market, overseas offshore wind farms and parallel sectors. If it delays, then investment will be made elsewhere to meet demand and then there will be little incentive to repeat that investment here.

To help the UK Government, industry and wider commentators, this report provides evidence on the potential scale of activity that will be generated by offshore wind projects in the UK and the rest of Europe, and the opportunity this presents for the UK supply chain. Two scenarios have been prepared that are in line with Government projections for UK offshore wind activity. These show that there are clear opportunities for securing UK investment in manufacturing facilities for wind turbines and foundations, as well as offshore substations, subsea cables and the wider supply chains that will coalesce around all these key components.

Importantly, the level of opportunity correlates to the level of deployment, and our two scenarios present contrasting pictures of the future UK offshore wind market.
In our lower scenario, shown in Figure 1, significant industry growth does not begin until 2018, leading to 13GW installed by 2020 and 33GW by 2030. Our higher scenario, shown in Figure 2, shows an offshore wind industry that is a cost-effective part of the UK energy portfolio, with sustained investment in new capacity and a decreasing cost of energy, driven by confidence in a long-term future. This scenario sees a rapid growth in the installation of new capacity, with a UK installed capacity of 18GW by 2020 contributing to a European total of 36GW.

Figure 1. **UK offshore wind installed capacity from 2013 to 2030 based on Scenario 1**

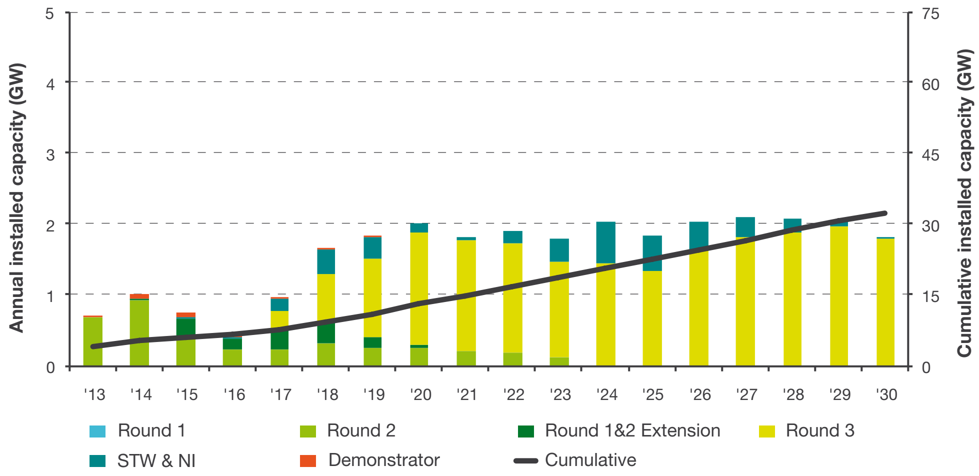
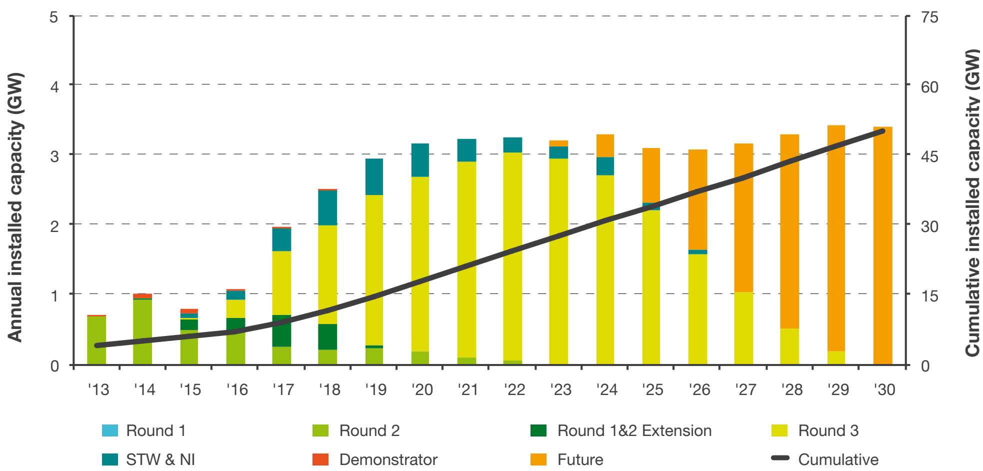


Figure 2. **UK offshore wind installed capacity from 2013 to 2030 based on Scenario 2**



Although both scenarios will generate significant levels of activity, the lower scenario runs a greater risk of not stimulating inward investment in the UK. This is because the commercial and logistic benefits of setting up in the UK may not be a sufficient incentive for Tier 1 suppliers, who will instead look to supply offshore components from existing Continental supply chains. This lower growth scenario will also limit the ability of the industry to deliver cost savings.

These scenarios are illustrative yet are important for demonstrating the sliding scale of opportunity available to the UK. The UK will be in competition with other European countries for the production facilities that will be required but it is important to note that even the lower scenario offers strong opportunities for the UK to secure activity.
Another important difference between the two scenarios is the level of new UK capacity beyond 2020. Greater levels of activity in the long term will spur greater industry confidence and encourage more inward investment in the UK. It is clear, however, that for continued deployment beyond 2020, the offshore wind industry will need to have delivered on commitments to reduce its cost of energy and hence be able to compete with other low-carbon technologies for market share. In part, its ability to do this depends on a clear long-term Government vision for offshore wind. It is critical that industry and Government have confidence in each other and a shared long-term vision of the growth of offshore wind in the UK.

Finally, it is relevant to note that industry confidence in UK market plans is especially important as other markets, in particular that of Germany, may offer lower long-term levels of activity but an earlier ramp-up in demand, which means that investment may be committed elsewhere before the UK regains its market lead.

Stimulating UK manufacturing investment

The supply chain for the offshore wind market is rapidly developing, and many companies have well-advanced investment plans. Figure 3 and Figure 4 show the progress being made in the building of coastal turbine and foundation production and installation facilities required to meet forecast European demand in 2020 under each scenario. This shows that 40% of the facilities required are already operational for scenario 1 and a third of the facilities required are already operational for scenario 2. Further announcements from leading offshore wind companies for new production facilities would, if delivered, account for a further third of the required supply chain capacity. Coastal production facilities also act as customers for lower-tier suppliers, thus offering further local supply opportunities.

Figure 3. **Turbine and foundation coastal manufacturing and installation facility demand required to meet European demand in 2020 (with UK capacity based on Scenario 1)**

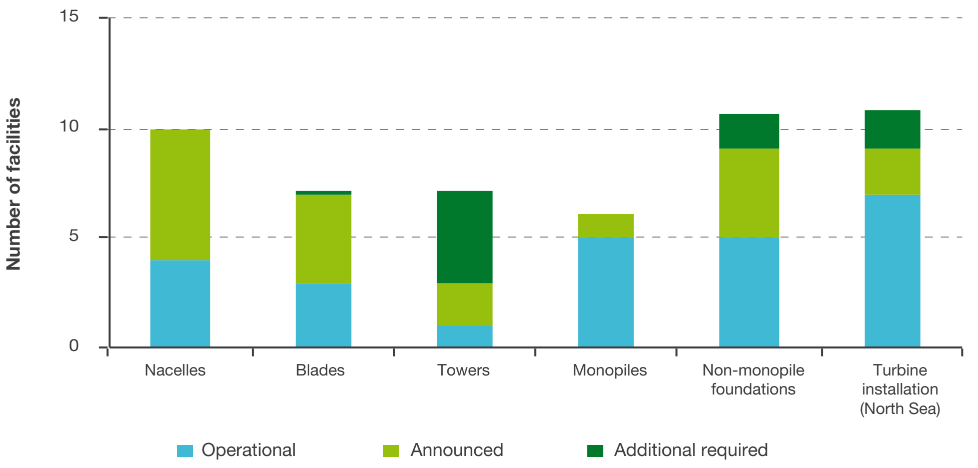
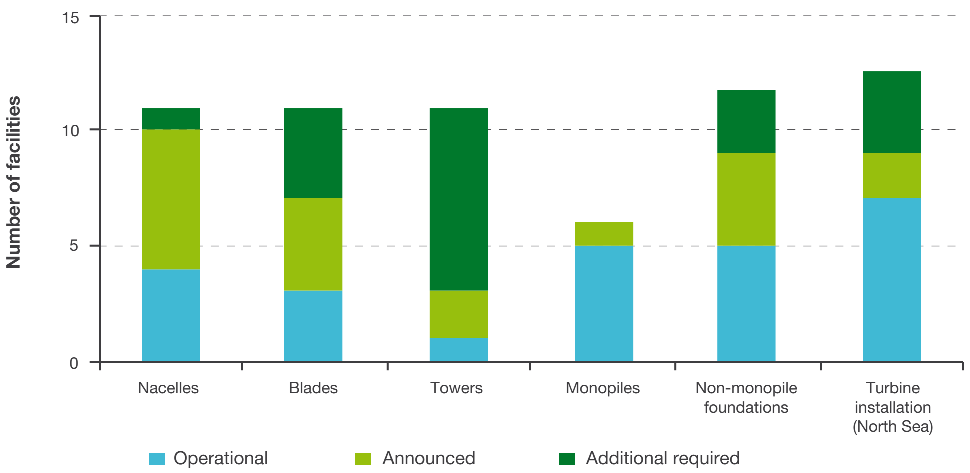


Figure 4. **Turbine and foundation coastal manufacturing and installation facility demand required to meet European demand in 2020 (with UK capacity based on Scenario 2)**



Of these operational and announced facilities, fewer than a quarter are located, or are planned to be located, in the UK, and uncertainty in its market is currently inhibiting future infrastructure investment. The opportunity for industrial development in the UK is still considerable but the Government must give companies confidence about the size and stability of the long-term market to secure a significant proportion of the remaining investment in the face of strong international competition.

Developing the UK supply chain

The size and scale of our market is the key lever for the Government to grow supply chain activity in the UK but other measures are also needed in some sub-sectors, such as ports, where structural issues mean that increased levels of national demand are not enough to secure the activity for the country. Such tools include a more proactive approach in shaping the development of industrial clusters, underwriting investment in infrastructure and strengthening requirements for UK content. These are needed because of the fierce competition for offshore wind jobs coming from elsewhere in Europe. Countries such as Germany and France are already financially incentivising infrastructure development and emphasising the importance of domestic content to attract inward investment and support indigenous growth. This means that the UK Government needs to take action to allow companies investing in UK facilities to compete on a level playing field with Continental facilities.

1. Introduction

Over the next two decades, the UK faces the combined challenges of replacing a significant proportion of its electricity generation capacity, minimising increases in energy bills, reducing its carbon footprint and improving the security of energy supply in the face of increasing global competition for resources.

The most practical means of resolving these challenges will be through a portfolio approach using a range of different renewable and low-carbon energy production technologies. A vigorous debate continues to run about what balance should be used but, subject to achieving the anticipated improvements in the cost of energy, offshore wind is certain to be a key technology.

Beyond these headline considerations, however, a further factor that affects the choices made by the Government is the economic impact of the large-scale deployment of different forms of generation. This includes both the savings that could be achieved by avoiding the cost of imported fossil fuels and the economic benefits of creating facilities and jobs to build components and provide development, installation and maintenance services.

This report has been prepared to deepen and extend the analysis in RenewableUK's 2010 report *UK Offshore Wind: Building an Industry*. It is focused on providing detailed evidence on the potential scale of activity that could be generated by a strong UK offshore wind market and the opportunities that this presents for UK economic activity. It also considers this level of activity within the wider European context, both in terms of the relative importance of UK-generated demand and the existing and future levels of the domestic supply chain. The report has two audiences: Government and wider business. It seeks to support continuing positive Government action by providing accurate market information setting out what a confident market – at a scale sufficient to attract inward investment and develop UK manufacturing – looks like. For the supply chain, the report highlights market bottlenecks that offer key opportunities for proactive players.

The report starts out with a consideration of two scenarios for UK demand up to 2030 and explores some of the headline drivers and consequences of different levels of demand. This is then used to assess the potential demand for key components under the different scenarios and examines what facilities are required to meet this demand and the timescales for their development. This is compared to the level of industrial development that has already taken place across Europe, to estimate the additional supply capacity needed to meet the rapid increase in growth that is expected over the next decade.

This report has been prepared through extensive dialogue and consultation with a wide range of companies covering all aspects of the supply chain. A list of these companies can be found in Appendix 1.

2. Historical and near-future activity

The first commercial offshore wind project in the UK was installed in 2003, and the amount of capacity installed has increased every year since then. This trend is unique to the UK compared with other countries where there have often been significant gaps between projects. As a result, the UK now has the largest installed offshore wind capacity in the world, by some margin.

Since the *UK Offshore Wind: Building an Industry* report was published in 2010[1], the UK has accelerated past the milestone of a gigawatt of cumulative installed capacity so that, by the start of 2013, more than 2.6GW have been installed. The average project size has also grown, with Greater Gabbard being the first project to have a capacity of more than 500MW.

Despite this strong progress, the UK offshore wind industry faces a significant challenge in the short term, as this year-on-year growth in annual installation is expected to end with a forecast dip in activity in 2013 and 2014. This trend is largely attributed to the lack of project consents that were granted between 2009 and the summer of 2012. An attempt to fill this demand gap was made with the 'extensions' initiative, which was launched in 2010 by The Crown Estate. This provided additional capacity licences for Round 1 and 2 projects, with the expectation that these could be more rapidly deployed. Unfortunately, these have not progressed as quickly as predicted due to consenting requirements and industry priorities, so are now more likely to add capacity after 2015 than during the anticipated slow-down.

Although other European countries have had a more stop–start history, there has still been strong progress outside the UK. Building on its particularly strong record in onshore wind, Denmark was the first country to develop offshore wind capacity in the early 1990s and is now approaching one gigawatt of installed capacity. Germany was somewhat late in the development of its first offshore wind project, and currently has approximately 500MW of installed capacity but is now expecting rapid acceleration. The Netherlands, Belgium and Sweden have also all installed commercial-scale offshore wind projects.

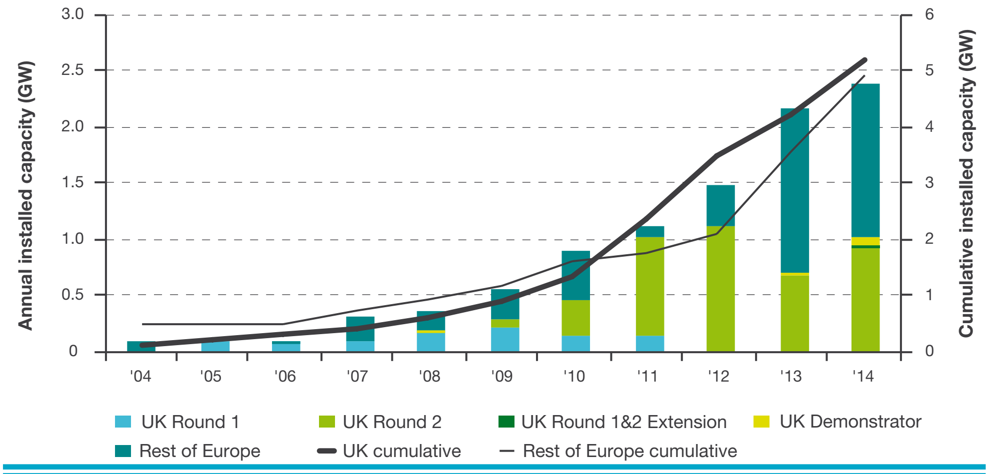
As shown in Figure 5, a forecast increase in activity across the rest of Europe in 2013 and 2014 is expected to balance the short-term dip in UK demand, but this slowing of domestic growth comes at a crucial stage in the development of the UK offshore wind supply chain. If companies are to be ready to meet the demands of a rapidly growing European market in the second half of the decade, major investment decisions in research and development, infrastructure, and manufacturing facilities will need to be made in the next two to three years. Once a company has committed to developing a facility, it is also likely that it will

1. *UK Offshore Wind: Building an Industry*, RenewableUK, June 2010, available online at http://www.renewableuk.com/en/publications/reports.cfm/UK-Offshore-Wind-Building-an-Industry, last accessed November 2012.

seek to focus future investment in this location. As such, decisions made at this point are expected to have a major influence on the future shape of the industry. The sustained levels of UK activity so far have triggered some significant investment into, and within, the UK but much larger opportunities remain as the majority of components and services are still being supplied from the Continent.[2] The strong track record of UK development, combined with ambitious market plans, was expected to attract companies to set up in the UK. This confidence has been shaken by the lack of clarity about the future plans of the Government, due to its Electricity Market Reform (EMR) initiative. The market lull in 2013 and 2014 will also do little to encourage supply chain development during this period.

Industry feedback is that the measures set out in the Energy Bill published in December 2012 are likely to give greater confidence about the medium-term stability of the market. Given the short-term delays, however, it is felt that its progress through the legislative process must be maintained to give the supply chain renewed confidence in the market beyond 2014. Such action is required to avoid the risk that suppliers choose to delay investment or decide to focus investment in their existing locations elsewhere on the Continent.

Figure 5. **Past and forecast European installed offshore wind capacity from 2004 to 2014**



2. *UK Content Analysis of Robin Rigg Offshore Wind Farm*, BVG Associates for E.ON Climate & Renewables, September 2011, available online at www.eon-uk.com/E.ON_Robin_Rigg_UK_content_report_October_2011.pdf, last accessed November 2012.

3. Installed capacity scenarios

As in *UK Offshore Wind: Building an Industry*, this report presents scenarios of future levels of installed UK offshore wind capacity and then uses these to assess the levels of demand that this will generate in the supply chain.

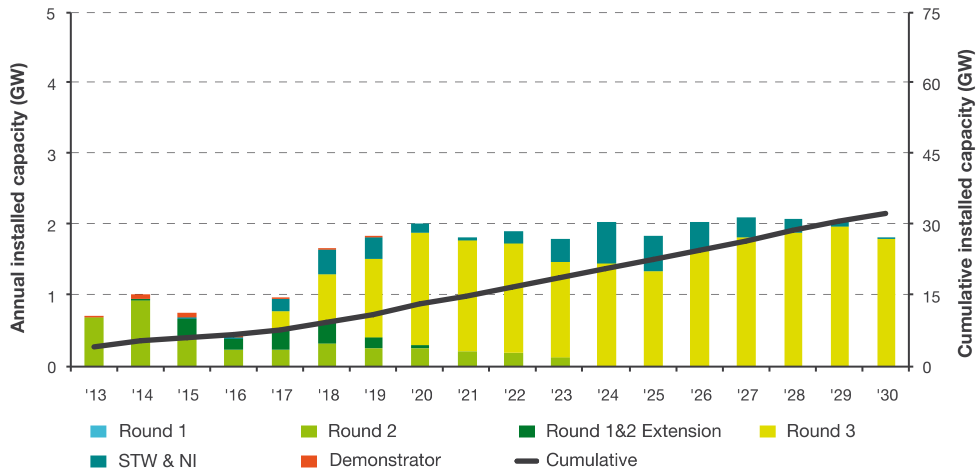
These scenarios are based on project-specific data, with assumptions about the timing of construction based on a range of factors. The methodology for the development of these scenarios is presented in Appendix 2, along with comparisons with forecasts from key stakeholders.

The scenarios do not include decommissioning or repowering activity (replacing old turbines with new, higher-rated models), as this will only account for approximately 1GW of capacity by 2030 assuming a 20-year wind farm operational life. Consideration of these activities will become more significant for the years after 2030.

In all figures in this report, vertical bars represent annual activity and lines represent cumulative activity. UK-focused bar charts show the split between UK development rounds: Round 1, Round 2, Round 1 and 2 Extensions, Round 3 and 'regional' development rounds covering Scottish Territorial Waters (STW) and Northern Irish (NI) projects. The installation of demonstration projects has also been included because they are significant in bringing emerging technologies to market, even if they contribute minimal additional capacity. For Scenario 2, we look beyond existing rounds of activity and show further licensing activity. For the purposes of this report, it has been assumed that this future capacity is developed at an average distance of 100km offshore and in 40m water depth. It is noted, however, that advances in floating foundations may mean that future projects are located closer to shore in deeper waters if such technology offers a cost-of-energy advantage.
A detailed analysis of the factors that could shape the future of the UK offshore wind market can be found in Appendix 2.

Scenario 1

Figure 6. **UK offshore wind installed capacity from 2013 to 2030 based on Scenario 1**

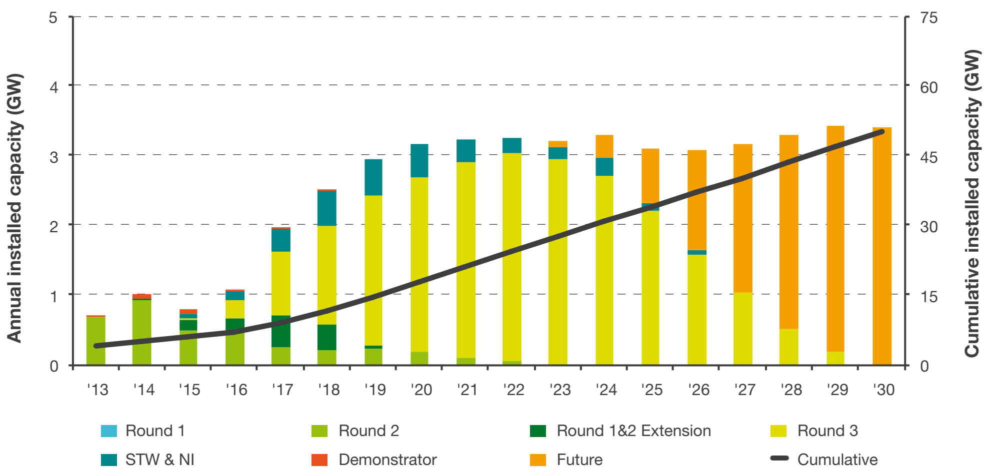


Scenario 1 assumes that the main ramp-up in offshore wind activity happens from 2018 and that the UK reaches an annual installation rate of about 2GW to give an installed capacity of approximately 13GW by the end of 2020. As more than 4GW of capacity is already operational or under construction in the UK, deployment activity out to 2020 would mainly be construction of the 8GW of capacity that has either received planning consent or has been submitted for consent. As this capacity is predominately covered by Round 2 projects or project extensions, only a small proportion of Round 3 and regional projects are forecast to be installed by 2020.

In this scenario, it is assumed that annual installation rates remain level after 2020 at approximately 2GW per year so that approximately 33GW of capacity is installed by 2030. This level of demand can be entirely met by planned offshore wind farms, which means no further development licences are required. This scenario also assumes that only the equivalent of approximately 60% of the total capacity awarded to date is constructed by 2030.

Scenario 2

Figure 7. **UK offshore wind installed capacity from 2013 to 2030 based on Scenario 2**



Scenario 2 assumes that the UK ramp-up in construction starts earlier than in Scenario 1 and that the UK reaches an annual installation rate of more than 3GW by 2020, giving a cumulative installed capacity of approximately 18GW by the end of 2020.

This construction schedule means that the majority of Round 2 and project extensions are completed, and up to 9GW of Round 3 and regional projects are installed by the end of 2020.

This level of activity is sustained up to 2030 with the remaining Round 3 and regional projects followed by new licensing activity starting in 2023. With the annual installation rates remaining at between 3GW and 3.5GW per year, approximately 50GW of capacity is installed by 2030. Such a level of capacity would be capable of meeting approximately half of the UK's electricity demand, although this level of development would probably be accompanied by the development of an integrated 'supergrid' that would mean energy could be exported to the rest of Europe.[3]

It should be noted that, although this scenario sees Round 3 effectively 'completed', this does not mean that all the licensed capacity is installed. It still assumes that some zones, or phases of zones, are not constructed due to consenting or economic barriers. As such, it is assumed that approximately 65% of Round 3 is developed under this scenario.

This scenario represents an evolution of the original 'healthy industry' scenario that was published in the first Building an Industry in 2010. The most significant change is the reduction of forecast 2020 installed capacity by approximately 25%. This reflects delays in development in the industry, caused primarily by increased uncertainty in the UK market. There are a number of factors at work here, but most significant is the Energy Market Reform initiative and plans for the introduction of a new Contract for Difference (CfD) mechanism. It is also based on the higher Government ambition that was first stated in its UK Renewable Energy Roadmap (published in July 2011) and reiterated in its 2012 update.

Forecasting growth

These two scenarios show a spectrum of growth within which it is expected that the actual level of UK development will fall. Of course, it is also possible that the Government may allow a situation in which the market delivers less than that set out in Scenario 1. Such a situation, however, would almost certainly eliminate all opportunities for offshore wind-related manufacturing growth and simultaneously limit the chance of reducing costs. Industry feedback is that the level of activity (compared with wider European demand) set out in Scenario 1 will attract Tier 1 suppliers to the UK market, though only in limited numbers. The smaller opportunity would also impact on the ability of the industry to deliver agreed cost reductions. The outcome of this lack of cost reduction is that the industry may struggle to compete in the energy marketplace in the long term. Furthermore, without significant price falls and UK economic benefit, political support would be jeopardised for future developments. As such, this lower deployment level increases the risk of a vicious circle in which there is not enough activity to encourage cost reduction and no cost reductions to stimulate more activity.

Finally, industry feedback is that the uncertainty caused by the Energy Market Reforms over the past two years means that this lower level of installed capacity remains dependent on the Energy Bill, and the dependent secondary legislation such as strike prices, being

3. 'Chapter 5: Electricity' (pp. 115–56), *Digest of United Kingdom Energy Statistics 2012*, July 2012, available online at http://www.decc.gov.uk/assets/decc/11/stats/publications/dukes/5949-dukes-2012-exc-cover.pdf, last accessed November 2012.

passed without major complications or delays. As such, without continued Government focus, developers may have installed as little as 9GW of capacity by 2020.

Delivery of such a scenario is likely to mean the country fails to build on the strong installation track record of the last decade and misses the associated opportunities for large-scale industrial development. In line with the Offshore Wind Cost Reduction Pathways Study published by The Crown Estate, it assumes that any reductions in cost of energy are insufficient to get below the £100/MWh target set by Government for 2020.[4]

In contrast, Scenario 2 would see offshore wind confirmed as a sustainable, cost-effective part of the UK energy portfolio. It assumes that significant reductions in the cost of energy are achievable and backed by joint industry-governmental work. It also assumes that Government demonstrates its confidence in the sector to unlock significant investment.

Similarly, it is possible to have a buildout rate beyond Scenario 2. In discussion with the industry, a third scenario was considered, which looked at what could occur if there was renewed policy impetus, coupled with faster development of a European supergrid and the need for offshore wind to make a larger contribution to energy needs both in the UK and abroad. Under such a scenario, offshore wind would account for a greater fraction of energy demand, enable the UK to build a world-class industry and achieve greater reductions in the cost of energy.

It was decided that such a scenario should not be included in this analysis, however, as it may distract from the current focus on ensuring a sustainable UK offshore wind sector is secured with successful deployment of Round 3 schemes, matched by UK manufacturing and cost reduction. Increased delivery is within the capability of the supply chain, given sufficient confidence to invest. Should industry and Government show clear signs of progressing towards the deployment equivalent to Scenario 2, it would be possible to review future development.

The final issue to consider is the influence of the wider European offshore wind market. UK energy companies and manufacturers are looking at how the markets in the UK and the rest of Europe will fit together. This means that policy-makers need to understand how the decisions of other European governments will affect the development of the UK market and industry. The UK is a leader in the deployment of offshore wind, but it is at a disadvantage in terms of current manufacturing sites. This challenge – in which the UK needs a higher level of deployment to secure an equivalent level of manufacturing than other European countries – is one that needs to be solved by industry and Government together. Of course, once the UK has secured offshore wind manufacturing, it will be in a strong position to then export products into other markets and use this activity to underwrite UK manufacturing. We are not yet at that point, so it is critical to understand the influence of different deployment scenarios.

4. *Offshore Wind Cost Reduction Pathways Study*, The Crown Estate, May 2012, available online at http://www.thecrownestate.co.uk/media/305094/Offshore%20wind%20cost%20reduction%20pathways%20study.pdf, last accessed November 2012.

4. UK industry demand

The UK scenarios described above have been developed on a bottom-up, project-by-project basis. This means it is possible to combine site characteristics and project timing with expected technology trends to forecast the associated level of demand for the different components of an offshore wind farm under each scenario.

In line with the original *UK Offshore Wind: Building an Industry* report, this section considers demand for turbines, foundations, array cable, export cable, installation vessels, and operations and maintenance (O&M) vessels. This update also considers demand for offshore substations. The detailed methodology underpinning each of these element forecasts can be found in Appendix 3.

This section also includes a high-level analysis of the infrastructure requirements and likely production run rates of relevant manufacturing facilities. This has been used to estimate the likely number of average-sized facilities that will be required to meet UK demand under the different scenarios. It should be noted that this facility demand does not automatically mean UK facilities. Indeed, given the existing location of the majority of the supply chain, it is highly likely that a proportion of supply will continue to come from overseas.

Lead times

The combined pressure to reduce the cost of energy from offshore wind and develop projects in deeper water and further offshore means that technology development is taking place in almost every element of an offshore wind project. Furthermore, the expected growth in physical size of turbines and foundations means that most companies will not have the capability to produce their next-generation designs in their existing facilities. Finally, establishing a new production facility involves long consenting and construction lead times, which means a supplier must financially commit years in advance of the start of supply. If the supply chain is to develop in time to meet the forecast growth in demand, it is important that companies have long-term confidence in the market.

The report therefore provides indicative timescales associated with the development of new technology and manufacturing capacity for each element of supply, and considers what hurdles could delay or restrict development.

Wind turbines

Demand

Figure 8. **UK demand for wind turbines from 2013 to 2030 based on Scenario 1 (by year of manufacture, offset from turbine installation by one year)**

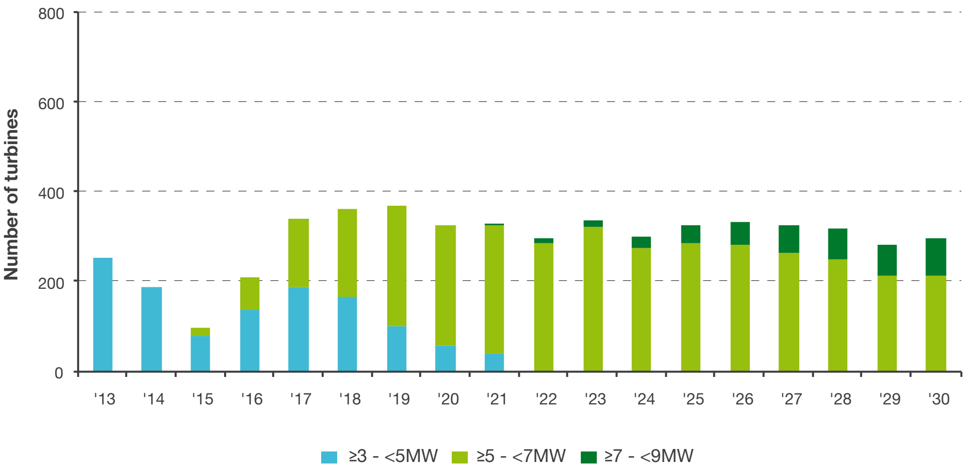
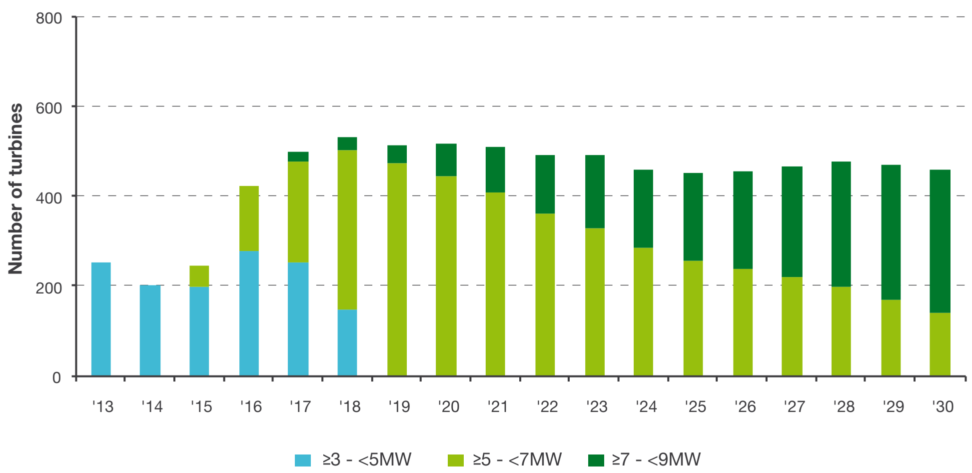


Figure 9. **UK demand for wind turbines from 2013 to 2030 based on Scenario 2 (by year of manufacture, offset from turbine installation by one year)**



The wind industry as a whole has seen sustained growth in the rated capacity of turbines throughout its history, and this has played a key role in reducing the cost of energy to a point at which it is competitive with fossil fuels on certain onshore sites. Logistics challenges may start to restrict the size of turbines installed onshore but there is currently no indication of any hard limit on the maximum size of turbines for the offshore market. As such, the rated capacity of offshore wind turbines is expected to continue to grow in the future, underpinning demand for new designs.

To date, the large majority of turbines used for offshore wind projects have been 'marinised' onshore designs, with a rated capacity of between 3MW and 4MW. These designs have been optimised over time, for example via the introduction of larger rotors, but this class of turbine is expected to be superseded in the next five years by a new generation of dedicated offshore wind turbines with higher rated capacities. Deployment of these new turbines has already started, first in onshore and offshore demonstration projects and more recently in commercial projects. The first of these offshore-specific turbines have had rated capacities of 5MW but there is now an increasing focus on devices rated between 6MW and 8MW. Subject to continuing market demand, this increase in rated capacity is expected to continue beyond 2020, with turbines of rated capacity of greater than 10MW developed in time. With the current understanding of technology, it is anticipated that the step from 3MW to 4MW turbines up to 6MW to 8MW turbines gives much of the cost of energy reduction available through the use of larger turbines, and that designs with a rated capacity of 10MW or more offer little further advantage. Given the history of the wind industry to date, however, it is anticipated that, by the time that the current ‘next generation’ of turbines are well proven, new technology will be available that enables a further generation of even larger turbines to be more cost-effective.

Details of the turbine ‘class’ breakdown and average turbine size for each scenario are presented in Appendix 3.

In all scenarios, an important consequence of this increase in turbine rated capacity is that the number of turbines required per annum reduces over time in a stable market, as fewer units are required to achieve the same aggregate capacity. Feedback from a number of existing suppliers is that the increased size of turbines and components would mean this lower unit throughput would not result in lower revenue or spare production capacity due to the larger physical size of each turbine. This is disputed by some companies, who feel that increases in automation and experience would compensate for the additional effort of handling larger components. In this case, a more advanced facility may seek to maintain production levels in terms of unit numbers but with larger turbines. This would increase competition in the long term, as unit demand decreases.

Lead time for new product development

The initial product development phase of a next-generation offshore wind turbine, from concept to detailed design, may take around 24 months for companies with an offshore wind pedigree. Companies without a track record often rely on developing partnerships with key suppliers with experience in wind, such as gearbox and generator suppliers, in order to accelerate their product development programmes.

The first stage of the demonstration phase will be the production of a prototype turbine, which is likely to be installed onshore to facilitate easier access during commissioning, testing and operation. There is currently little additional technical benefit in testing the prototype turbine offshore, as wind conditions are not that different and system dynamics onshore can be tuned to represent those experienced offshore.

Prior to the installation of this first turbine, prototype blades and, in some cases, other critical components are extreme-load tested. Typically, the prototype turbine is the subject of a series of Type tests relating to power performance, noise, grid compatibility and mechanical load measurement. In parallel to the prototype operation, fatigue tests on the blades and potentially on the gearbox or complete drivetrain and other systems will be carried out. Parallel testing increases the risk of needing to carry out repeat work but can reduce time to market. Clearly, if significant design faults are found during this phase, it will delay progress.

Installation of the prototype turbine will be followed by the installation of a small number of demonstration turbines at onshore and offshore sites. Apart from the high cost and decreased economic attractiveness of small projects with increased technology risk, one of the main bottlenecks at this stage is the availability of suitable test sites with a high wind regime and, in the case of offshore sites, relevant seabed conditions and water depths.

The turbine may also be deployed in an early commercial project on a relatively limited scale in order to accelerate the establishment of a pedigree. Typically, 15 turbine-years of operation over at least three years has been seen as necessary to give sufficient confidence to developers in order for them to consider using a new turbine in a large commercial project. This schedule will depend on the novelty of technology and the risk mitigation offered by the turbine manufacturer. Unless a more proactive approach to increasing confidence in new technology is taken, however, it is anticipated that this time may increase because of the track record of series faults remaining dormant for this period of time and the greater cost of a serial defect on the larger projects now in development.

A turbine consists of three main components – the nacelle (mounted at the top of the tower, housing the drivetrain and other auxiliary components), the blades and the tower. Today, these three components are typically produced in separately located facilities using subcomponents from a geographically distributed supply chain. Nacelles are assembled in-house, towers are almost all outsourced, and wind turbine manufacturers have used both strategies for blades. Until full commercial deployment, the manufacturer may produce the small number of turbines required in existing or temporary facilities. Such an arrangement will not offer optimal economies of scale but does act as a stopgap until sufficient commercial commitment has been provided to justify full-scale investment in suitably sized facilities with direct waterside access.

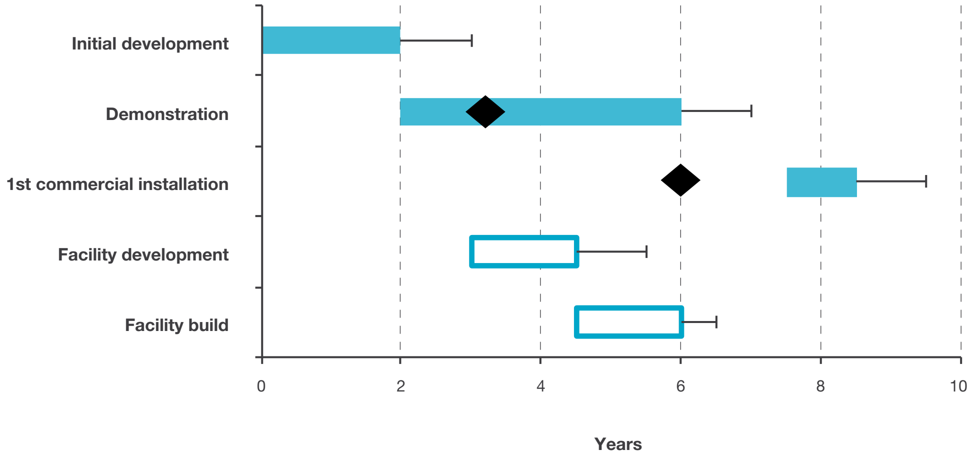
The majority of existing or planned nacelle, blade and tower facilities have a production capacity of at least a hundred 6MW turbines per year, with some planned to be at least twice this size. The planning and preparation of quayside and waterside land is location specific. Assuming a prepared port location is available, the development of nacelle, blade and tower facilities is expected to take approximately three years. This assumes a planning process of 18 months (subject to any significant complications) and a build and setup time of 18 months. New manufacturing facilities may also typically require a 'ramp-up' period of one to two years to achieve full production output.

As the timescales in Figure 10 indicate, companies seeking to develop turbine production capacity that will be ready in time for the forecast 2017 jump in UK demand in Scenario 2 will be required to have undertaken significant product development activity already, have a prototype turbine operating and an offshore demonstration programme underway by 2014. Such a schedule would also mean a commitment to major infrastructure investment in or before 2014.

Assuming annual production rates of 100 units per year, Scenario 1 represents a UK market need of three to four average-sized facilities each for nacelles, blades and towers or a combination of fewer, larger facilities. Feedback from the industry is that it is possible that up to half of this capacity could be provided by a single UK-based player. Assuming some supply from the Continent, the remaining opportunity may be insufficient to prompt significant inward investment from other wind turbine manufacturers. The additional demand in Scenario 2 would be likely to facilitate the establishment of two to three additional players in the UK compared with Scenario 1, given reasonable inward investment support.

It is important to note that the resulting direct nacelle assembly and blade and tower manufacturing activity would only represent a fraction of the total economic benefit to come from securing new coastal facilities. Rather, it is expected that the majority of the benefit will come from the significant and wide-ranging supply chain required by these facilities, which would be likely to be spread across the UK.

Figure 10. **Indicative lead times for turbine design and manufacturing facility development**



Black milestones represent first prototype installation and first commercial financial close.

Black bars represent potential delays to given stage.

Research and Development

Infrastructure Development

Foundations

Demand

Figure 11. **UK demand for foundations from 2013 to 2030 based on Scenario 1 (by year of manufacture, offset from turbine installation by two years)**

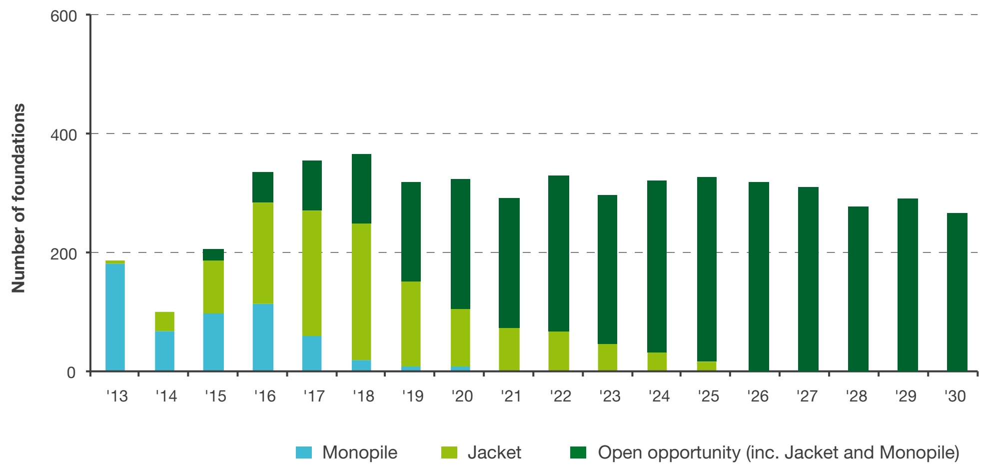
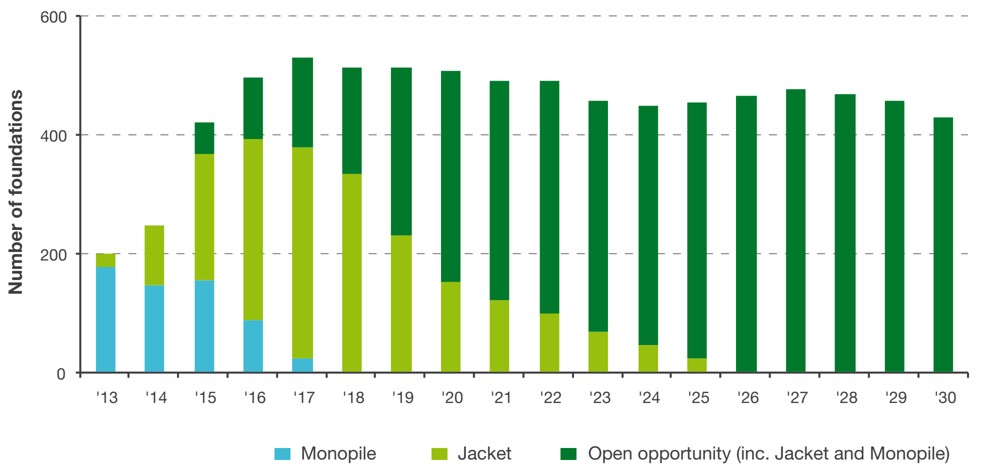


Figure 12. **UK demand for foundations from 2013 to 2030 based on Scenario 2 (by year of manufacture, offset from turbine installation by two years)**



To date, more than three-quarters of all installed European offshore wind projects have used steel monopile foundations, with most of the remainder using concrete gravity base designs. Monopile technology is considered to be tried and tested by the industry for 3MW to 4MW turbines, and there are already strong levels of existing manufacturing and installation capacity in the market.

For turbines with a greater rated capacity (typically associated with an increased turbine mass, larger rotor diameter and lower rotational speed), the cost of monopile supply and installation rapidly escalates because of the increased steel demand (in part to provide sufficient stiffness to preserve the structural dynamics of the overall system) and the need for larger, and therefore less-numerous, installation vessels and tooling. This means that there is a tipping point at which the total installed cost of using monopiles outweighs the cost of other designs. Currently, this tipping point is approximately 30m to 35m of water depth for projects using turbines with a rated capacity of 4MW or less, and 20m for turbines with a rated capacity of around 6MW. Work is underway to stretch the envelope of use of monopiles to larger turbines in deeper water, although there will still be practical, supply chain and economic limits for projects in water depths of 30m using, for example, 6MW turbines.

There is a range of alternative designs currently being proposed for projects in which monopiles are not a feasible option, and there is uncertainty about which technologies are likely to dominate in the long term. The current industry expectation is that the most common 'deeper water' design will be the four-legged steel jacket (a braced, welded, space-frame structure), but other steel designs, such as tripods and tripiles, have also been used on some Continental projects. Furthermore, other steel designs have been proposed, such as braced monopiles, monopods that use suction buckets to provide the seabed connection, and jacket variants with designs of three or six legs or 'twisted' structures.

The use of concrete foundations is also potentially a cost-effective solution, but there is uncertainty about how widely such designs may be used. Basic concrete gravity base foundations have been used extensively in shallow-water sites in the Baltic Sea, and benefits include reduced exposure to relatively volatile steel prices and removing the need for seabed piling, which is likely to be a major planning constraint for some projects. Set against these benefits is the fact that the design and installation method used in the Baltic Sea does not scale cost effectively for deeper-water North Sea conditions. In order to address this issue, 'next-generation' concrete designs have been developed. These new designs have the advantage of not needing the costly heavy-lift crane vessels required for piled steel foundations, and some have also been designed to allow the complete installation of the turbine on the foundation at the quayside before it is delivered to site. This 'float-out-and-sink' approach may also eliminate the need for turbine installation vessels, although there are also potential environmental and installation issues that will need to be considered and addressed before it can be used on a commercial scale.

These new concrete design options are considered well suited to deeper waters and larger turbines, and prospective suppliers highlight the common usage of concrete structures in the oil and gas industry and marine bridge building sector. Others in the industry argue that there are technical issues specific to offshore wind turbine foundations and that convincing developers to use these designs on a commercial scale represents a major challenge. If these problems can be overcome, however, and the potential cost benefits are realised, then industry feedback suggests it is possible that concrete solutions could account for a substantial proportion of the market well before 2030.

Beyond these steel and concrete seabed-fixed designs, floating foundation designs are also being developed to allow projects to be located in areas with high wind resources and water depths of 60m or more. Such technology is still relatively immature in the offshore wind sector, and developers are expected to focus on shallower water sites in the short to medium term. Work is progressing to accelerate the technology to market, however, and two full-scale floating foundation demonstrators have already been installed in Portugal and Norway, with more planned. If these are successful, it is possible that commercial projects will be deployed in the 2020s, and it is also possible that the technology will be cost-effective in waters shallower than 60m.

The forecasts of foundation demand set out in Figure 11 and Figure 12 reflect all of this uncertainty about future technology choices. By 2020, the greater mass and rotor diameters of the next generation of larger turbines, combined with the development of projects in greater water depths, could mean that cost and logistics considerations will preclude the use of monopiles for many projects. It is likely that braced, space-frame jackets (in one form or another) will be the preferred alternative to monopiles in the short term, until other solutions are demonstrated. In the medium and long term, jackets are likely to retain a significant market share for a number of years, but may face much greater competition from other designs including alternative space-frame designs, 'next-generation' monopiles, concrete designs and even floating foundations, as these technologies are proven. As such, these forecasts assume that, as well as the projects that are likely to use smaller monopiles or jackets, there is a wider, long-term ‘open opportunity’ space for which all designs will compete. In the early years, multiple designs may be used in parallel on different wind farms but, by 2030, learning and technology development will probably mean the industry has focused on a small number of the most cost-effective options. Less optimal designs may remain in use due to the ongoing use of production facilities and vessels, and for sites with non-standard conditions, but such harmonisation is common for developing industries. It is believed that there is a considerable opportunity for companies to influence what becomes the long-term industry-standard solution.

The headline number of foundations in each scenario is dictated by the number of turbines forecast above. Indeed, a key cost benefit associated with increasing the rated capacity of turbines is that the number of foundations required per gigawatt is reduced while the cost per foundation does not rise proportionally. As with the turbine forecasts, this trend means that all the scenarios involve a diminishing number of units over time, although actual tonnage throughput will depend on future trends in project water depth, which significantly influence foundation mass and cost. We note that far fewer substation foundations are required than turbine foundations, so these are not considered here, although the designs are relatively similar.

Lead time for new product development

As there are so many different foundation designs, it is not easy to define indicative times for new product development activities. What is shown in Figure 13 is for a new concept development, rather than simply a site-specific variant. As with the turbine development cycle, the initial product development stage involves preparing a concept design basis that considers loads and environmental factors. This stage may also include scale testing of the design and analysis of materials usage. The engineering activity involved at this stage may take from 12 to 18 months but the key challenge that may lead to substantial delays in the timeline is developing a sufficiently strong commercial case through customer commitment and research and development funding to justify greater investment, especially in more novel designs. In some cases, organisations have been working on this stage for five or more years.

The demonstration stage typically involves the offshore installation of one or more units supporting full-scale turbines in site conditions that are as similar to those of commercial projects as possible. Onshore demonstration, and scale demonstration with offshore meteorological stations are not considered to be suitably rigorous for facilitating full commercial deployment, although these may be used as a useful step towards this goal. The value of offshore demonstration depends on the specific foundation design, but demonstration of manufacturing, installation and access processes, structural dynamic interaction with the turbine and seabed and ongoing structural integrity are all important considerations.

Once the decision has been made to proceed with a demonstration project, the prospective supplier will prepare a complete design specification based on the loads from the intended turbine and the specific water depth, seabed and metocean conditions of the demonstration site. Depending on the amount of work that has been done in the development stage, this (and the resulting design work, including loading and structural dynamic iterations with the wind turbine manufacturer) is likely to last between six and 12 months. Assuming the use of a consented test site, the construction and installation of the demonstration foundation again typically takes six to 12 months. It is then likely that the full assessment of the demonstration will take place over a period of one to two years, depending on the risks relating to the design. There is significant demand from suppliers for demonstration sites but very few consented test sites, which is considered to be constraining the opportunities for proving new technology.

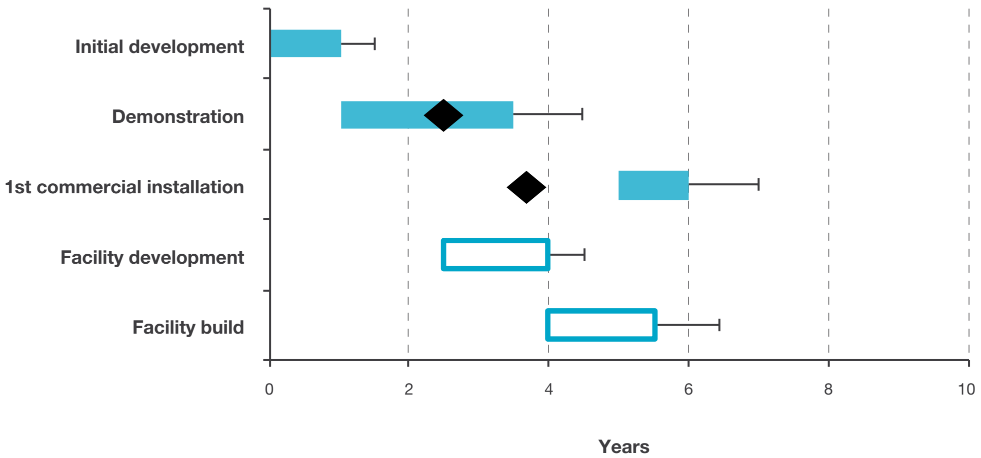
Based on publicly announced proposals and industry feedback, it is expected that a large-scale production facility would be expected to have an annual production capacity of up to 100 units, although annual run rates of 50 to 80 units may be more common.

As with turbine suppliers, early demonstration units may be manufactured using temporary facilities, and investment in specialist infrastructure and serial production tooling only committed once a pipeline of activity is secured. Many of the prospective suppliers of steel foundations have a background in large-scale oil and gas fabrication, with existing facilities that can be adapted for serial production. Assuming the availability of a prepared port location, the development of a production facility can take between 12 and 24 months. It is noted that the resurgence in demand for North Sea oil and gas capacity means that the case for significant investment in wind-only facilities may become more challenging with uncertain offshore wind market conditions.

Assuming a foundation installation date of 2016 for projects with turbine installation scheduled in 2017, prospective suppliers of designs with significant novelty in offshore wind will need to have an offshore demonstrator installed by 2014.

Based on the Scenario 2 forecast demand above and assuming average annual production rates of 80 units per year, this represents a UK market demand for at least six average-sized foundation facilities.

***Figure 13.* Indicative lead times for foundation design and manufacturing facility development**



Black milestone represents customer financial commitment.

Black bars represent potential delays to the given stage.

Research and Development

Infrastructure Development

Offshore substations

Demand

Figure 14. **UK demand for offshore substations from 2013 to 2030 based on Scenario 1 (by year of manufacture**

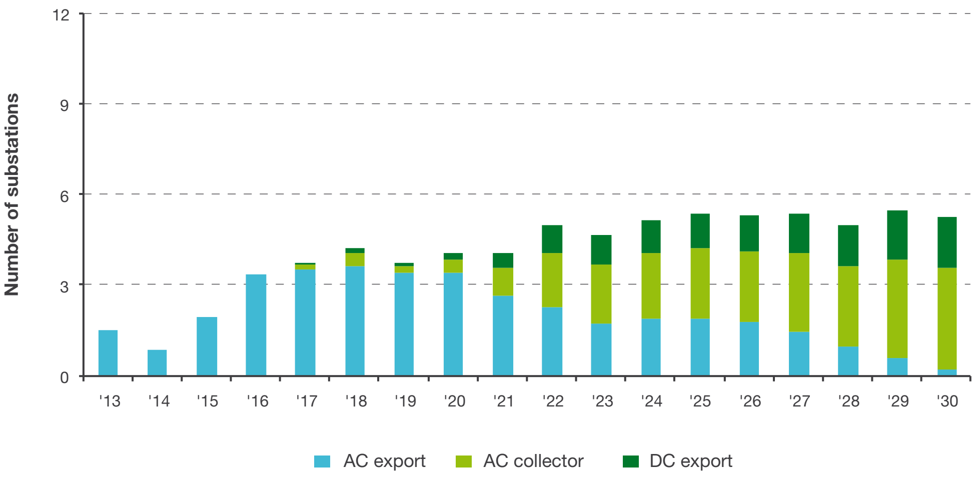
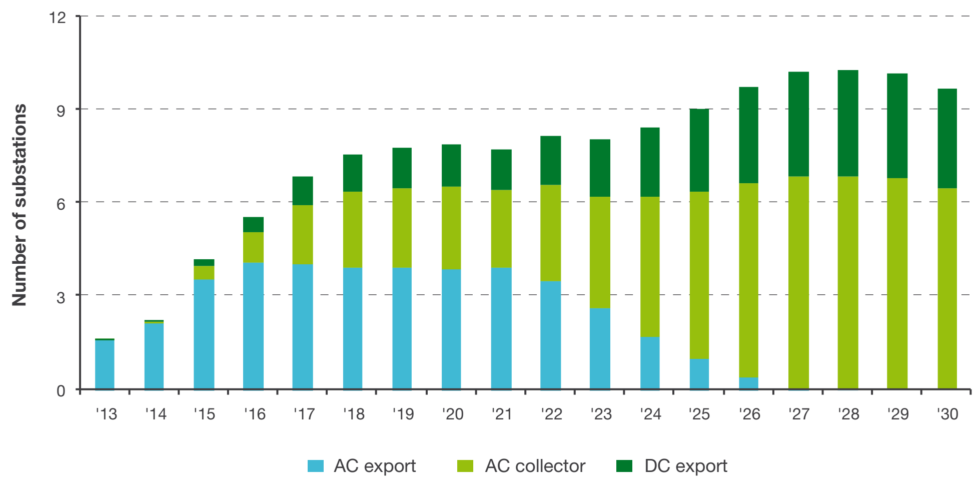


Figure 15. **UK demand for offshore substations from 2013 to 2030 based on Scenario 2 (by year of manufacture, offset from turbine installation by two years)**



With the exception of a small number of early projects that were connected to the grid without offshore substations, all the UK offshore wind projects completed to date have incorporated one or more offshore high-voltage alternating current (HVAC) substations and a new, or extended, onshore substation. The industry faces an issue with the ongoing use of HVAC systems, as increasing transmission distances are associated with substantial decreases in electrical transmission capacity and the risk of electrical instability. The transmission of power through HVAC systems requires compensation equipment located either offshore, onshore or both (depending on the length of the cable and the power carried), which adds to project costs. Over longer distances, the voltage limitations of three-core cable technology also mean that power capacities of single circuit solutions are relatively low, so multiple circuits and cables are required to transmit the levels of power required.

High-voltage direct current (HVDC) systems allow more power to be carried by less cable at higher voltages over long distances compared with HVAC systems. This is for a number of reasons, including that no reactive power is required to compensate for the cable capacitance. HVDC systems also have a reduced cable material demand because the cables only require two smaller ‘cores’ compared with three for HVAC, and fewer HVDC circuits are needed for transmitting the equivalent power compared to HVAC. This last characteristic also allows narrower onshore cable corridors, which reduces land take and makes more direct routes possible. Set against these benefits is the fact that the onshore and offshore HVDC substation infrastructure is currently more expensive than that of HVAC systems, due to the use of high-power semiconductor devices and related equipment, and the use of a more specialist supply chain compared with that of conventional HVAC transmission equipment.

Overall, these benefits and disadvantages mean there is a tipping point at which the additional cost of HVDC substations is outweighed by the savings in cable costs and the increased revenue generated by reduced electrical losses. Industry assessments of this tipping point currently range from 80km to 100km. In the short term, developers may consider using HVAC even where it is marginally less efficient due to the longer lead time of HVDC systems. In the long term, it is expected that the distance at which HVDC systems become cost-effective, compared with HVAC systems, will reduce as standardisation and technical improvements in the manufacturing process reduce the lead time, cost and risk associated with HVDC systems.

The forecast increasing use of large-scale HVDC substations is expected to be accompanied by increasing demand for smaller HVAC collector substations. These will be required on gigawatt-scale projects that will be spread over 300km2 to 500km2. These substations will be located across a wind farm to minimise the transmission distances from turbines at lower voltages, and hence reduce electrical transmission losses. These collector substations will include transformers to step up the voltage from a typical 33kV or 66kV to 220kV for input to the HVDC substation. For the purposes of this report, it is assumed that two 500MW HVAC collector substations will be deployed alongside each 1GW HVDC substation.

A further key innovation that will affect future demand is the development of an offshore transmission grid. To date, all large projects have been linked radially to onshore national distribution networks by a direct cable to the shore and a dedicated onshore substation. This approach has been necessary because of the relatively small number of projects that have been undertaken, the financing structure for individual wind farms and the current regulatory system, which has not encouraged the development of coordinated transmission infrastructure.

As more projects are developed around the coast of the UK, however (and in the North Sea in particular), a more coordinated approach offers cost reductions. By linking the electrical transmission systems of a number of projects together, it is possible for developers to share the cost of offshore and onshore substations and cables. This approach also limits offshore cable corridors, cable landings and onshore infrastructure, which reduces environmental impacts, lessens the risk of planning constraints and facilitates more strategic reinforcement of the onshore grid. An interconnected offshore network would also mean that power could still be routed onshore in the event of a system failure at one point. The challenges for such a coordinated approach include the complexity of coordination, the significant early financial spend, and the risk for developers of committing to orders for wind farm components and installation vessels when a third-party provider of the cable connection might slip its construction schedule. As such, industry feedback from key companies is that such coordination will only occur with the necessary government legislation to support speculative investment.

The uncertainties related to such an arrangement mean that the analysis here is based solely on a radial connection arrangement. In 2011, however, The Crown Estate and National Grid published a report that assessed different levels of Round 3 and STW deployment and varying levels of interconnection.[5] The main savings from this approach

3. ‘Chapter 5: Electricity’ (pp. 115–56), *Digest of United Kingdom Energy Statistics 2012*, July 2012, available online at http://www.decc.gov.uk/assets/decc/11/stats/publications/dukes/5949-dukes-2012-exc-cover.pdf, last accessed November 2012.

are generated through reduced offshore and onshore cable demand but the report indicates that a coordinated approach could also reduce substation numbers by around 2%, equivalent to around one export substation by 2030 in Scenario 1 and two in Scenario 2. The associated benefits of improved planning and costs for onshore infrastructure, and reduced electrical losses, have not been quantified in our analysis.

A potentially disruptive technology that could also significantly affect this demand forecast is MVDC connections directly from turbines. This technology is still currently under development, but it could mean that certain projects up to 70km from shore could be connected directly to an onshore substation without an offshore substation, or that projects using HVDC systems may not require collector substations. Again, there is uncertainty when, and to what extent, such a solution could be first implemented, so the potential impact of this technology is noted but not incorporated into this analysis.

As shown in Figure 14 and Figure 15, the trend for projects to be developed further offshore means that demand for HVAC export substations is gradually reduced over time. At the same time, demand for HVDC export substations increases, although unit growth is moderated by the higher capacity that has been assumed for an HVDC substation. This is accompanied by a substantial growth in demand for HVAC collector substations. It should be noted that this analysis does not consider onshore electrical infrastructure demand.

Lead time for project-specific solution development

Although HVDC systems have been widely used in onshore applications in the past, the specific requirements of offshore wind (in particular the need to minimise the size of offshore infrastructure and to connect to potentially weak sections of the grid) mean that voltage source converter (VSC) systems (as opposed to current source converter (CSC) systems) are expected to become the industry standard. Only two companies, Siemens and ABB, have demonstrated suitable offshore VSC HVDC systems so far, but a third player, Alstom Grid, has now entered the market with the latest German project, DolWin3. Other players are also known to be considering a move into this sector, but the time required to develop a VSC system and build a sufficiently strong track record of onshore delivery to justify the move offshore means there is a high hurdle for new entrants in the short and medium terms. As such, the timeline in Figure 16 does not consider the pre-commercial development of these systems.

Feedback from companies involved in the German market is that HVDC projects are taking around four years from order to energisation. Following the confirmation of an order by a developer, a supplier will undertake the specification and design work for the electrical system, which can take from six to 12 months, depending on the complexity of the project. Although the duration of this design stage may reduce somewhat in the future through increasing standardisation, the project-specific characteristics of the onshore grid connection and the connection arrangement between the turbines, the HVAC collector substations and (in time) the interconnections with other HVDC substations, means it is likely to continue to involve significant site-specific design activity.

Once the design is complete, the fabrication of the offshore substation, both the topside and foundation, can be started in parallel with the manufacture of electrical, welfare and other components, followed by the fitting-out of these items. This process is estimated to take at least two years. Once complete, the installation and commissioning of the offshore substation may take from six to 12 months before the first export of power, depending on the weather windows available.

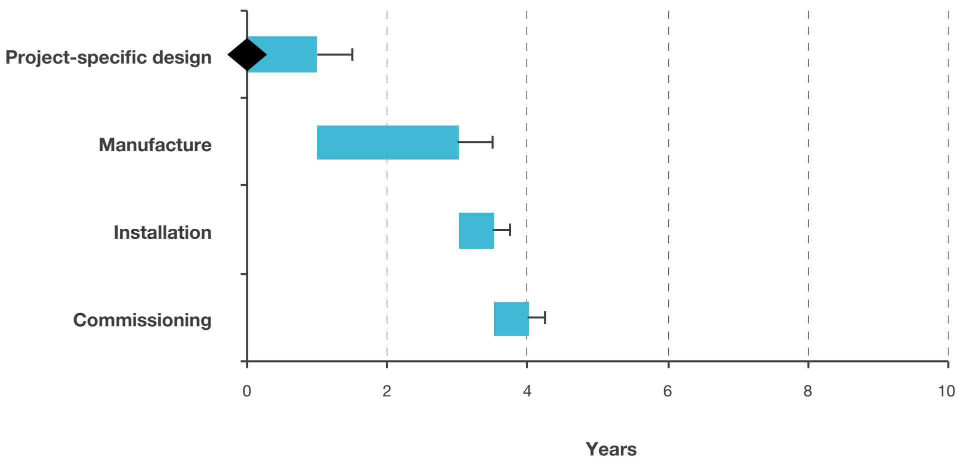
Fabrication of HVDC and HVAC offshore topsides and foundations typically takes place at existing shipyards or oil and gas marine fabricators. The size of HVDC structures means there are relatively few fabricators with suitable facilities, but industry feedback indicates that demand levels for HVDC systems are unlikely to cause a bottleneck.

Assuming that some overlap can be planned between projects, a suitable production facility is estimated to be able to produce one HVDC substation topside every 18 to 24 months. Based on the Scenario 2 forecast demand above, this represents a UK market demand for approximately six fabrication facilities. It is noted that some larger facilities may have the capacity to undertake two or more projects in parallel, which would reduce demand for fabrication locations accordingly.

As can be seen in Figure 16, the lead time from customer commitment to installation of an HVDC substation is at least 36 months, with significant likelihood of at least an additional 12 months, which has potentially significant implications for developers. For example, if a developer has scheduled turbine installation and connection to take place in 2017, it is likely that HVDC infrastructure will need to be ordered in 2013, which would precede even the granting of consent, let alone the expected date of the financial investment decision.

The reduced size and complexity of HVAC substations, plus the greater availability of viable suppliers, mean the overall timescales for these units are approximately 12 months shorter than HVDC, and have more certain schedules. Assuming a production capacity of one HVAC substation topside every 12 months, the peak demand is approximately seven fabrication facilities.

***Figure 16.* Indicative lead times for project-specific HVDC substation design and manufacturing**



Black milestone represents customer financial commitment.

Black bars represent potential delays to the given stage.

Subsea cable

Demand

Figure 17. **UK demand for array cable from 2013 to 2030 based on Scenario 1 (by year of manufacture, offset from turbine installation by two years)**

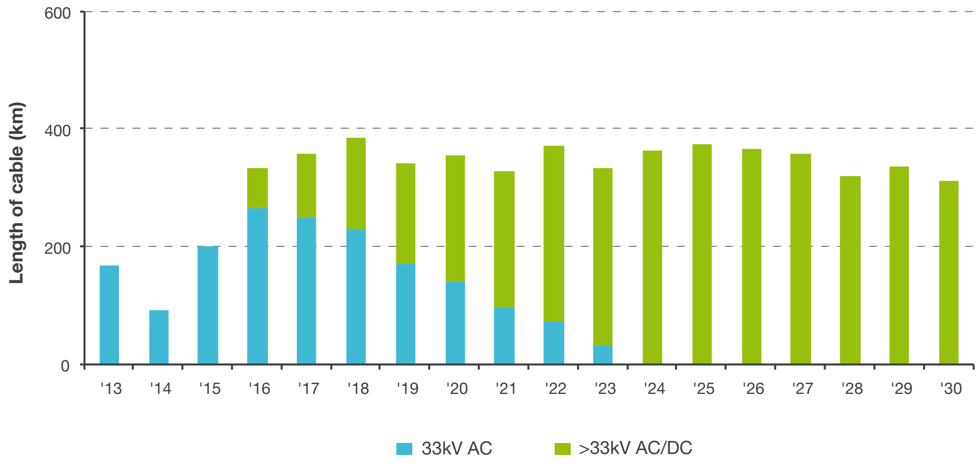


Figure 18. **UK demand for array cable from 2013 to 2030 based on Scenario 2 (by year of manufacture, offset from turbine installation by two years)**

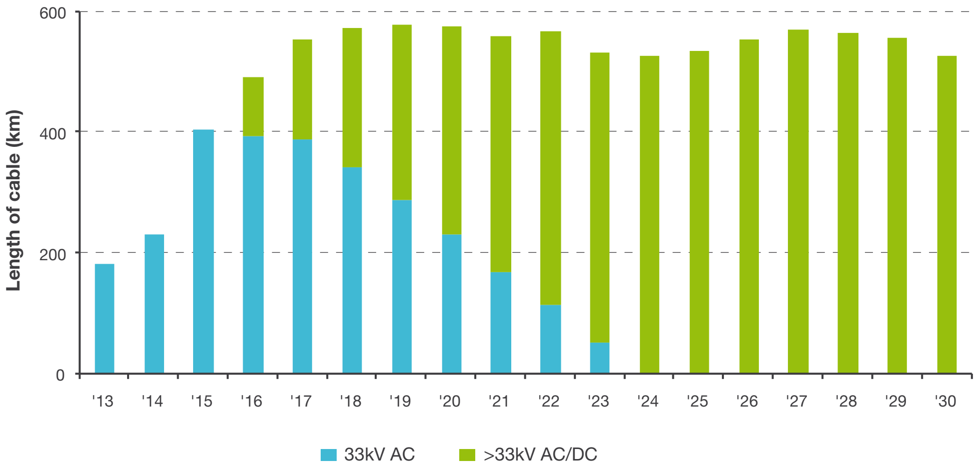


Figure 19. **UK demand for export cable from 2013 to 2030 based on Scenario 1 (by year of manufacture, offset from turbine installation by two years)**

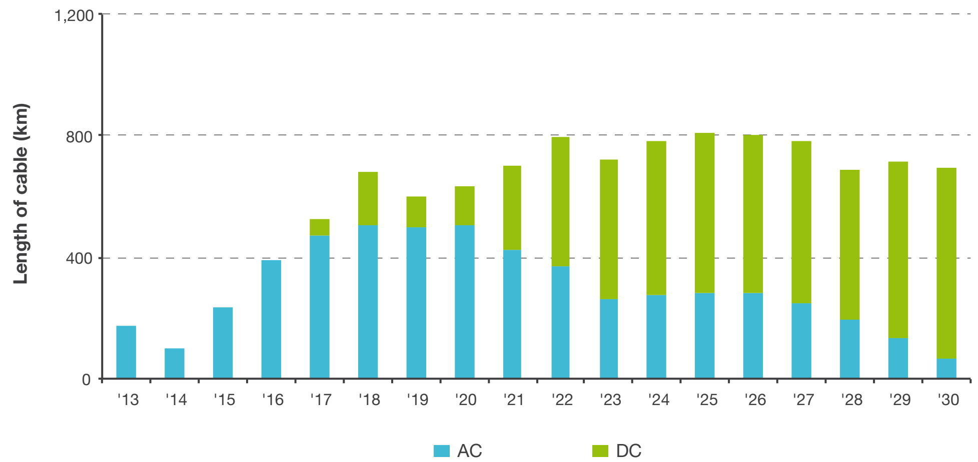
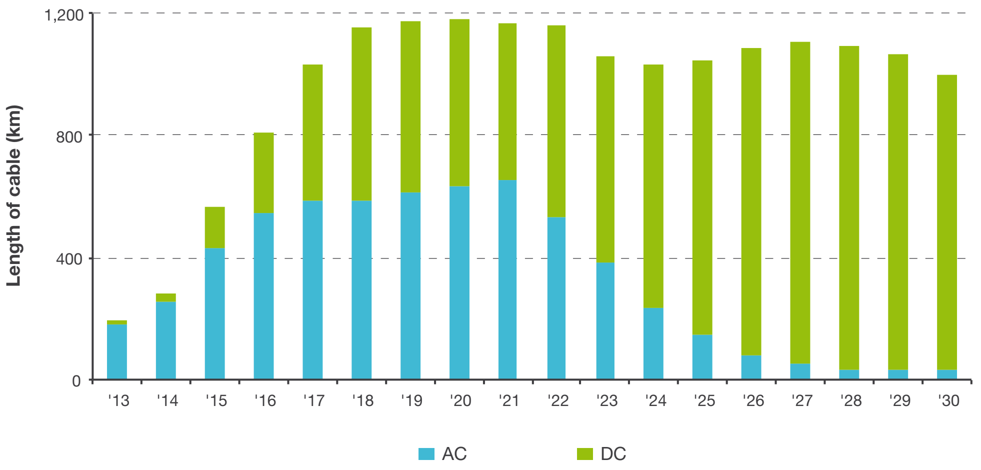


Figure 20. **UK demand for export cable from 2013 to 2030 based on Scenario 2 (by year of manufacture, offset from turbine installation by two years)**



Associated with the demand for offshore substations described above is the need for array cables to connect turbines to offshore substations and export cables to connect collector substations, export substations and the onshore grid.

Array cable demand is influenced by the forecast increase in the rated capacity of turbines. As larger turbines are used, the number of turbines required per gigawatt is reduced, which decreases the number of connections that are required. At the same time, the increase in rated capacity is expected to be accompanied by an increase in the diameter of the rotor. This increases the spacing of turbines, which increases the demand for array cable.

Another important trend expected to take place over the next ten years is the introduction, and large-scale adoption, of higher-voltage array cables. Increasing the voltage from 33kV to around 66kV or higher has the potential to reduce electrical losses significantly and preserve the number of turbines in each string connected to the substation as the rated capacity of turbines increases. At 66kV, it also becomes cost-effective in some circumstances to install turbines on a number of ring circuits from the offshore substation, rather than in a radial circuit as generally used today. This adds upfront costs but allows the turbines to continue generating electricity in the event of a single cable or switchgear fault. This redundancy therefore is only beneficial in an environment in which subsea cables fail or are damaged relatively frequently. The challenges are that the standards and electrical hardware associated with higher-voltage cable are currently still in development for offshore wind applications.

Figure 17 and Figure 18 show there is expected to be an increasing demand for array cables up to 2018, with demand then remaining relatively constant out to 2030. Based on industry feedback, it is expected that higher-voltage array cable could be first used by 2016 and then account for a rapidly increasing market share, so that lower-voltage designs are phased out in the years after 2020.

For export cable, the key driver for future demand is the development of projects further offshore, which will require greater lengths of cable. This demand is split between HVAC and HVDC cables (see ‘Offshore substations’ above).

For export cables, Figure 19 and Figure 20 show the demand for HVAC export cable increases up to 2020 or 2021, before decreasing as the use of HVDC cable increases. Some HVAC export cable demand remains out to 2030 due to the need to link HVAC collector substations to HVDC export substations. Other technical developments may extend the distance at which HVAC systems may be cost-effective, such as low-frequency AC transmission or the use of relay stations, but these have not been considered. As noted in ‘Offshore substations’ above, the adoption of turbines directly connected to an MVDC export cable is also a potentially disruptive technology that is currently under development but has also not been considered in this analysis.

As discussed above, this study has not modelled the impact of a coordinated offshore transmission network on cable requirements. Based on the results of The Crown Estate and National Grid *Offshore Transmission Network Feasibility Study*,[6] the impact of a coordinated offshore transmission network is estimated to increase the length of offshore HVAC cable potentially by 50% due to the additional interconnection between zones, but reduce the amount of HVDC cable by about 20% due to the reduced number of cable connections to shore. For Scenarios 1 and 2, this is equivalent to an additional demand of 4,300km and 4,600km of HVAC cable, and a reduction of 1,100km and 2,300km HVDC cable being required by 2030 respectively.

This study has not considered onshore cables, but it is noted that, in addition to the connection between the landing point and the substation, there will also be a need for onshore transmission and distribution grid reinforcement. This may also be reduced with a coordinated approach, dependent on the extent of network coordination.

Lead time for new product development

In order to meet the forecast market demand, it is expected that cable manufacturers will need to increase their production capability significantly and adapt to supplying new products. Higher-voltage array cable has yet to be deployed in an offshore wind farm, and it is anticipated to take at least two years to demonstrate. In the meantime, there is a risk for array cable suppliers in increasing manufacturing capacity that becomes redundant due to the development of new technology.

The export cable market is currently dominated by only a small number of players: ABB, Nexans and Prysmian, and the entry barriers for new players are significant. It has been reported in various studies that future demand for export cables will not be met without significant new investment.[7] This may be through the existing players increasing their capacity or the entry of new companies into the market.

The timescales shown in Figure 21 are intended to represent those of an existing supplier of HVAC array cables entering the HVDC export cable market. The design of HVDC cable is already well known, but the key challenges are the high level of infrastructure investment required for manufacture and the lead time to supply the polymer used for extruded cross-linked polyethylene (XLPE) cables (the principal technology choice for projects to date and expected future choice). As such, the concept design stage can be relatively short, with the process of assessing market conditions and confirming the cable design taking from six to 12 months. As well as planning permission, facility development also includes time to specify and procure the equipment, which also has a significant lead time.

Prequalification typically takes place with the direct involvement of customers followed by Type Approval testing, which assesses the electrical performance of the cable. The analysis of repair joint technology runs in parallel with Type Approval testing. Testing and approval of the cable can therefore take between 24 and 30 months. Cable production times vary greatly between manufacturers and depend on the size of the project and the manufacturing capacity available at the time. As such, manufacturing lead times of between eight and 24 months have been reported.

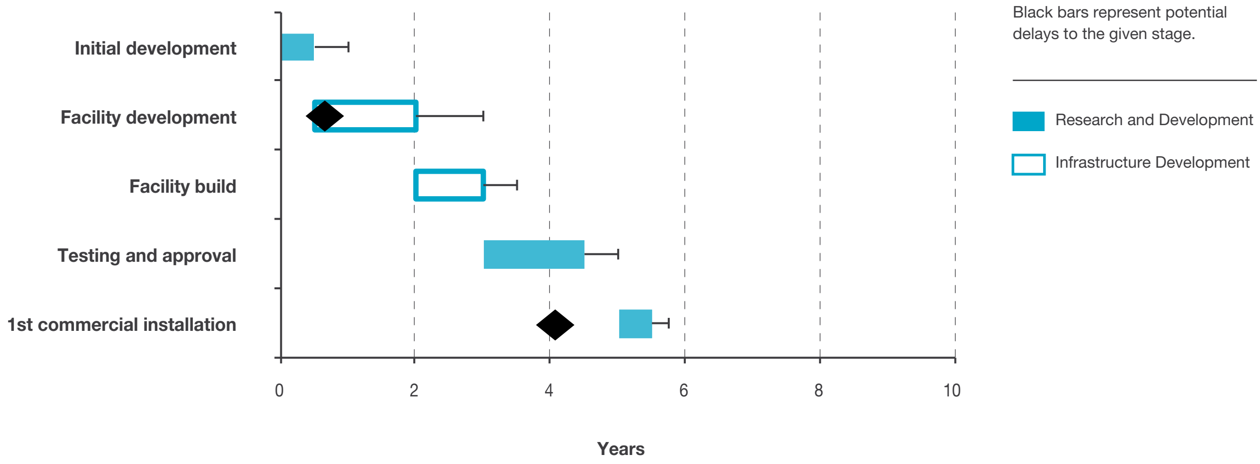
Assuming finance and a suitable waterside site are available, it is estimated to take at least

6. *Ibid.*
7. *Towards Round 3: The Offshore Wind Supply Chain in 2012*, BVG Associates for The Crown Estate, June 2012, available online at http://www.bvgassociates.co.uk/Publications/BVGAssociatespublications.aspx, last accessed November 2012; and Cable Manufacturing Capability Study, Cable Consulting International (CCI) for The Crown Estate, July 2012, available online at http://www.thecrownestate.co.uk/media/341885/Windfarm%20export%20cable%20market%20study.pdf, last accessed November 2012.

five years to obtain planning consent, construct and commission a new facility, produce a first cable and have this Type Approved. A manufacturer with an existing facility available may be able to take a year off this programme, and an established high-voltage cable manufacturer may be able to reduce this by a further year if increasing production capacity. When combined with the long lead times for HVDC substations shown in Figure 16, this has potentially significant implications for developers wishing to use HVDC technology. A key challenge for cable manufacturers is committing the significant investment required to develop new designs and manufacturing capacity, given the market uncertainty seen to date.

An average facility is assumed to have the capacity to produce 500km of core per year with three cores per HVAC cable and one core per HVDC cable. Based on the Scenario 2 demand forecast above, this represents a peak UK market demand for approximately three export cable facilities and a further three array cable facilities.

Figure 21. **Indicative lead times for HVDC export cable design and manufacturing facility development**



Black milestones represent the decision to proceed and first commercial financial close

Black bars represent potential delays to the given stage.

Installation vessels and O&M jack-up vessels

Demand

Figure 22. **UK demand for installation and O&M jack-up vessel charter from 2013 to 2030 based on Scenario 1**

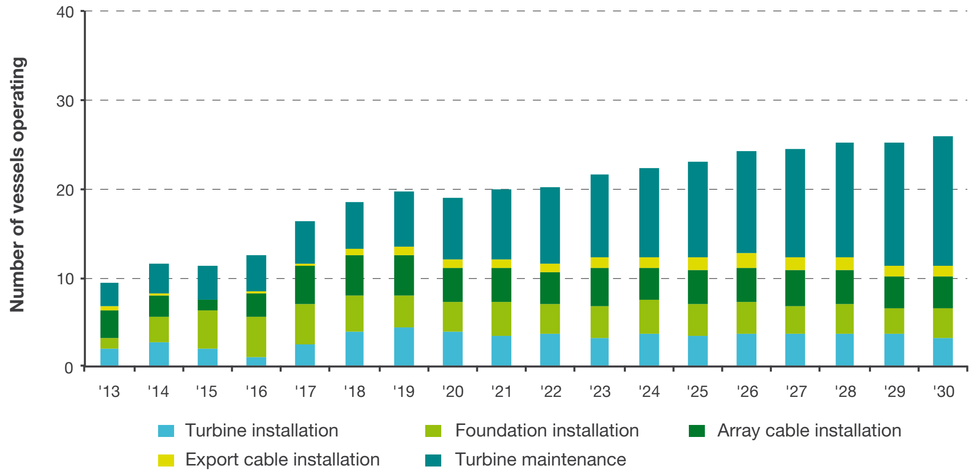
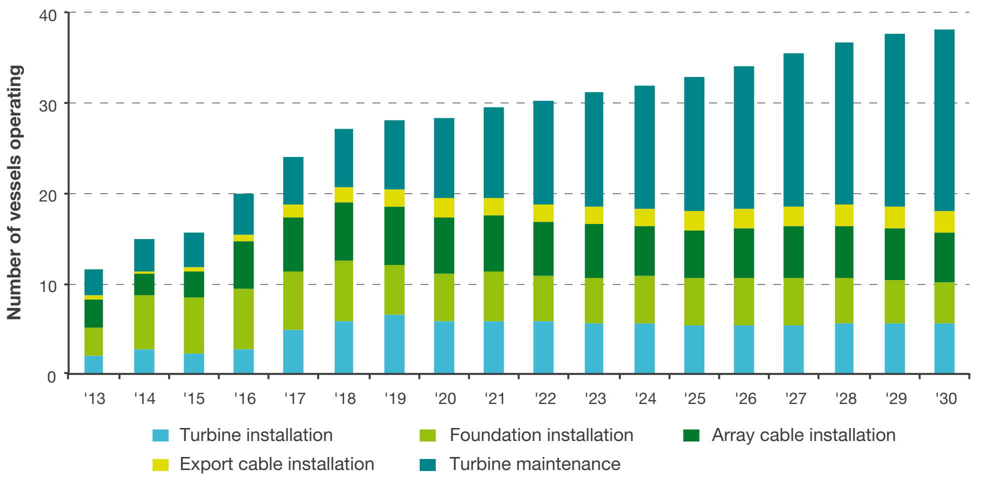


Figure 23. **UK demand for installation and O&M jack-up vessel charter from 2013 to 2030 based on Scenario 2**



Early offshore wind projects were installed using general-purpose offshore construction vessels that were originally built for the oil and gas sector and other offshore markets. These were only partially suitable for the specific challenges of offshore wind so, as the market has developed, specialist vessels have been constructed or adapted, and there is now a growing bespoke fleet available. The first such vessel was MPI Resolution (formerly Mayflower Resolution), which was first used in 2003.

Vessel efficiency (in terms of installation time per turbine, taking account of weather delays) is a key influence on overall vessel demand, and there have already been significant improvements since early projects. For example, designers have sought to offer greater on-board storage space to increase the number of units or length of cable that can be carried at any one time, in order to reduce the number of trips to the installation port. There has also been a drive to use vessels that are capable of operating in more extreme wind and wave conditions, in order to allow them to work for a greater proportion of the year. As well as these technology developments, installation contractors also stress the improvement in performance that has been achieved through project experience. For example, it is reported that the time to install a turbine was reduced by half over the course of the installation of London Array I. Set against these improvements are the challenges of installing projects further offshore, where increased transit times and more hostile environmental conditions add time and reduce efficiency. Other challenges include soft or unstable seabed conditions and increased water depths.

The forecast increase in the rated capacity of turbines also has an impact on vessel demand. The associated increase in the size of turbine components and foundations reduces the number of units that can be carried on a vessel, but this is more than compensated for by the fact that there is a reduction in the number of units that need to be installed per gigawatt.

Larger wind farms located further from shore also drive demand for cable installation vessels that can operate in harsher conditions and can carry more cable.

For foundation installation vessels, our analysis has not differentiated between jack-up and floating dynamic positioning vessels. The cycle times that have been used assume a mix of such vessels, with a move to using more floating vessels over time. Also, a key cost benefit associated with the use of ‘next-generation’ concrete gravity base foundations is that it allows developers to avoid the need to use specialist foundation installation vessels. The need for a turbine installation vessel can also be avoided using ‘float-out-and-sink’ designs (albeit most of these designs require a bespoke installation vessel, which costs far less than a heavy-lift crane vessel and a turbine jack-up). The uncertainty about future foundation choices discussed above means that this forecast does not take the large-scale use of concrete gravity base foundations into account when deriving vessel demand post-2020, but it is noted that, depending on market uptake, this may reduce vessel demand.

For substations, the HVAC topsides used to date have been designed at a scale at which they can be lifted into position using heavy-lift crane vessels. The introduction of HVDC substations, with an anticipated mass of 12,000 tonnes or more, may drive the use of alternative arrangements including float-over solutions and ‘self-installing’ systems that have integrated jack-up legs so that the structure can be floated out to the site, positioned on the seabed, then raised into position without significant additional vessel use. Whatever system is used, the volume of activity is so much less than that required by turbines and foundations that it has not been considered in this analysis.

The forecasts presented are focused on the main construction vessels, as they account for most of the total installation cost, but it is noted that offshore operations involve a significant fleet of vessels, including component transportation barges and vessels, personnel transfer vessels, guard ships, and vessels for specialised tasks such as the application of scour protection.

As shown in Figure 22, demand for the main installation vessels peaks in Scenario 1 in 2019 at around 13 vessels. Improvements in productivity, and decreasing turbine and foundation numbers, mean that this demand reduces to less than 10 by 2030. In Scenario 2, demand remains more consistent, at more than 20 vessels during the 2020s.

In addition to this demand for installation vessels, there is also an ongoing need for vessels to undertake the removal and replacement of major components, such as turbine blades or gearboxes, during operation. This is separate to demand for dedicated O&M vessels, which are used for the routine maintenance of turbines and substations (see ‘Operation and maintenance vessels’ below). Developers may choose to address this demand in a number of ways: chartering vessels on an ad hoc basis to address issues as soon as they occur; waiting until a critical number of turbines have developed (or are predicted to develop) sufficient major faults and then chartering a vessel to address all of them; chartering a vessel on a routine basis on the assumption that such faults will occur within a wind farm of turbines; or purchasing a vessel themselves. So far, this unplanned service activity has been undertaken by the same vessels that have been used for installation, but these are typically overspecified for the task, with high charter rates, which has prompted demand for dedicated O&M jack-up vessels with less deck storage space. In reality, it is likely that as newer, more-advanced installation vessels come online, older installation vessels will be used for a greater proportion of this O&M activity.

A further activity that may be required is the replacement of components across a fleet of turbines due to a serial defect. Industry feedback is that this is often handled by chartering a vessel on a long-term agreement. The repeatable nature of this operation means that the mobilisation and demobilisation time of this activity is reduced compared with a case-by-case requirement.

Although there is a strong industry emphasis on improving the reliability of turbines, it is still expected that approximately 5% of the total number of operational turbines will require large-vessel intervention in any given year due to either serial or case-by-case defects. As can be seen in Figure 22 and Figure 23, this means that demand for this activity increases as the total number of operational turbines grows so that it is equal to, or even exceeds, total installation vessel demand by 2030 in both scenarios.

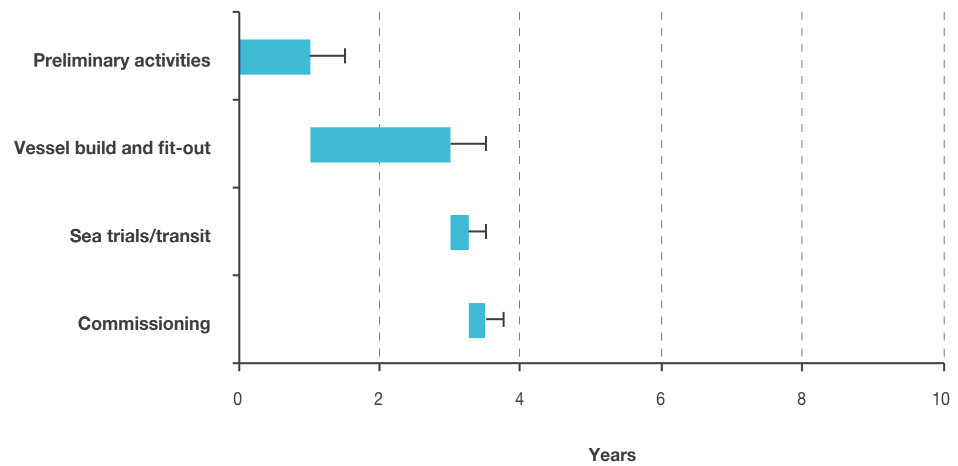
Lead time for new vessel development

Even assuming the use of an off-the-shelf design, industry feedback indicates that it is reasonable to assume that preliminary activities including vessel specification, yard selection and commercial approval are likely to last at least 12 months before commitment is given to start construction. Construction of a 'next-generation' turbine and foundation installation vessel has typically taken at least two years to complete. In some cases, companies are considering adapting existing vessels, although they report that the lead time of key items, such as cranes, means that this approach is unlikely to offer significant reduction in the overall development. To date, the majority of all the new installation vessels have been built in Singaporean, Middle Eastern, German, Chinese, Korean or Polish shipyards.

If a vessel is constructed in Asia, it must be delivered to Europe as well as undergoing commissioning and initial sea trials, which could take up to six months.

Black bars represent potential delays to a given stage.

Figure 24. **Lead times for installation vessel design and development**



Operation and maintenance vessels

Demand

Figure 25. **UK demand for operating O&M vessels from 2013 to 2030 based on Scenario 1 (by year of operation; bars represent cumulative demand)**

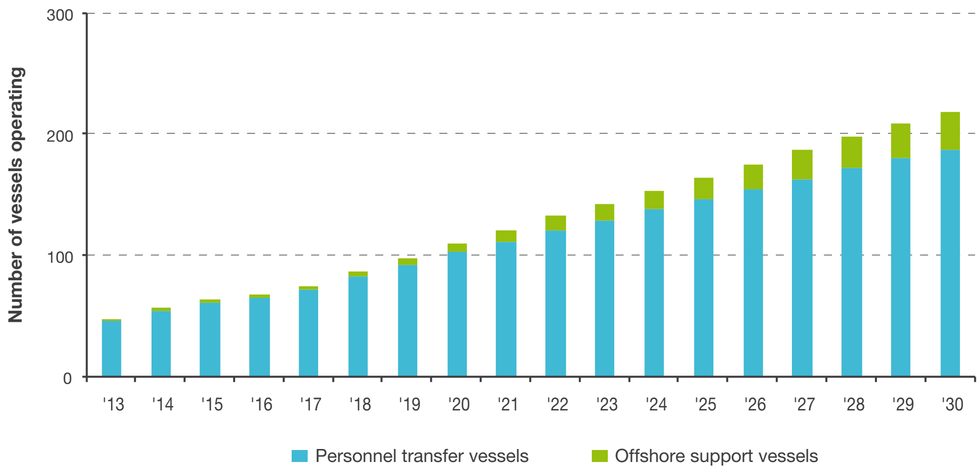
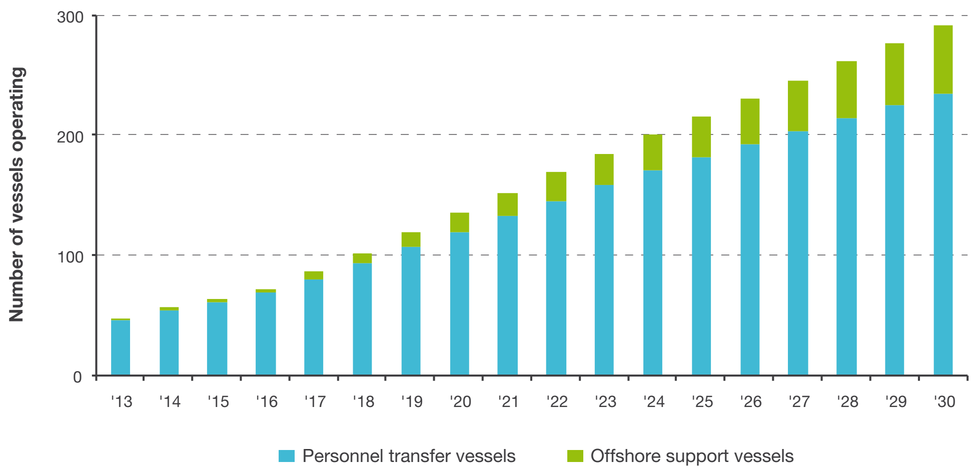


Figure 26. **UK demand for operating O&M vessels from 2013 to 2030 based on Scenario 2 (by year of operation; bars represent cumulative demand)**



Wind turbines and offshore substations incorporate a substantial number of technically complex systems that are expected to operate continuously for at least 20 years in particularly hostile conditions. As a result, an operator must undertake maintenance throughout the operational lifetime of a wind farm. Increasing reliability and greater levels of remote monitoring should reduce the amount of onsite activity, but there will always be work that can only be carried out by a technician present in a turbine or substation. This creates the challenges of transporting, loading and unloading personnel and equipment in difficult sea and weather conditions, while prioritising safety. Furthermore, there is a strong financial incentive for addressing issues that halt the production of electricity as quickly as possible.

With the exception of major component replacement (see 'Installation vessels and O&M jack-up vessels' above), the large majority of turbine maintenance is currently undertaken using personnel transfer vessels. These vessels are used to undertake daily visits carrying approximately 12 technicians at a time as well as basic spares and equipment. Larger crew transfer vessels are already being developed that will be able to carry more people and a greater variety of spares. As projects are developed further offshore, however, this approach becomes increasingly impractical, as technicians must spend a significant proportion of the working day being transported to, from and around the sites. Harsher sea conditions may also mean that a small-vessel strategy means technicians are in no condition to start complex maintenance work for some time after they have arrived. There are also Health and Safety implications with transporting personnel back to shore should an incident occur.

To address these issues, alternative solutions are expected to be used, such as offshore support vessels, motherships and accommodation platforms. Offshore support vessels are floating dynamic positioning (DP) vessels that are typically designed to be equipped with advanced personnel access systems, cranes, workshops, a helideck and accommodation for approximately 60 technicians. Motherships are also floating DP vessels, but they have on-board docks for two or more ‘daughter’ personnel transfer vessels. As well as accommodation for approximately 150 technicians, they are also expected to have extensive catering and recreational facilities, office space and workshop areas.

Such vessels will be semi-permanently stationed offshore and can therefore respond to issues more quickly. It is also expected that they will be able to transfer technicians onto turbines in much more challenging sea conditions than smaller vessels. While the need for these vessels will be greatest for far-from-shore projects, it is expected that they will also be used on projects closer to shore as the technology is developed and proven at sea.

Figure 25 and Figure 26 show the cumulative fleets of vessels that will be required as installed UK capacity increases. In both cases, demand for small personnel vessels is greatest in the early years but peaks and then levels off after 2018, as fewer projects are developed close to shore, with the subsequent demand made up of the ‘daughter’ personnel transfer vessels required with motherships. Scenario 2 forecasts that, by 2020, approximately 120 personnel transfer vessels will be operating. The demand for offshore support vessels or motherships appears relatively modest in comparison, but a forecast demand of more than 55 vessels by 2030 in Scenario 2 represents a major challenge for an industry that currently has only one such vessel operating in a small Belgian project and none in the UK. Furthermore, there is little consensus about what specific vessels, technology and methodologies should be used. It is expected that demand for these vessels will not start until the second half of this decade.

A final option for O&M that has not been included in this analysis is the use of helicopters. Although this option does offer a significant reduction in transit time and the ability to access the wind farm in high sea states, the high cost of this approach means it is unclear whether it will be widely used.

Lead time for new product development

The construction and commissioning of the type of small personnel transfer vessels currently used takes around six months to complete, with sea trials lasting a further two weeks. These vessels tend to be based on a relatively standard design with only minor bespoke refinements made for each customer. This build time may increase by up to six months, as this type of vessel gets larger to accommodate more people and equipment.

A variety of different designs and concepts of offshore support vessels and motherships are currently in the market, with a number of designs having already been used in other offshore industries, such as oil and gas. A vessel that can accommodate approximately 60 personnel is likely to take approximately the same (or slightly less) time to manufacture as an installation vessel, once account is taken of the procurement process, construction, sea trials and commissioning.

5. Meeting European offshore wind demand

An extensive supply chain is required to build and operate an offshore wind farm, and each project is likely to generate activity for hundreds of companies. This report has so far been focused on the demand generated by the UK offshore wind market but it is important to recognise that national boundaries are not considered to be significant for most elements of the supply chain.

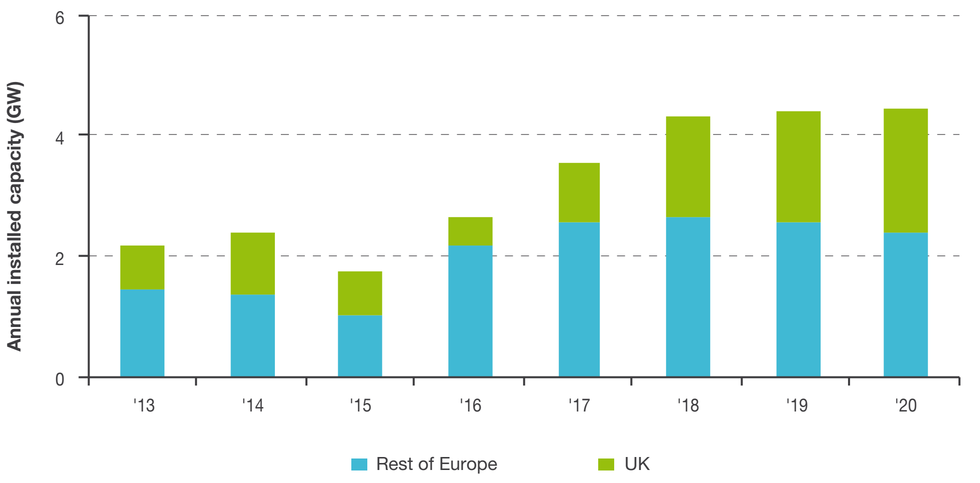
Many companies have existing production capacity on the Continent and are already committed to developing new facilities, in particular, in Germany and France. As such, the UK must compete with these countries, and others, to either attract companies to set up facilities or support the entry of domestic companies into the market.

A European-wide market

For this study, a single medium-level scenario for Continental activity has been prepared (see Appendix 2) and combined with the two main UK scenarios. The Continental scenario assumes an annual installation rate of approximately 2.5GW by 2020, with a cumulative market size of 18GW at the end of 2020. Of this capacity, approximately 50% is anticipated to be in German waters.

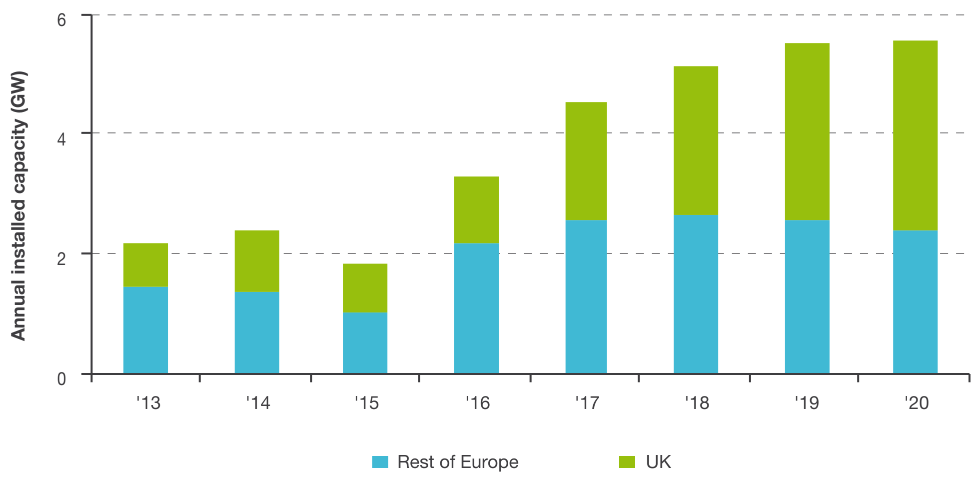
When combined with Scenario 1, the UK accounts for approximately 40% of the total cumulative European market by 2020. In this case, the UK would still have the largest single market but its capacity advantage over Germany would be small. Given increased political and economic certainty in the German market, industry feedback is that this scenario is unlikely to be sufficient to justify a move by a supplier away from an established Continental base.

Figure 27. **European offshore wind installed capacity from 2013 to 2020 (with UK capacity based on Scenario 1)**



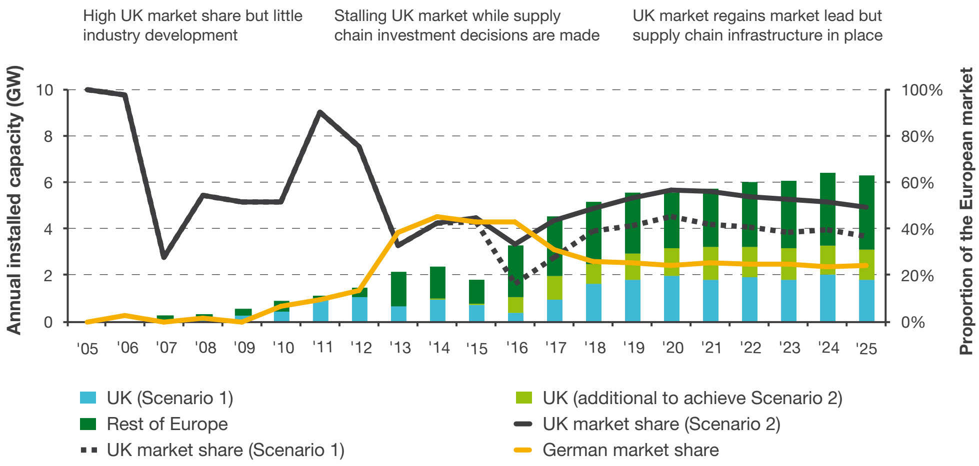
Combined with Scenario 2, this results in a UK market accounting for 50% of the cumulative market by the end of 2020. Industry feedback is that such a balance is more likely to attract activity to the UK, particularly with the ramp-up of UK installed capacity between 2017 and 2020.

Figure 28. **European offshore wind installed capacity from 2013 to 2020 (with UK capacity based on Scenario 2)**



This European-wide scenario highlights a key issue in the relative timing of the forecast ramp-up in installation levels in the UK and elsewhere in Europe.

Figure 29. **Comparison of annual installation rates in the UK and the rest of Europe, and the market share in the UK and Germany**



The historic and forecast levels of annual installation in the UK and in the rest of Europe, and the associated market share that this would give the UK, are shown in Figure 29. This also highlights the market share of Germany, assuming that it meets its objective of 10GW by 2020 and then makes steady progress towards its 2030 target of 25GW.

This shows that the UK has accounted for a majority of the total demand in the past, but this has been during a period when there has been relatively little need to develop new industrial capacity because existing facilities have been able to meet demand. In the critical middle years of this decade, however, a period of rapid growth in the German market means it will have an equivalent or higher market share than the UK (even in the healthy scenario). This is important because it is during this period that many investment decisions are expected to be made by leading companies in the supply chain. Although the UK regains its leading position in the longer term, this means that there is a significant risk that a short-term imperative to win activity elsewhere, and in particular in Germany, will mean these companies will choose to locate facilities elsewhere.

This demonstrates the challenge faced by the UK Government in its efforts to build an offshore wind industry. Manufacturers are active across a number of national markets and need to make investment decisions based on the cost of logistics, supply chain development, customer proximity and political pressure. They have a range of options, including making use of existing manufacturing sites, extending these facilities or investing in new sites.

To maintain ongoing public and political support for offshore wind, it is important that the UK development community and Government work together to influence the decisions of manufacturers and ensure strong levels of inward investment. Such activity cannot be judged in isolation, as other European governments are also active in courting inward investment. The analysis of this report reinforces industry feedback that the UK Government must give clear messages about its intentions to support a long-term market that is large enough to allow companies to look past short-term trends and make the decision to invest in the UK.

Comparing demand and supply

To assess some of the opportunities for developing UK supply chain capacity, these European scenarios have been used to estimate future demand for turbines and foundations, and compare them with existing and planned production capacity. They have also been used to consider demand for turbine installation infrastructure for projects in the North Sea. This allows an assessment of the level of outstanding demand, which can be converted into an estimate of the number of additional facilities required based on the probable production run rates or installation capacity.

It is assumed that technology trends will be largely similar across Europe, so unit demand has been calculated using the same technology analysis methodology used to assess UK market demand, which is set out in Appendix 2. When assessing the supply capacity required, a 20% redundancy has been included to take account of the natural inefficiency of supply chains in which not all players are busy all of the time. Analysis of existing and planned capacity is based on desktop research of public plans and discussion with key companies. A site is considered 'operational' even if a company is currently only producing components for smaller-scale turbines but has announced plans to upgrade infrastructure. A site is considered 'announced' if a company has publicly stated that it intends to develop production capacity in a specific location. It should be noted that, within this latter category, there is considerable variation in terms of proximity to market, and it is far from certain if all of the capacity 'announced' will be developed.

Production facility run rates are based on an analysis of existing facilities and discussions with key industry players about their future plans and their understanding of how facility sizes are expected to grow.

Research has been focused on European-based production capacity but it is noted that companies around the world are also likely to feed into this market. For example, turbine manufacturers in China are developing wind turbines for the offshore wind market, and steel fabricators have already supplied monopiles to one UK project. Such companies will benefit from lower manufacturing costs but are also likely to incur higher logistics costs. The fact that China and other Asian countries have growing offshore wind ambitions may also mean that these companies focus capacity on their domestic markets before looking overseas.

Supply and demand analysis has not been undertaken for the production of subsea cable, offshore substations or vessels.

In the case of subsea cable demand, uncertainties about the development of future transmission systems (including a European supergrid) mean that it is not appropriate to apply the same radial connection methodology used before on a European scale. For subsea cable supply, there are competing markets for production capacity (such as interconnectors in the wider transmission grids across Europe), which must be taken into account when comparing supply with demand. Other studies have undertaken such analysis and identified that there will be a supply deficit, but feedback from cable suppliers has been that there has not been sufficient market certainty to justify additional investment. Furthermore, they state that new capacity can be made available in time to meet demand, subject to receiving orders. It should also be noted that, with the exception of the sole UK player in this field (JDR Cable Systems), additional subsea cable production capacity is expected to be developed around the existing production facilities of the main players in Italy, Sweden, Norway and Germany.

All offshore substations built to date have been constructed in existing oil and gas or ship fabrication yards. In the UK, this has included the Harland and Wolff facility in Belfast and the Heerema facility in Hartlepool. As with subsea cables, these facilities also compete in other markets and undertake work on a project basis depending on capability and

8. *Ibid.*

availability. Furthermore, the increased size and complexity of HVDC substations compared with HVAC mean that facilities capable of the latter may not be suitable for the former. To date, no UK facility has undertaken the construction of an HVDC substation project. Again, these factors mean it is not possible to undertake a realistic desktop assessment of capacity without a wider analysis of other relevant sectors and discussions with yards (including those with the production capability but no existing track record in offshore wind) about their expectations of future priorities.

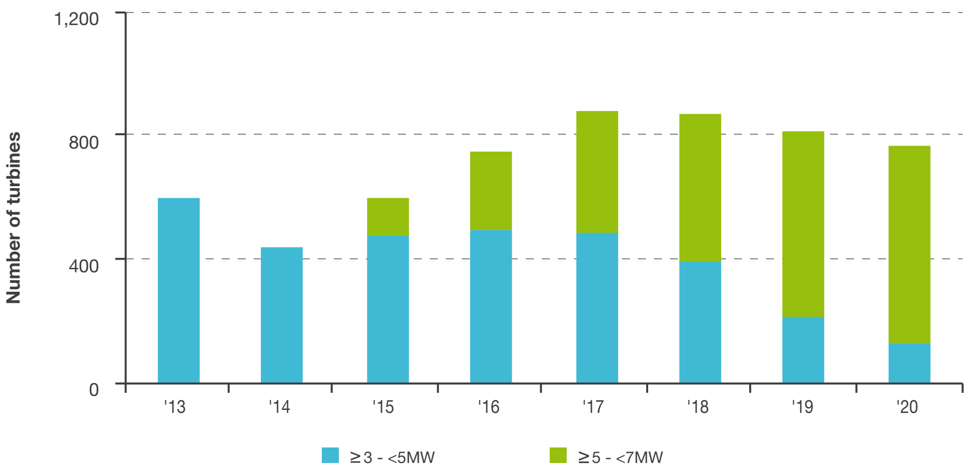
The supply of suitable turbine and foundation installation vessels has been considered a potential bottleneck in the past, although a significant level of investment has meant that supply is now less restricted.[9] There is still a need for more offshore wind-optimised vessels, but UK shipyards have not been successful in winning any of these projects in the past, and industry feedback is that it is highly unlikely that they will be competitive with facilities in Singapore, the Middle East, Germany, China, South Korea or Poland.

Finally, the UK already has a number of companies with strong track records of producing O&M personnel transfer vessels including Alnmaritec, CTruk and Alicat Workboats (which acquired market leader South Boats in 2012). Demand for the bigger offshore support vessels and motherships is not expected to develop until the second half of the decade but, as with installation vessels, UK shipyards are expected to struggle to be competitive with overseas facilities.

Turbine production

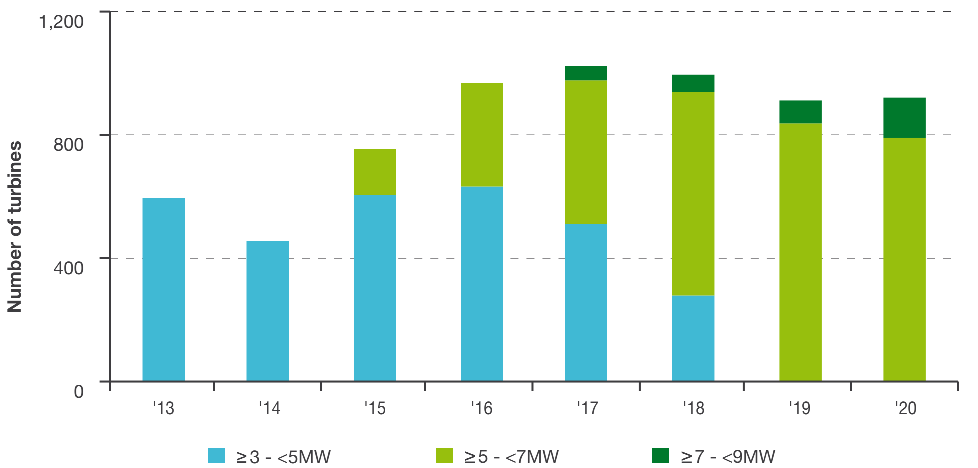
By 2020, the forecast growth in the size of turbines associated with increasing rated capacity means it is highly likely that it will only be possible to produce the main components (nacelle, tower and blades) in waterside facilities. Assuming that turbines with a rated capacity of 3MW to 4MW will continue to be produced at existing inland facilities, this gives a peak demand for larger turbines of almost 590 turbines per year in 2019 (for installation in 2020) in Scenario 1 and almost 910 turbines per year in Scenario 2. Note that this demand is offset from the installed capacity forecast by one year to reflect the timing of supply chain activity.

Figure 30. **European demand for wind turbines from 2013 to 2020 based on Scenario 1 for UK capacity (by year of manufacture, offset from installation by one year)**



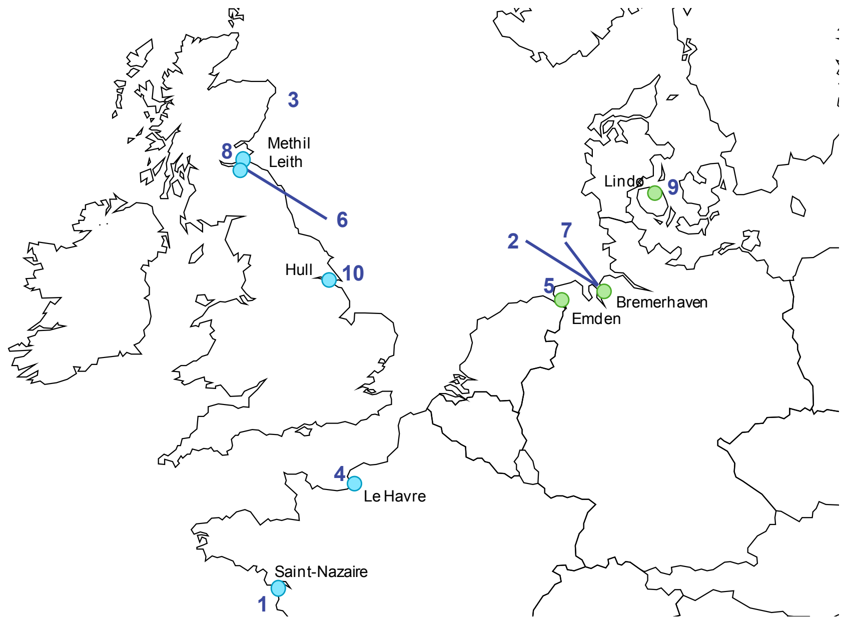
9. *Towards Round 3: The Offshore Wind Supply Chain in 2012,* The Crown Estate, June 2012, available online at http://www.thecrownestate.co.uk/media/357674/towards-round-3-the-offshore-wind-supply-chain-in-2012.pdf, last accessed December 2012.

Figure 31. **European demand for wind turbines from 2013 to 2020 based on Scenario 2 for UK capacity (by year of manufacture, offset from installation by one year)**



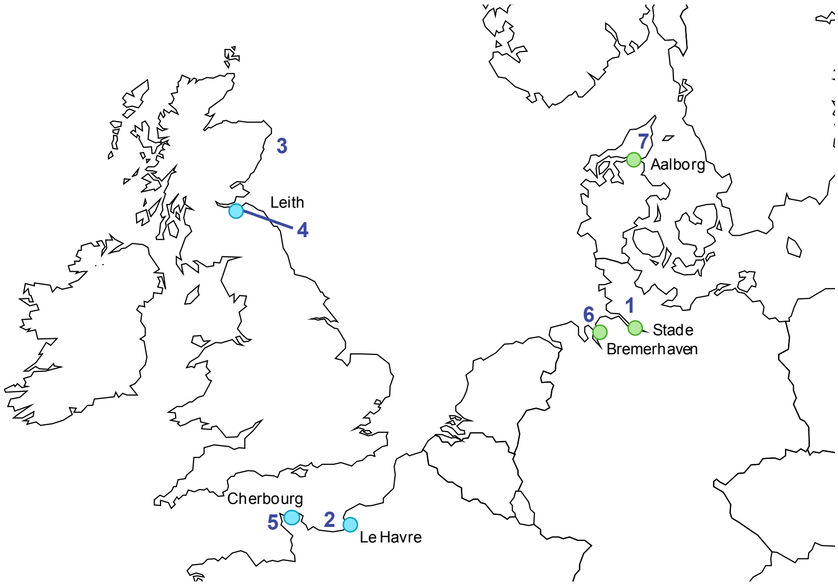
The locations of operational and announced production and assembly facilities for turbine components (nacelles, towers and blades) can be seen in the maps below.

Figure 32. **Operational (green) and announced (blue) coastal offshore wind nacelle assembly capacity**



	Nacelle manufacturer	Location	Country
1	Alstom	Saint-Nazaire	France
2	Areva	Bremerhaven	Germany
3	Areva	NRIP East Scotland	UK
4	Areva	Le Havre	France
5	Bard	Emden	Germany
6	Gamesa	Leith	UK
7	REpower	Bremerhaven	Germany
8	Samsung	Methil	UK
9	Siemens	Lindø	Denmark
10	Siemens	Hull	UK

Figure 33. **Operational (green) and announced (blue) coastal offshore wind blade production capacity**



	Blade manufacturer	Location	Country
1	Areva	Stade	Germany
2	Areva	Le Havre	France
3	Areva	NRIP East Scotland	UK
4	Gamesa	Leith	UK
5	LM Wind Power	Cherbourg	France
6	PowerBlades	Bremerhaven	Germany
7	Siemens	Aalborg	Denmark

Figure 34. **Operational (green) and announced (blue) coastal offshore wind tower production capacity**

	Tower manufacturer	Location	Country
1	Ambau	Cuxhaven	Germany
2	SIAG Nordseewerke	Emden	Germany
3	Unnamed on behalf of Alstom	Cherbourg	France

Figure 35 shows that, under Scenario 1, there is already in operation more than 40% of the coastal nacelle assembly capacity required to meet demand for projects forecast to be installed in 2020 (with turbines produced in 2019). Furthermore, the forecast capacity of all of the publicly announced developments would exceed the forecast demand under this scenario. Figure 36 shows that the increased demand in Scenario 2 would mean that additional capacity would be required as well as the development of all 'announced' facilities. Assuming a typical run rate of a hundred nacelles a year, this additional capacity is equivalent to the output of one additional facility, although it could potentially be met by increasing the production capacity of other facilities.

Figure 35. **Coastal turbine manufacturing capacity required to meet forecast European demand in 2020 under European forecast based on Scenario 1 for UK capacity**

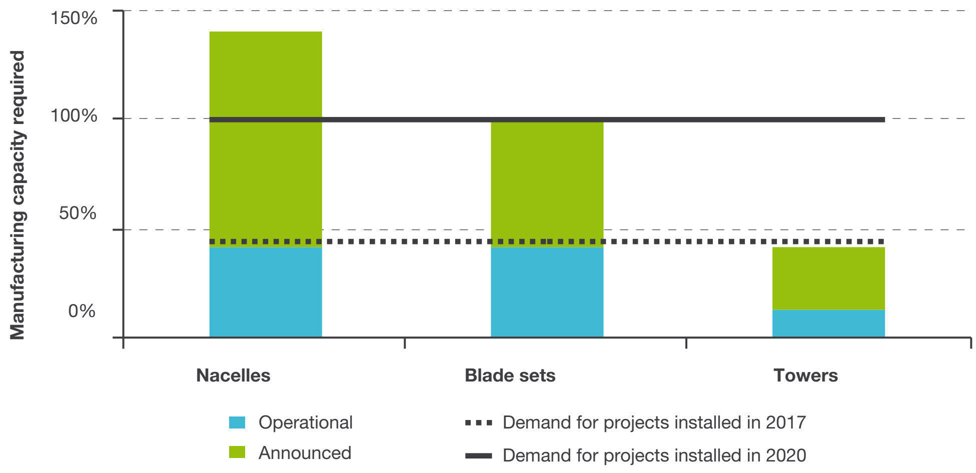
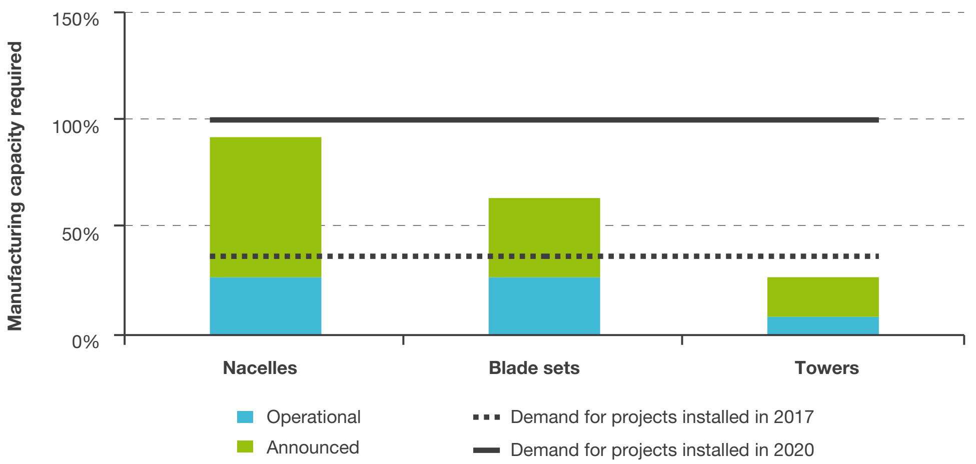


Figure 36. **Coastal turbine manufacturing capacity required to meet forecast European demand in 2020 under European forecast based on Scenario 2 for UK capacity**



As noted above, uncertainty about whether 'announced' facilities would actually be developed means that this demand for additional capacity could increase. For example, while some developments have been fully consented and are awaiting a final investment decision, other plans currently only amount to an early-stage agreement with a port or regional enabling body. Furthermore, as was shown by the withdrawal by Vestas from its plans in Sheerness, even an apparently firm commitment to developing capacity will not necessarily be translated into reality. These forecasts also do not include some major companies with known offshore wind turbine development programmes but no current commitment on production capacity; in particular, Mitsubishi and Vestas.

It should also be noted that this assessment does not consider the cost-effectiveness of production capacity. For example, companies such as Alstom and Siemens have set up temporary facilities in Saint-Nazaire and Lindø to produce prototypes and early series orders, but these sites will not benefit from investment in tooling and infrastructure that will allow faster throughput and more efficient delivery. From the perspective of these companies, however, this capacity will be available to meet short-term customer demand if market conditions are not suitable for full-scale investment.

For both blades and towers, there are greater levels of additional supply required, although this is to be expected as turbine suppliers are more likely to focus on the location of their main nacelle facility before confirming the location for production of other main components. Furthermore, third-party providers of these components are also likely to wait to confirm the location of their main customers before proceeding with any particular location, to ensure they can optimise their logistics.

Assuming typical run rates of a hundred blade sets and towers per year, this demand is equivalent to approximately four additional tower facilities under Scenario 1 but no additional blade facilities. Under Scenario 2, it is equivalent to up to eight additional tower facilities and approximately four additional blade facilities.

The red line on both graphs indicates the level of forecast ‘next-generation’ turbine demand for projects being installed in 2017 (with turbines produced in 2016), when the expected jump in UK installation levels is expected to take place in Scenario 2. As can be seen, under both scenarios, demand for turbine components can be largely met with existing or announced capacity with only towers showing a small shortfall in Scenario 2.

Foundation production

The uncertainty about future foundation technology choices means it is more challenging to forecast the required manufacturing capacity to meet future foundation demand.
As before, the demand in Figure 37 is offset from the installed capacity forecast by two years to reflect the timing of activity in the supply chain. This means that there is a small difference in the number of foundations and turbines required in 2020, although the relatively flat growth in annual installation rate at this point means that this difference is marginal.

Figure 37. **European demand for foundations from 2013 to 2020 based on Scenario 1 for UK capacity (by year of manufacture, offset from installation by two years)**

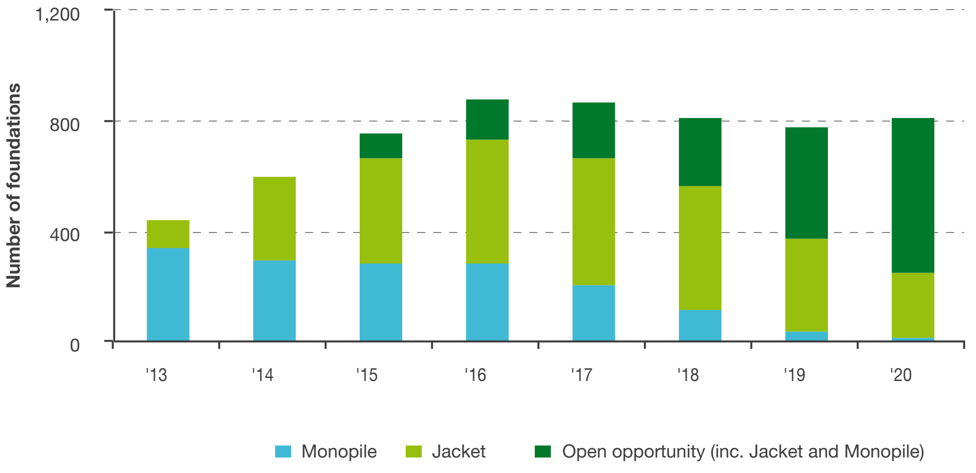
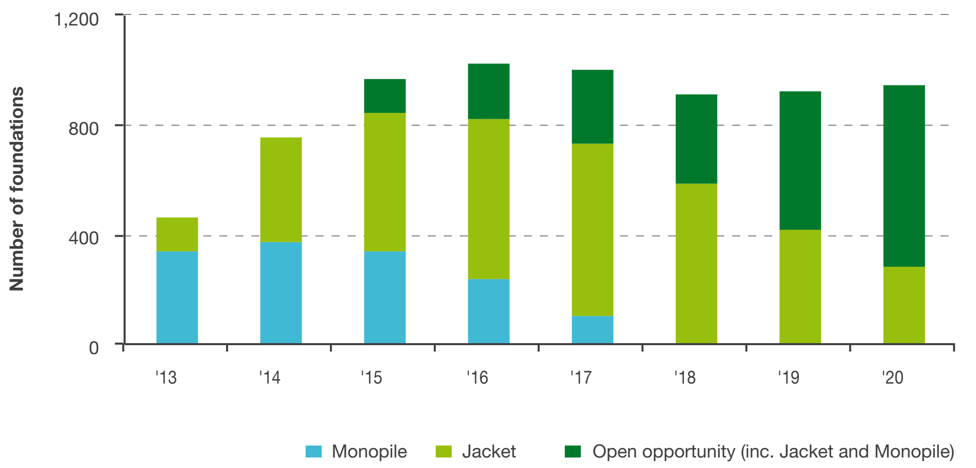
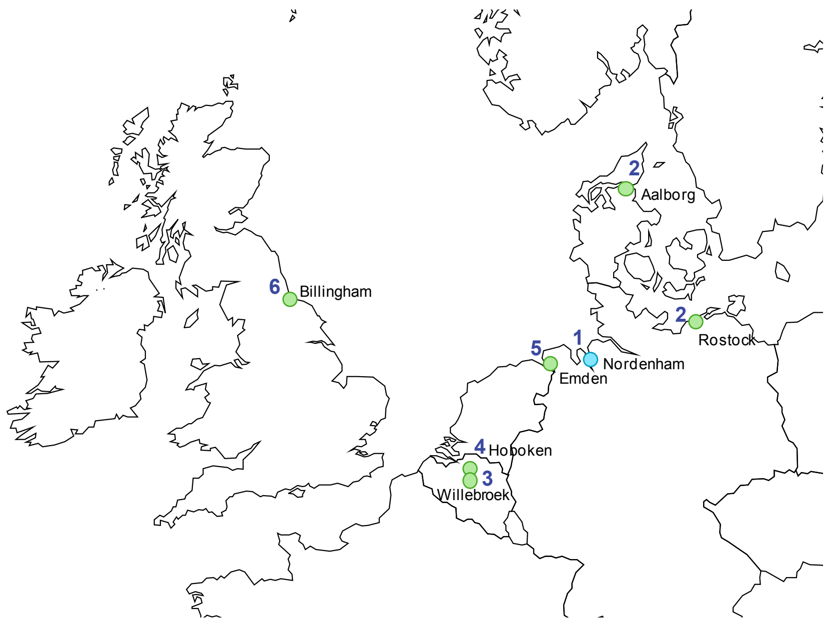


Figure 38. **European demand for turbine foundations from 2013 to 2020 based on Scenario 2 for UK capacity (by year of manufacture, offset from installation by two years)**



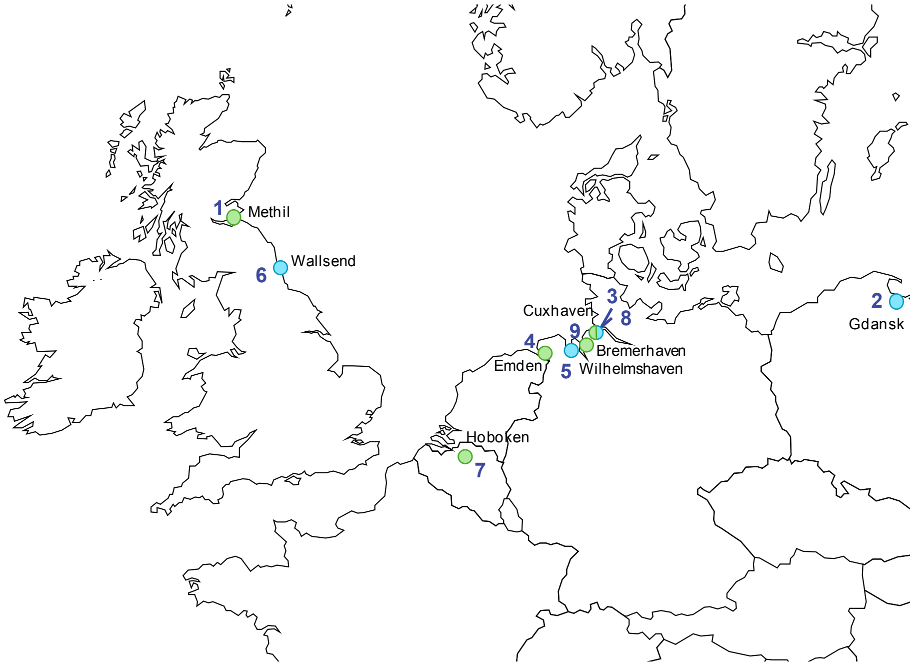
The locations of operational and announced production facilities for monopiles and 'non-monopile' foundations can be seen in the figures below.

Figure 39. **Operational (green) and announced (blue) coastal offshore wind monopile production capacity**



	Monopile manufacturer	Location	Country
1	Dillinger	Nordenham	Germany
2	EEW/Bladt	Rostock/Aalborg	Germany/Denmark
3	GGI/Odessa	Willebroek	Belgium
4	SIF/Smulders	Hoboken	Belgium
5	SIAG Nordseewerke	Emden	Germany
6	TAG	Billingham	UK

Figure 40. **Operational (green) and announced (blue) coastal offshore wind non-monopile foundation production capacity**



	Non-monopile foundation manufacturer	Foundation type	Location	Country
1	BiFab	Steel jacket	Methil	UK
2	Bilfinger Berger	Steel jacket	Gdansk	Poland
3	Cuxhaven Steel Construction	Steel tripile	Cuxhaven	Germany
4	SIAG Nordseewerke	Steel jacket	Emden	Germany
5	Jade Werke	Steel tripile	Wilhelmshaven	Germany
6	OGN	Steel jacket	Wallsend	UK
7	Smulders	Steel jacket	Hoboken	Belgium
8	Strabag	Concrete gravity base	Cuxhaven	Germany
9	WeserWind	Steel tripod	Bremerhaven	Germany

For monopiles, Figure 41 and Figure 42 compare manufacturing capacity with peak monopile demand, which is anticipated to be in 2014 (producing units for projects due to be completed in 2016). It is noted that, in this case, no allowance for redundant supply capacity has been made, given the shorter-term nature of the forecasts. This shows that, under Scenario 1, there is already overcapacity, although this is more marginal in Scenario 2.

As discussed earlier in the report, monopiles may be part of the technology mix in 2020, but it is likely that the large majority of demand will be for deeper-water designs, with a potential mix of steel and concrete designs. To account for this uncertainty, Figure 41 and Figure 42 also illustrate the demand if 20% of foundations in 2020 are monopiles (produced in 2018). This assumes it is possible to adapt existing designs to suit deeper-water conditions and large turbines, and this may still be an overestimate given the potential challenges in terms of tooling and logistics. Given the significant oversupply that occurs in both scenarios, it is expected that some suppliers will seek to build on the relationships and experience they have with developers and designers to produce other steel designs suitable for deeper waters and larger turbines, or rely on increased supply to other sectors. It is also noted that some of the existing suppliers may not have the capability to produce larger monopiles, which will also reduce oversupply.

Figure 41. Coastal monopile manufacturing capacity required to meet forecast peak European demand under European forecast based on Scenario 1 for UK capacity (no allowance for redundant capacity)

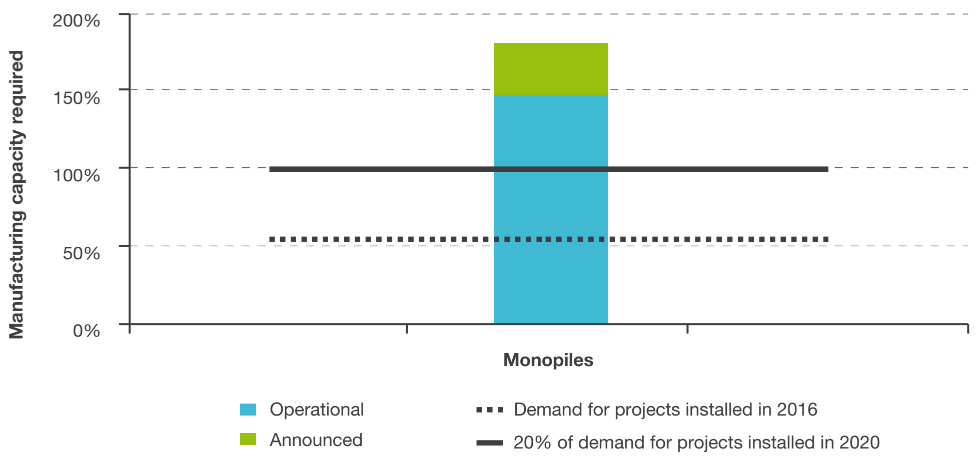


Figure 42. Coastal monopile manufacturing capacity required to meet forecast peak European demand under European forecast based on Scenario 2 for UK capacity (no allowance for redundant capacity)

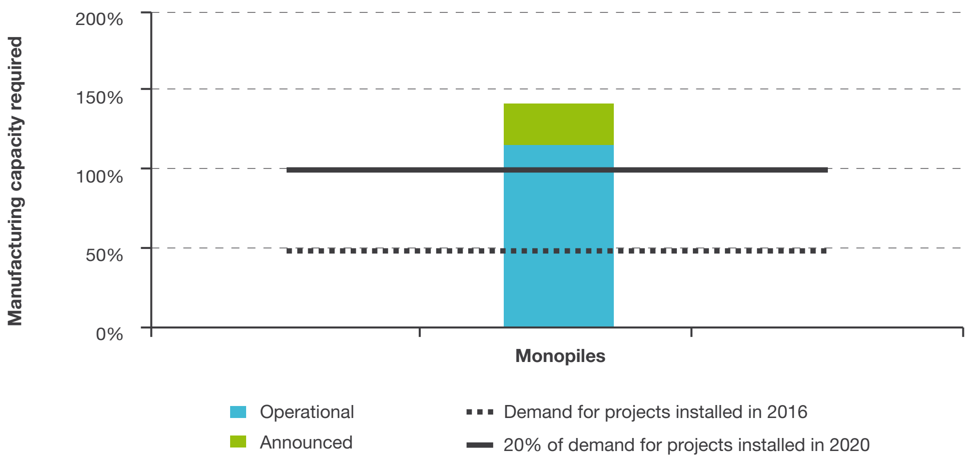


Figure 43 and Figure 44 compare the forecast demand for non-monopile foundations that occurs in 2020 with existing and announced production capacity. In line with the assumptions made above, it is assumed that 20% of the market uses monopiles.

Figure 43. **Coastal non-monopile foundation manufacturing capacity required to meet forecast European demand under European forecast based on Scenario 1 for UK capacity**

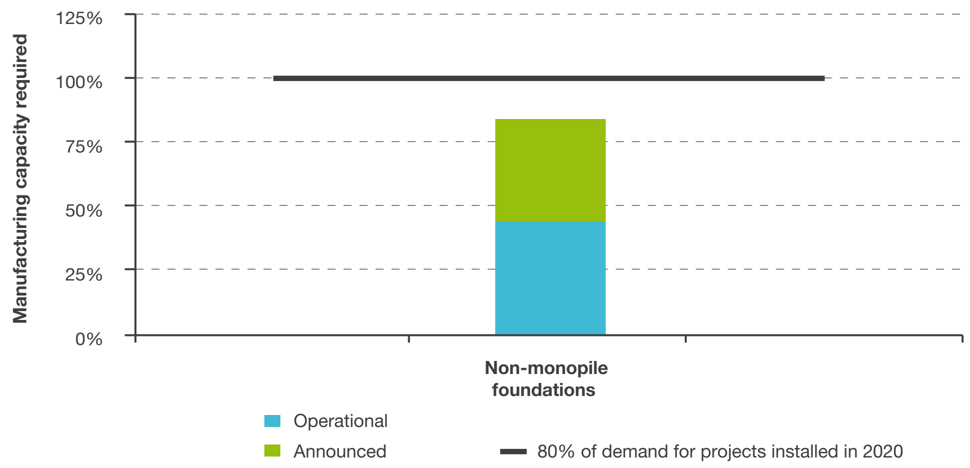
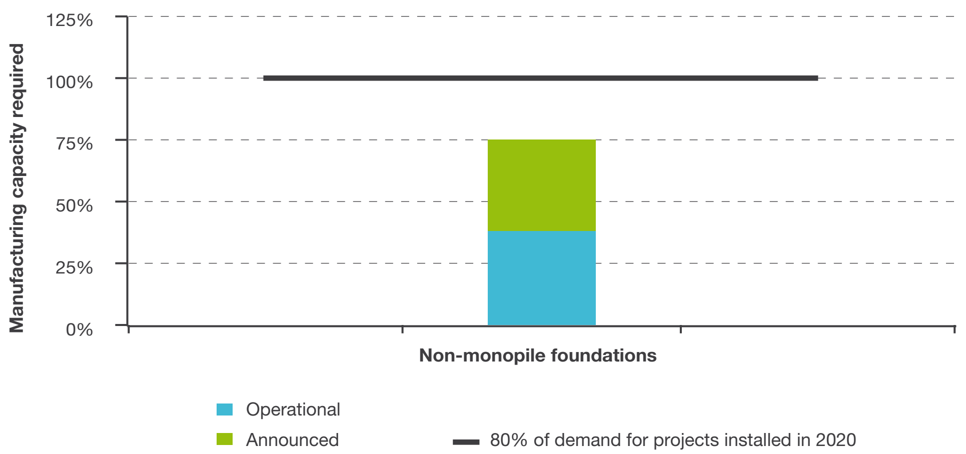


Figure 44. **Coastal non-monopile foundation manufacturing capacity required to meet forecast European demand under European forecast based on Scenario 2 for UK capacity**



These show that, under Scenario 1, there is already sufficient capacity to meet 45% of demand in 2020 and that there is sufficient announced capacity, which means approximately two additional facilities are required (assuming a production capacity of approximately 80 units per year). In Scenario 2, the demand increases so that approximately three additional facilities are required.

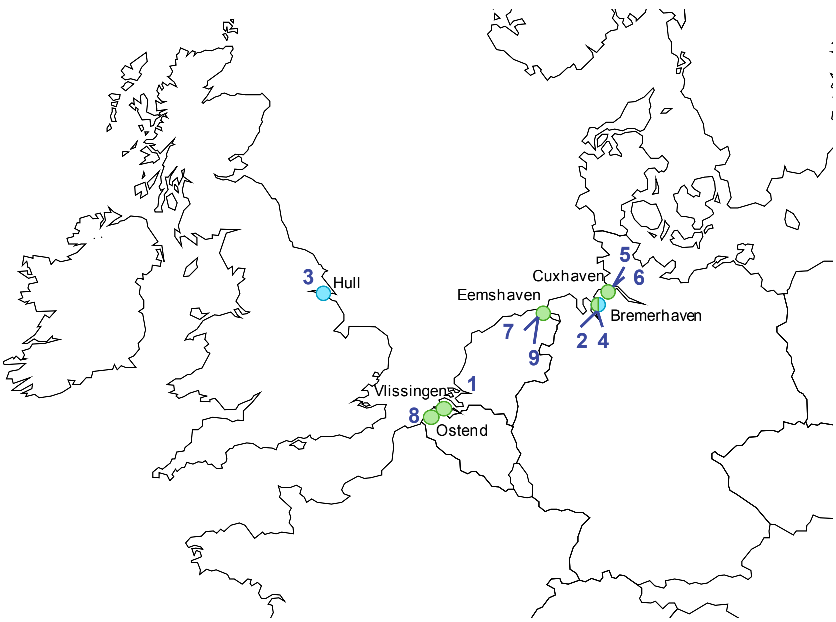
It should be noted that the majority of existing or announced non-monopile foundation production capacity is for steel space-frame designs with only the Strabag facility in Cuxhaven expecting to produce concrete gravity base foundations. As discussed, concrete gravity base foundations have a number of advantages over existing steel designs including mitigating the need for expensive installation vessels and avoiding piling noise (which is also applicable to suction bucket steel designs). Subject to successful demonstration of these new designs, therefore, it is considered likely that market demand will encourage the development of non-space-frame solutions.

This sector has also seen relatively high levels of instability to date due to a range of factors. This includes Smulders and SIAG Nordseewerke both filing for administration in 2012, Cuxhaven Steel Construction closing and Kvaerner announcing it was withdrawing from the market to focus on the oil and gas sector. Again, this means that it should not be assumed that all the announced capacity will be fully developed or that all operational capacity will still be available in the future.

Turbine installation for North Sea projects

This analysis of installation facilities is focused on demand for turbine installation facilities, as it is assumed that the cost of double-handling deep-water foundations will mean that they will be installed directly from the manufacturing sites. It is also assumed that projects in the Irish Sea, the English Channel and the Baltic Sea will be served by local installation facilities so will not compete for land with manufacturing facilities that are expected to focus on North Sea locations. The forecast demand from North Sea projects was estimated using the bottom-up data used in preparing the scenarios. This North Sea demand was then compared with existing or announced turbine installation capacity as shown in Figure 45. To reflect the challenge of handling turbines with a capacity of 5MW or more, only facilities that have a track record of handling these larger turbines (or have stated plans to have a capability to do so) have been included.

Figure 45. **Operational (green) and announced (blue) offshore wind turbine (5MW+) installation capacity for North Sea projects**



	Installation facility	Location
1	BOW Terminal	Vlissingen
2	Container Terminal 1	Bremerhaven
3	Green Port Hull	Hull
4	Offshore Terminal	Bremerhaven
5	Offshore Terminal I	Cuxhaven
6	Offshore Terminal II	Cuxhaven
7	Orange Blue Terminal	Eemshaven
8	REBO	Ostend
9	Wagonborg	Eemshaven

As shown in Figure 46, the existing and announced capacity is sufficient to meet demand from North Sea projects in 2017 under Scenario 1, although additional capacity will be required to meet 2020 levels. Figure 47 shows that the increased demand seen in Scenario 2 means that additional capacity will be needed to even meet 2017 needs. Assuming a typical annual installation capacity of a hundred 5MW turbines or larger a year, approximately two additional facilities would be required to meet 2020 demand in Scenario 1 and up to four under Scenario 2.

Figure 46. **Turbine installation capacity required to meet forecast European demand under European forecast based on Scenario 1 for UK capacity**

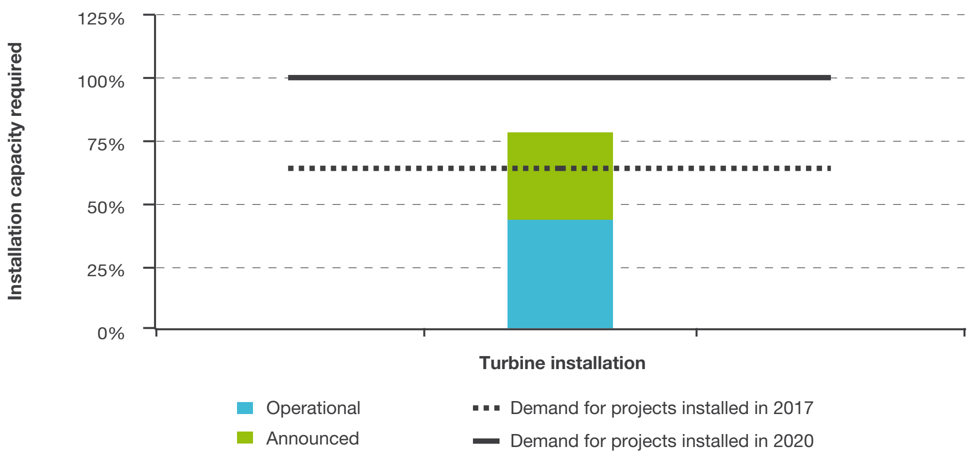
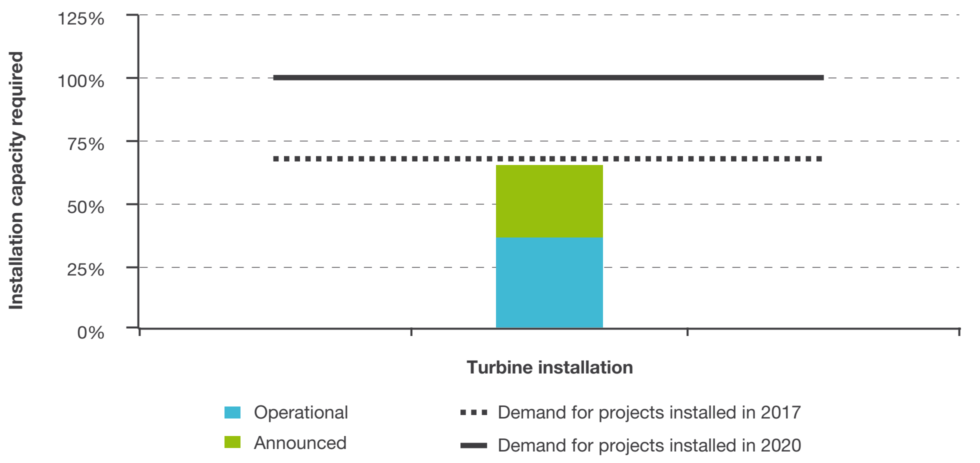


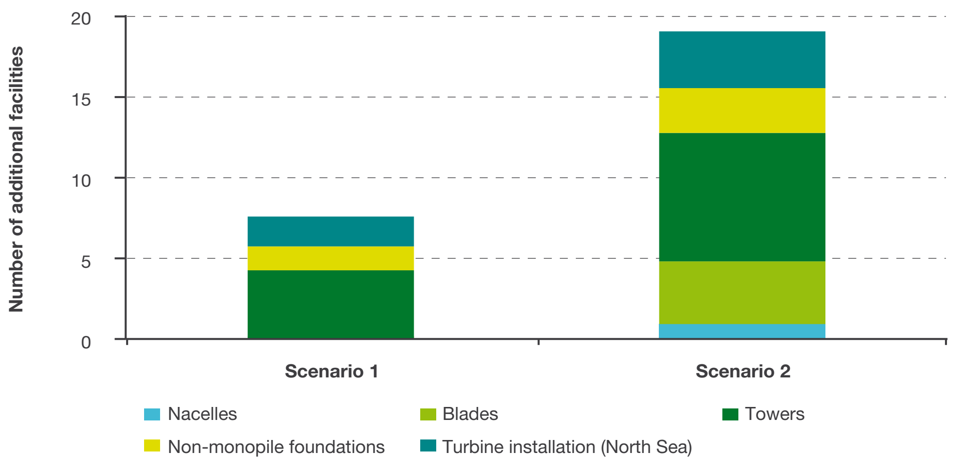
Figure 47. **Turbine installation capacity required to meet forecast European demand under European forecast based on Scenario 2 for UK capacity**



Total additional facilities

In total, the forecast European demand in 2020 under Scenario 1 requires approximately eight turbine- or foundation-related facilities beyond those already operational or announced. Under Scenario 2, this increases to 19 additional facilities.

Figure 48. **Additional coastal turbine and foundation production and installation facilities required to meet European offshore wind demand in 2020**



The creation of this level of additional capacity will require significant levels of investment by the supply chain and the development of large areas of waterside land. This analysis also shows, however, that there has been a significant level of progress already, with a total of 25 facilities already operating. This is equivalent to nearly half of the total number of facilities required to meet the European foundation and turbine demand in 2020 under Scenario 1 and 40% of demand under Scenario 2.

There have also been 19 facilities that have been publicly announced with at least a preferred location. There is a strong incentive for companies to progress with plans once they have been made public, but market conditions, customer interest and financial constraints all mean that a proportion are likely to be withdrawn.

It should be noted that the number of operational and planned facilities is not consistent across the supply chain with, for example, investment in turbine tower and blade facilities lower than in those for assembling nacelles or producing monopiles.

Figure 49. **Turbine and foundation coastal manufacturing and installation facility demand required to meet European demand in 2020 (with UK capacity based on Scenario 1)**

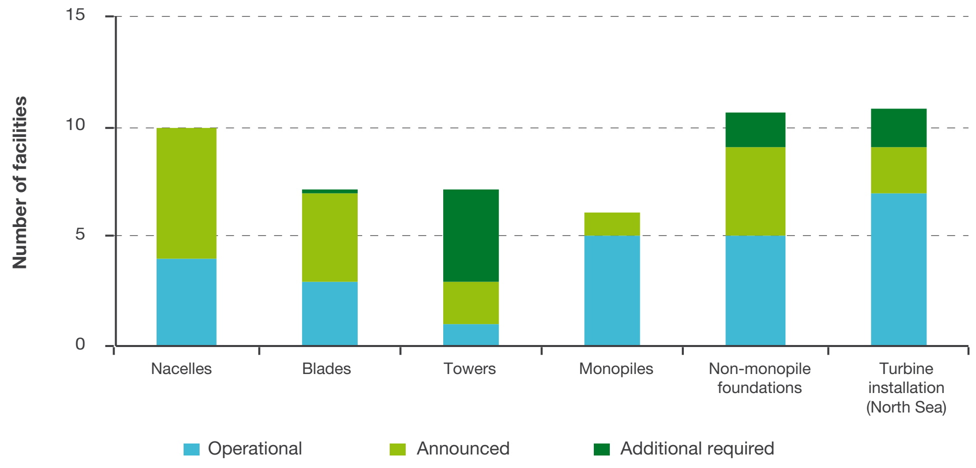
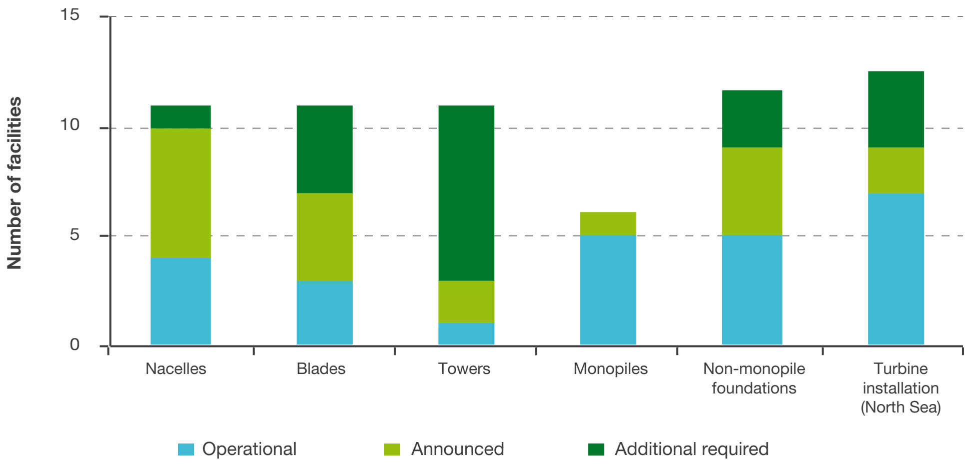
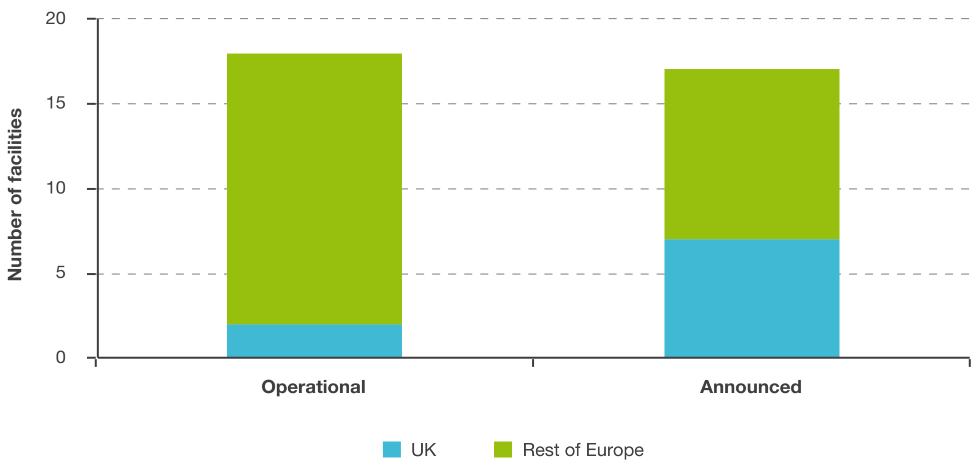


Figure 50. **Turbine and foundation coastal manufacturing and installation facility demand required to meet European demand in 2020 (with UK capacity based on Scenario 2)**



Finally, Figure 51 shows that only a small proportion of the operational facilities are based in the UK, despite its current position as the global leader in installed offshore wind capacity.

Figure 51. **Operational and announced coastal production facilities for turbines, components and foundations, split by location**



A larger proportion of announced plans for the development of new sites are focused on the UK than any other single market. In large part, this is a reflection of the size of opportunity within the UK market. Despite these announcements, however, other factors continue to hold back this development. Feedback from the industry is that the rapid progress of the Energy Bill into legislation is considered essential for encouraging future supply chain development. It is important to recognise, however, that this may be a necessary, but not sufficient, condition for attracting companies to the UK. Many of the key companies originate from Germany or Denmark and may be unsure about whether a UK supply chain can be competitive with their existing arrangements. Other countries are also taking a proactive approach in attracting companies, with greater support, particularly in terms of land and port development. Finally, the UK has traditionally maintained a 'light touch' policy in terms of the levels of domestic content that is required in projects, while other countries have been more overt.

The potential benefits of jobs and tax revenue, both directly and indirectly, from developing a UK offshore wind supply chain are significant, but the opportunity to attract the key Tier 1 suppliers is time-limited, as other countries also seek to capture the benefits. [10]

10. *The Macroeconomic Benefits of Investment in Offshore Wind,* CEBR on behalf of Mainstream Renewable Power, June 2012, available online at http://www.mainstreamrp.com/content/reports/benefits-of-offshore-wind.pdf, last accessed December 2012.

6. Conclusions

A battle for offshore wind jobs

The UK is in fierce competition with the rest of Europe for the jobs that will be created by the offshore wind industry. It is anticipated that there will be a significant increase in installation activity from 2017, with project developers needing to give commitment to suppliers in 2014 and 2015. To meet this demand, many companies will decide where to invest in new facilities and port infrastructure in the next two to three years. These decisions will determine the long-term shape of the supply chain for the next 20 years.

Different countries have particular advantages in this struggle for jobs. The UK has developed a world-leading track record in offshore wind delivery and built up a pipeline of projects that could potentially account for more than 50% of the total long-term European offshore wind market. Germany and Denmark benefit from existing supply chains (though often not in the right locations), while France has designed its licensing process to encourage indigenous supply chain growth by placing an emphasis on domestic socioeconomic impact when awarding projects. The UK market dominance so far has been during a period when the industry has not needed to invest in new coastal manufacturing facilities, due to the level of demand and manageable logistic constraints. Now, when the step-ups in market demand and technology scale require new facilities and infrastructure, it is even more important that the UK preserves its lead to incentivise the establishment of a strong local supply chain.

The competitive advantage for the UK of being seen as the dominant market by the industry should not be underestimated, but the domestic market has lost momentum. The annual installation rate for the next four years is anticipated to be relatively stable before a rapid increase in 2017. Market uncertainty and reduced ambitions risk a situation in which the UK is just one market amongst many. In this case, the argument for investing in the UK is less compelling, with the advantage going to those countries that have an existing supply chain, where short-term demand can be met from operating facilities and investment can be made incrementally.

The consultation and analysis for this report suggest that if the UK is to succeed in building a dynamic domestic supply chain, two things must happen. First, Government must demonstrate that it will support sufficiently strong market demand to ensure that the UK market remains ahead of other markets. It also needs to consider the market beyond 2020, as the relatively low margins available in the offshore wind sector generally require major investment decisions to be taken with a business plan of 10 years or more. Second, project developers need to underline the importance of UK content, such that the supply chain sees the business advantages in being UK based.

Differentiating the UK market

The scenario of 13GW of installed capacity by 2020 may still result in the UK being the largest market in Europe, but the industry advises that it will not generate the scale of logistic and commercial benefit to tip the balance of investment decisions towards investing here: indeed, much of the manufacturing and installation capacity that is required to meet future European demand under this scenario is either operational or being planned elsewhere.

Industry feedback is that a market of 18GW by 2020 achieves the level of demand that will attract investment, as long as reasonable incentives are provided to allow UK-based companies to compete fairly with their Continental rivals. It is also essential that the plans for this market scale be confirmed early enough to avoid investment decisions being taken to establish infrastructure elsewhere first.

The investment that will be secured through this market size is also critical to delivering the cost-of-energy reductions that the industry says are achievable and that the UK Government sees as essential for its continuing support. There is a win–win here, combining the benefits of scale and the cost-of-energy reduction.

A longer-term vision

The UK Government has so far expressed its ambition for offshore wind mainly in terms of its ability to provide sufficient generating capacity to meet its renewable energy targets in 2020. This is a relatively short-term horizon for companies planning to invest significant resources in infrastructure, tooling and new products. Other governments, such as that of Germany, have stated 2030 targets to give investors an indication of the extent of their ambitions.

To overcome these concerns, the UK Government and industry need to agree on a long term vision for offshore wind that will give industry confidence to invest in the technology and facilities that will be critical to bringing down the cost of offshore wind.

Appendix 1

Consultees

The following companies participated in this study by providing their perspectives and insights on UK market forecasts, technologies trends and industrial development.

A2Sea
Ard Sonas
AREVA
Bond Pearce LLP
Carbon Trust
David Brown Gears
DONG
EDF Energy
Eneco Wind Energy
E.ON
Eversheds LLP
Gamesa
Garrad Hassan
GE Power Conversion
Hochtief
KBR Power
Mabey Bridge
Mitsubishi Power Systems
Europe
REpower
RES
RWE npower
Siemens
SLP Energy
Tata Steel
The Crown Estate
Vinci

Appendix 2

Methodology for defining the installation forecast for each scenario

Up to 2012, installed capacity is based on the publicly stated dates for first energy generation for each project. For the earlier projects with a total capacity of less than 100MW, installation of all turbines was completed first, followed by commissioning. For larger projects, there is often an advantage for developers in commissioning tranches of turbines to enable earlier first generation and hence an earlier revenue stream. This has meant that the 'installation date' for capacity in large projects can be spread over a number of years.

Each scenario is based on the project-specific information provided in *Offshore Wind Project Timelines* published by RenewableUK.[11] The project schedules and capacities in this document were provided to RenewableUK by project developers. Following the current trend of commissioning tranches of turbines, it has been assumed that the installed capacity will come online between the stated dates for the start of offshore construction and project completion. For projects with a forecast construction period of two years, capacity is split evenly between the two years. For projects with a construction period of three or more years, capacity is distributed following a simple bell curve. It is noted that this is likely to bring forward average installation dates slightly.

For projects between 2013 and 2014, we have assumed that developer timescales are largely fixed and that projects are likely to proceed to schedule, as activity is either already underway or firm orders have been placed. For later projects, we have used a probabilistic model to manipulate the data from *Offshore Wind Project Timelines* to produce the three scenarios. This manipulation is applied in three stages:

- **Capacity attrition:** A project may not be developed because planning permission is refused or because a developer decides that it is not economically viable to construct. Rather than make arbitrary choices about which projects will proceed, a probabilistic capacity penalty has been applied to each project based on the consideration of a range of factors including:
  - the size of the grid connection that has been granted (if known)
  - the current stage of the project in the planning process
  - the licensing round of the project, and
  - the forecast cost of energy for that project.

The forecast cost of energy of a project was calculated using the known physical characteristics of the project and existing BVG Associates' models that have been developed through extensive engagement with the industry over a period of time.
It is recognised that, in most cases, a project will either be constructed at full size or not be constructed at all. The probabilistic approach reduces the capacity of many projects to between approximately 20% and 60% of their nominal capacity.

- **Stretched construction period:** While it is relatively easy to forecast the construction start date of a project that is scheduled within two years, uncertainties about the planning process, grid connection and project economics mean that start dates for later projects are relatively uncertain. In order to reflect this, the duration of the construction

11. *Offshore Wind Project Timelines,* RenewableUK, May 2012, available online at http://www.renewableuk.com/en/publications/index.cfm/offshore-wind-project-timelines-poster, last accessed November 2012.

period stated in *Offshore Wind Project Timelines* for later projects has been increased. This has the effect of spreading the installed capacity of each project more thinly over time. This does not mean that it is expected that the construction of any given project will actually take longer but rather that there is a reduced probability of specific project capacity being installed in any given year.

- **Slipped construction start date:** Where possible, we have sought to retain the forecast start date stated by the developer in *Offshore Wind Project Timelines*. In order to achieve the annual installation rates expected in the different scenarios, however, it has been necessary to delay the start of some projects. As with stretching the construction period, this is justified because of the high level of uncertainty associated with the schedules of projects planned to start construction so many years ahead.

This probabilistic approach is an evolution of the methodology previously applied by BVG Associates in *Offshore Wind: At a Crossroads* (2006),[12] *UK Offshore Wind: Moving Up a Gear* (2007)[13] and the offshore deployment chapter in the *State of the Industry Report 2011*.[14] No consideration has been given to decommissioning or repowering, as less than 1GW of installed capacity will have been operating for more than 20 years by 2030, and it is anticipated that project owners will, in a number of cases, seek to extend the use of their projects beyond this nominal lifespan.

Cumulative installed capacity and annual installation rates were, in the first instance, based on analyses undertaken by the Department of Energy and Climate Change (DECC), National Grid and the Committee on Climate Change. In Scenario 1, the installed capacity of approximately 13GW by the end of 2020 is in line with the low ambition that the Government set out in its *UK Renewable Energy Roadmap*,[15] and subsequent update,[16] the 'Slow Progression' scenario presented by National Grid in its *UK Future Energy Scenarios* document,[17] and the baseline scenario set out by the Committee on Climate Change in its *Renewable Energy Review*.[18] The installed capacity of approximately 18GW by the end of 2020 in Scenario 2 is in line with the upper end of the current central scenario of the UK Government roadmap and the National Grid 'Gone Green' scenario, and the continued growth to 50GW installed by 2030 matches that of the National Grid 'Accelerated Growth' scenario.

Draft scenarios were prepared and discussed with the RenewableUK steering group that was assembled for this report. These were then presented in two workshops on 7 and 9 November 2012 involving members of the RenewableUK Supply Chain Strategy Group, the Economics and Markets Strategy Group, and the Offshore Wind Delivery Group. Feedback from these workshops on the scenarios and resulting demand was then incorporated.

The non-UK scenario was developed using a similar principle, with publicly available information on projects and consideration of national targets, current political support, deployment track record and supply chain capacity. The scenario assumes a cumulative market size of 18GW at the end of 2020 and 50GW at the end of 2030. When combined with a cumulative UK market size of 18GW in 2020, as in Scenario 2, this is somewhat more conservative than the European Wind Energy Association (EWEA) forecast of approximately 40GW installed by 2020.[19] The subsequent buildout that is forecast in this report from 2020 to 2030 is also slower than the EWEA forecast, which shows continuing growth in European annual installation giving a cumulative European offshore market size of 150GW by 2030 (compared with 100GW when considering the non-UK scenario combined with the UK Scenario 2 presented here).

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12. *Offshore Wind: At a Crossroads, BVG Associates and Douglas Westwood on behalf of BWEA and Renewables East, April 2006.*
13 *UK Offshore Wind: Moving Up a Gear*, BVG Associates on behalf of BWEA, November 2007.
14 Future offshore deployment chapter (pp. 21–8), *Onshore and Offshore Wind: State of the Industry Report 2011*, Renewable UK, October 2011, available online at http://www.renewableuk.com/en/publications/index.cfm/Wind-SOI-2011, last accessed November 2012.
15 *UK Renewable Energy Roadmap*, Department of Energy and Climate Change, July 2011, available online at http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2167-uk-renewable-energy-roadmap.pdf, last accessed November 2012.
16 *UK Renewable Energy Roadmap Update*, Department of Energy and Climate Change, Dec 2012, available online at http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/7382-uk-renewable-energy-roadmap-update.pdf, last accessed December 2012.
17 *UK Future Energy Scenarios*, National Grid, November 2011, available online at http://www.nationalgrid.com/NR/rdonlyres/86C815F5-0EAD-46B5-A580-A0A516562B3E/50819/10312_1_NG_Futureenergyscenarios_WEB1.pdf, last accessed November 2012.
18 *The Renewable Energy Review*, Committee on Climate Change, May 2011, available online at http://hmccc.s3.amazonaws.com/Renewables%20Review/The%20renewable%20energy%20review_Printout.pdf, last accessed December 2012.
19 *Wind in Our Sails: The Coming of Europe's Offshore Wind Energy Industry*, European Wind Energy Association, November 2011, available online at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/23420_Offshore_report_web.pdf, last accessed November 2012.

Appendix 3

Methodology for defining demand for each wind farm element

For each wind farm element, underlying assumptions have been developed to allow the gigawatt capacity installation scenarios to be translated into specific component demand scenarios. In all cases, draft assumptions were developed based on existing knowledge, then refined through engagement with relevant industry players to incorporate technology developments and further deepen the underlying assumptions. The forecasts were then presented at two workshops organised by RenewableUK for further scrutiny. Finally, each element section, along with underlying assumptions, was peer reviewed by up to two leading industry players. A list of industry consultees is provided in Appendix 1.

Wind turbines

Industry feedback indicates that the rate of growth of the rated capacity of offshore wind turbines will be dependent on future market size and certainty, as these affect plans to invest in the development of new products. As such, different rates of introduction of larger turbines have been used in each of the three scenarios considered.

In order to model growth in turbine size, turbines have been split into four 'turbine classes' with 2MW steps in rated power: ≥3 to <5MW, ≥5 to <7MW, ≥7 to <9MW and ≥9MW (to reflect that there is currently no upper limit on potential offshore wind turbine size). For each turbine 'class', an average turbine size has been assigned: 4MW, 6MW, 8MW and 10MW respectively. It is recognised that this simple categorisation does not take into account important considerations such as the rotor diameter and drivetrain type, which impact on the anticipated cost-of-energy reductions and supply chain required.

To calculate the annual turbine unit demand for each 'turbine class' for each scenario, the annual installed capacity by year was multiplied by the percentage apportioned to each 'turbine class' in that year, divided by the average turbine size in each class.
In all cases, demand has been offset from the installation capacity forecast by one year, to reflect when component manufacturing activity takes place in the project construction programme.

Figure 52 and Figure 53 show the percentage shares of the 'turbine classes' in each year. In Scenario 1, it is assumed that there will still be growth in average turbine size, especially over the next decade, because of the considerable investment that has already been made by suppliers based on anticipated demand at a pan-European level. It is likely, however, that a weak UK market will not support as many companies entering the market, which will limit customer choice and reduce the competitive drive for larger turbines. As such, it is assumed that the existing 3MW to 4MW turbines will continue to be used by developers to some extent into the first half of the next decade. Work is also already underway on turbines with a rated capacity of 7MW and above, so these designs will also eventually reach the market albeit more slowly than in the other scenarios. Beyond this, there is strong industry feedback that further new turbine development is unlikely to be justified by the size of the market, so we will see a levelling off until some further market impetus impacts.

In Scenario 2, more buoyant market conditions encourage increased competition and more rapid product development so that, by 2020, the industry has moved on from using 3MW and 4MW turbines. This leads to a 'virtuous circle' in which the development of new technology is stimulated by a strong market, which accelerates improvements in the cost of energy of offshore wind, which then encourages further political support and further market confidence and growth. As such, in the longer term, the technology of larger 7MW to 9MW turbines is introduced more rapidly than in Scenario 1, paving the way for further turbine technology development beyond 2030.

Figure 52. **Forecast growth in rated capacity of offshore wind turbines under Scenario 1**

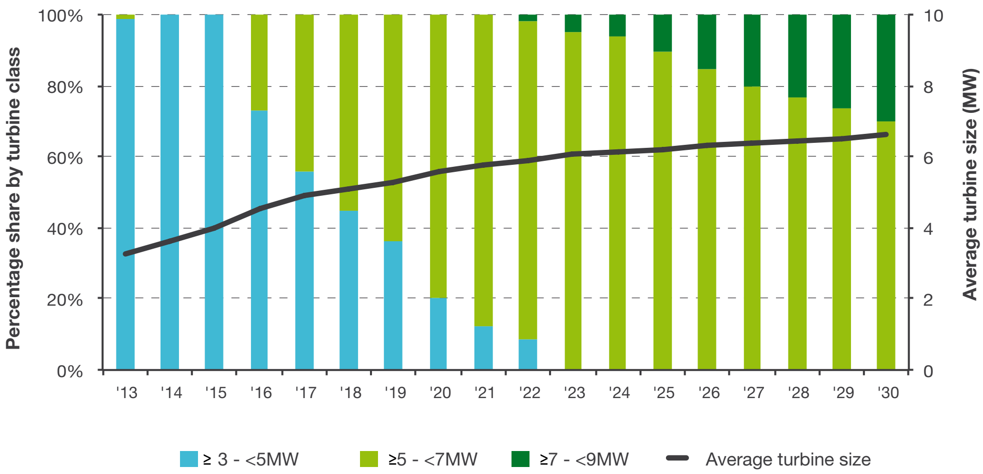
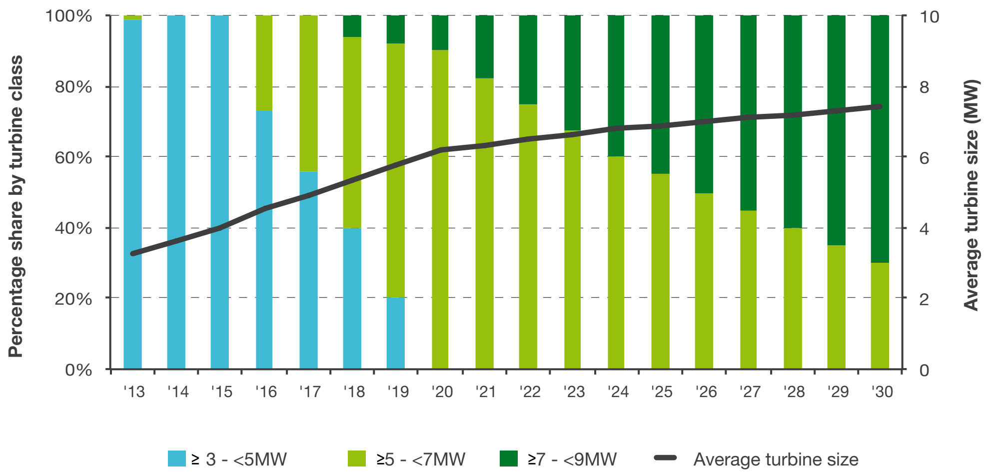


Figure 53. **Forecast growth in rated capacity of offshore wind turbines under Scenario 2**



Foundations

The demand forecasts for monopiles are based on project-specific water depths and the forecast growth of turbine capacity. Industry feedback indicates that the current crossover point between a monopile and a jacket is approximately 30m water depth for a 4MW turbine and 20m water depth for a 6MW turbine. This is in line with current industry feedback that, in these conditions, monopiles remain the most competitive option once installation costs are taken into account. It is acknowledged that there is work underway to extend the use of monopiles to water depths of up to 40m with 4MW turbines and shallower waters with turbines with a rated capacity of up to 6MW. As no turbines greater than 4MW have yet been installed on monopiles, however, the use of large monopiles is included in the ‘open opportunity’ category described below.

For projects in deeper waters or using larger turbines, it is assumed that developers will use alternative foundation designs. In the short term, this is most likely to be four-legged steel jackets, as these have already been deployed at a commercial scale on a number of projects, developers are more confident about their use in a range of site conditions and there is manufacturing capacity available. From the middle of the decade, however, there is the potential for other designs to be used in place of jackets. These may include large monopiles as described above, concrete gravity base designs, steel jacket variants and foundations using suction bucket seabed connections. Industry feedback suggests that market uncertainty and delays in offshore demonstration projects mean it is unlikely that any designs other than monopiles and jackets will be deployed in significant quantities before 2017. The split between jackets and the 'open opportunity' presented in the main report is somewhat arbitrary but considered realistic by peer reviewers.

In all cases, demand has been offset from the installation capacity forecast by two years, to reflect when foundation manufacture takes place in the project construction programme. No difference in approach to foundation type has been applied under the different scenarios considered, although it is likely that Scenario 2 will involve more technology development, both in terms of design and manufacturing methods, than Scenario 1.

Offshore substations

For the purposes of this report, the estimated export cable length of a wind farm has been used to determine whether a project will use an HVAC or HVDC transmission system. These lengths are based on the straight-line connection distances set out in the Offshore Development Information Statement published by the National Grid, supplemented by more recent public information gathered by BVG Associates. To reflect the likely short-term supply chain bottlenecks and the long-term technology development, it has been assumed that the tipping point is a 100km connection distance until 2022, when it drops to 80km. It is assumed that an average HVAC export or collector substation has a capacity of up to 500MW and an HVDC export substation has an average capacity of 1GW. These are indicative capacities, and industry feedback is that there is currently a trend towards a standard HVDC substation size of 900MW. Conversely, it has been forecast that future technology developments may enable increases in HVDC substation capacity of up to 2GW. Connections are rated at 100% of wind farm capacity, but it is noted that there are other trends that could affect this. One trend includes building up to 50% redundancy to reduce the impact of a transmission system failure. Conversely, it is possible to oversize the wind farm compared to the cable capacity, based on the assumption that capacity factors and outages mean that it will only occasionally operate at its full rated output. Neither approach has been incorporated here but could increase or reduce demand. The justification for the use of HVAC collector substations as part of HVDC systems is discussed in the main report.

In all cases, demand has been offset from the installation capacity forecast by two years. No difference in approach has been applied under the different installation scenarios.

Subsea cable

Demand for array cable has been determined based on the number of turbines that are forecast to be installed in a given year and the average turbine diameter in that year. The diameter of the turbine is derived by assuming a fixed specific rating (rated power over rotor swept area). In reality, it is expected that the optimum specific rating of a turbine will increase as turbine rated capacity grows, thus requiring less cable. This is likely to be offset, however, by a gradual increase of diameter spacing between turbines, based on industry learning, so the overall impact is assumed to be marginal. Cable length is based on a mean spacing of 7.5 rotor diameters in both directions.

The forecast split between 33kV and higher-voltage array cable is based on peer feedback, with higher-voltage cables first introduced in 2016. No DC array cabling has been considered, although such technology is expected to offer significant potential benefits after 2020. In all cases, radial arrangements are assumed.

Export cable demand is based on the straight-line connection distances discussed above with a 10% allowance to account for deviations from the nominal route. Two three-core export cables are assumed for each 500MW HVAC export substation, while two single-core cables are assumed for each 1GW HVDC export substation. A nominal allowance of 10km of HVAC cable has also been made for each HVDC export substation, to account for connections with the HVAC collector substations. The length of export cable required for each project is then calculated based on the distance to a shore-based connection point, the number and type of substations, and the number of cables required.

In all cases, demand has been offset from the installation capacity forecast by two years, to reflect when cable manufacture takes place in the project construction programme.

Installation vessels and O&M jack-up vessels

Recognising the need to simplify project-specific calculations to estimate global requirements, vessel demand has been calculated by estimating the average annual installation time for a turbine, a foundation, and array and export cables. These times vary with the size of the turbine or foundation and reduce over time, as processes are improved and newer vessels become available. The figures used in this report take into account mobilisation and demobilisation, periods of inactivity due to weather delays, and other factors. An assumed 15% vessel fleet inefficiency is also applied to take account of periodic vessel maintenance and the fact that vessel availability does not necessarily coincide with project schedules, resulting in some level of vessel inactivity.

The approach does not take into account the variation between specialised and general-purpose vessels, the impact of different installation strategies, or site characteristics.

Turbine installation and maintenance

Turbine installation vessel requirements were calculated according to the rated capacity of turbines and the year in which they are installed. A headline installation rate (in days per turbine) was used, taking into account the factors discussed above. For sub-5MW turbines, this installation rate was a constant 3.5 days per turbine, step changing to a constant three days per turbine in 2020. For turbines between 5MW and 7MW, a rate of four days, changing to 3.5 days per turbine, was used. For turbines with a rated capacity of 7MW or greater, a rate of five days per turbine, changing to 4.5 in 2017 and four in 2020, was used. The total days required in each year was then used to estimate the number of vessels. This demand was not offset from the installation forecast, as it is assumed turbines are energised soon after installation.

The demand for jack-up vessels used for turbine maintenance was also modelled. This was generated by assuming that 8% of the cumulative installed number of turbines requires a jack-up vessel each year, and that each turbine intervention takes seven days including weather delays, with maintenance jack-up vessels being available to work 300 days per year. It is noted that serial defects are often handled by chartering a vessel on a long-term agreement, which would allow a shorter time allowance as the mobilisation and demobilisation requirement is reduced.

Foundation installation

Foundation installation vessel requirements were calculated according to the foundation types installed in that year. For monopile foundations, an installation rate of 3.5 days per unit, changing to a three days per foundation in 2020 and beyond, was used. For non-monopile foundations, an installation rate of five days per foundation, changing to four days in 2016 and 3.5 days in 2020 and beyond, was used. In all cases, demand has been offset from the installation capacity forecast by one year, to reflect when foundations are installed in the project construction programme.

Array cable installation

Array cable installation vessel requirements were calculated by using the number of turbines per year and assuming an average annual installation rate of slightly less than four days per cable. There is no improvement in the installation rate built into the model. In all cases, demand has been offset from the installation capacity forecast by one year, to reflect when array cables are installed in the project construction programme.

Export cable installation

Export cable installation vessel requirements were calculated by taking the total length of export cable forecast to be installed in a year and assuming an annual average installation rate of approximately 2.5km of cable per day. The model assumes that 25% of HVDC cable pairs are laid separately. In all cases, demand has been offset from the installation capacity forecast by one year, to reflect when export cables are installed in the project construction programme.

Operation and maintenance vessels

Demand for O&M vessels has been split between personnel transfer vessels and offshore support vessels, with an assumed tipping point of 60km from a viable port, although it is expected that this will reduce over time as the industry becomes more familiar with far-shore strategies.

For near-shore projects, the number of personnel transfer vessels is derived from a trend based on existing project data, which assumes that four to five personnel transfer vessels are required to maintain 100 turbines, with reduced efficiency on smaller projects. This assumption is applied across all ‘near-shore’ projects although, in reality, a range of factors will influence the number of vessels used, such as the actual distance to the port and the typical metocean conditions of the site.

For projects more than 60km from a viable port, it is assumed that an offshore support vessel or mothership is required for every 100 turbines. It is also assumed that, for each offshore support vessel or mothership, two personnel transfer vessels will also be required to support turbine maintenance activities.

Cumulative vessel demand is presented to show the number of vessels that are required to be operating in a given year to service the cumulative number of turbines installed. Demand has not been offset from the installation capacity forecast, as it is assumed these vessels are also needed at the commissioning of the wind farm.

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