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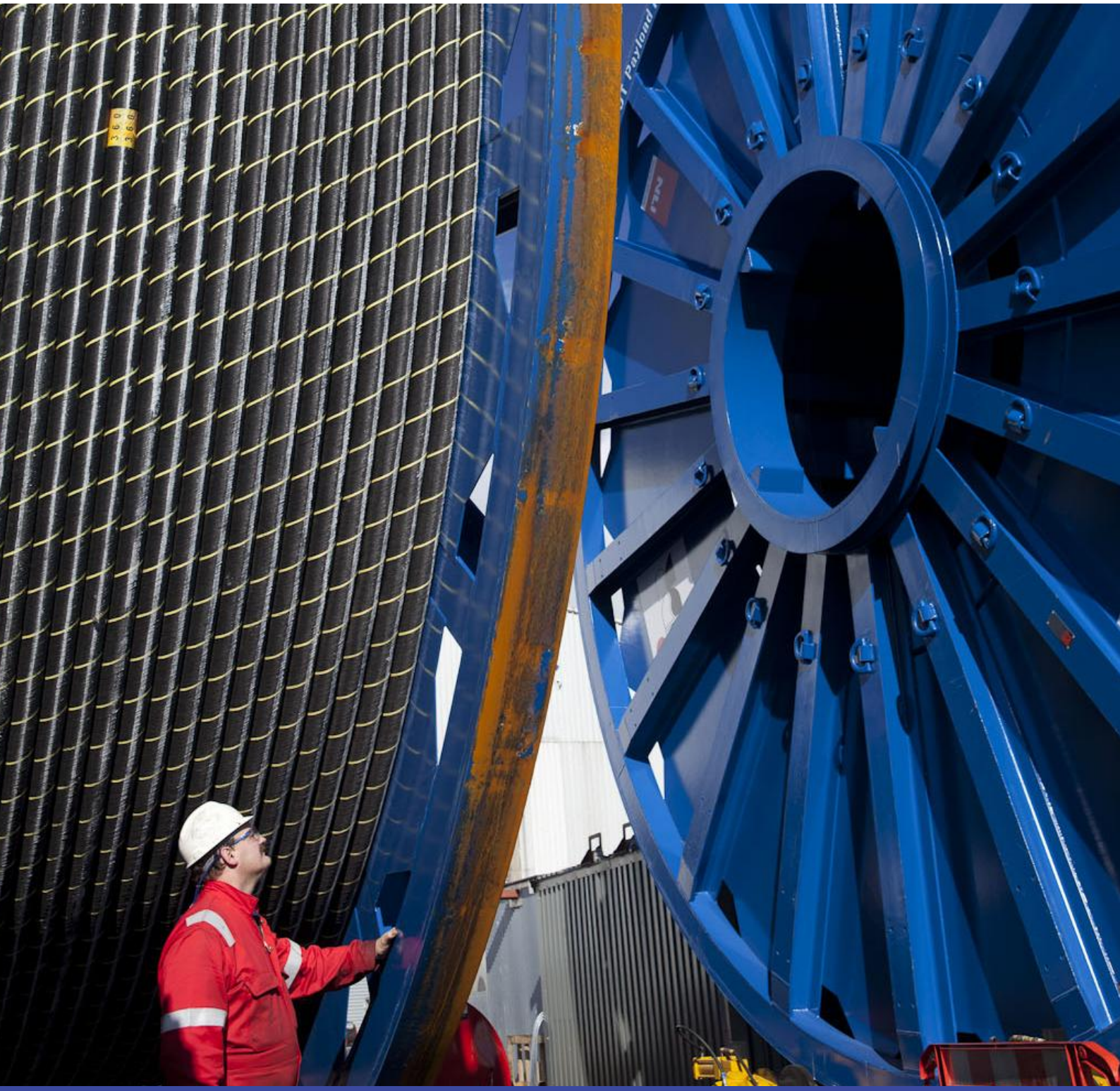

UK offshore wind supply chain: capabilities and opportunities

A report prepared by BVG Associates for the Department for Business, Innovation and Skills

January 2014

BVG Associates

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 140 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

Alun Roberts specialises in offshore wind supply chain analysis and development. He draws on a broad understanding of the offshore wind supply chain and project procurement trends in undertaking analyses on socioeconomic impact and skills analysis. A key area of work has been in enhancing the industry's understanding of UK content in offshore wind farms and led work on developing a methodology for measuring the UK content of future wind farms on behalf of the Crown Estate and the Offshore Wind Programme Board.

Mike Blanch focuses on wind turbine technology, support for innovation programmes, and wind farm implementation which has included due diligence for investors, economic modelling of offshore and onshore wind; medium sized wind turbine site selection and development, technical review and market forecasting, technical monitoring and assessment of R&D programmes and reliability.

Jess Weston undertakes industry research and engagement, market research, database development, socioeconomic analysis, and site selection and feasibility analysis. Jess has worked on a range of high profile projects undertaking numerical analysis and data gathering as well as wide ranging industry consultation.

Bruce Valpy founded BVG Associates in 2005 and has created a rapidly growing, diverse client base that includes the market leaders in the wind turbine and tidal turbine sectors, trade bodies, UK Government, utility providers, multi-nationals and private companies on four continents. He combines deep technical, engineering design and market knowledge to make a difference to customers both at the operational and strategic level.

Cover picture: JDR Cable Systems. Credit: Steve Morgan

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1. Introduction

In August 2013, the UK Government published the *Offshore Wind Industrial Strategy* which was developed in partnership with industry.[1] Its vision was that:

"Industry and Government work together to build a competitive and innovative UK supply chain that delivers and sustains jobs, exports and economic benefits for the UK, supporting offshore wind as a core and cost-effective part of the UK's long-term electricity mix."

This report has been produced to support the work of both industry and Government. As part of its work in supporting the development of the offshore wind supply chain in the UK, BIS commissioned this study to create a resource to inform the delivery of the industrial strategy. The report presents a first "map" of the UK offshore wind supply chain in the UK, identifying its strengths and weaknesses and the potential for businesses in each area to benefit economically from the growth in European offshore wind farm development, construction and operation.

For industry, it provides a resource to help it to grow UK supply, recognising that for the offshore wind industry to retain its momentum, it needs to significantly increase the economic benefit for the UK. For Government, it provides a high level evidence base to inform the delivery of the *Industrial Strategy*.

In this analysis, criteria were developed for assessing each area of the supply chain and these were discussed with established suppliers and developers in the industry and representatives from parallel sectors where the UK has established capability. BVG Associates and BIS are grateful to all the companies that gave time and insight.

The report does not provide conclusions or any recommendations as to how to strengthen the UK supply chain, recognising that it will be used by a number of organisations across Government.

The work has been undertaken in parallel with an analysis of the wider European offshore wind supply chain for The Crown Estate, which has kindly agreed that information gathered for that work can be included in this report.[2]

We welcome any feedback on our analysis.

[1] *Offshore Wind Industrial Strategy - Business and Government Action*, HM Government, August 2013, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226456/bis-13-1092-offshore-wind-industrial-strategy.pdf, last accessed December 2013

[2] *Offshore Wind: A 2013 Supply Chain Health Check*. A report prepared by BVG Associates for The Crown Estate, November 2013, available online at http://www.bvgassociates.co.uk/Portals/0/publications/BVGA%20TCE%20Offshore%20Wind%20SC%20Health%20Check%201311.pdf, last accessed December 2013

2. Methodology

2.1. Industry engagement

Our engagement with industry is at the heart of this analysis. We used a process that aimed to maximise the value that companies could provide while limiting our demand on individuals' time. The engagement was undertaken in two stages:

1. **Offshore wind industry consultation**, in which we undertook a number of interviews with established suppliers and developers.
2. **Engagement with UK parallel sectors**, in which discussions were held with industry analysts from the following sectors:
    a. Aerospace
    b. Automotive
    c. Composites
    d. Nuclear
    e. Oil and gas, and
    f. Rail.

Some of the information shared with us was commercially sensitive and therefore this has been aggregated and anonymised for publication.

After each formal interview, we issued draft notes presenting our understanding of the level of sensitivity demanded for each item of input received. Interviewees then had the opportunity to refine these notes and confirm the level of sensitivity, thereby allowing us to maximise the accuracy and detail presented, while respecting the commercial position of each company with which we engaged.

2.2. UK supply chain assessment

The supply chain was analysed by breaking it down into six elements, in line with *A Guide to an Offshore Wind Farm* and other BVG Associates reports published for The Crown Estate, RenewableUK and other enabling organisations:[3]

- Project management and development
- Turbine supply
- Balance of plant supply
- Installation and commissioning
- Operation, maintenance and service (OMS), and
- Support services.

Each element was divided into subelements for detailed analysis. The subelements were defined to reflect the different stages of the wind farm's life and typical contract boundaries. These were assessed using the following six criteria to capture the status of UK supply. The description of scoring for each criterion is presented in Table 2.1. The subelements mirror those previously used in a series of studies reviewing the status of the offshore wind supply chain for The Crown Estate, the most recent of which was published in November 2013.[2]

The transmission assets, that is the substations and export cable, were treated as a capital cost within balance of plant. Although wind farm owners will pay for the investment in infrastructure through charges to the offshore transmission owner (OFTO), the procurement and construction of the transmission assets is typically undertaken in parallel to the generation assets of the wind farm.

UK supply track record

This criterion considers how much UK-based companies have supplied to the offshore wind industry to date. We describe those UK companies that are "proven" suppliers of the offshore industry, defined as having supplied greater than 200MW equivalent of products or services. Future suppliers are described as those that either have supplied the industry but are not proven using the definition above, or are well placed to enter the sector in due course.

Market readiness of suppliers for commercial scale projects

This criterion considers how well advanced plans by supply chain companies are for investment in the UK that enables the supply to projects of scale 300MW and above.

UK investment risk

This considers the risks to investment in the UK. These may either be generic (applying also to investments made in other countries) or specific to the UK. Among the issues considered are the size of investment and the lead time for the first returns on that investment.

Logic of UK supply

This considers how strong the logic is for UK supply from customers. This includes the significance of the logistics benefit from supply from UK coastal locations close to the main areas of European offshore wind developments.

Availability of UK expertise

This considers how strong the UK's core expertise is and the synergy with the parallel sectors where the UK has strengths. Each of the parallel sectors listed in Section 2.1 was assessed using the following criteria:

[3] *A Guide to an Offshore Wind Farm*, BVG Associates for The Crown Estate, January 2010, available online at http://www.bvgassociates.co.uk/PublicationsForm.aspx?filename=http://www.bvgassociates.co.uk/Portals/0/publications/Wind_Farm_Guide_Final_LR.pdf, last accessed December 2013

- Low = There are few synergies with offshore wind or good synergies but for only for a small fraction of the value of products or services in this subelement.
- Medium = There are synergies with offshore wind for this subelement for a significant fraction of the value of products or services in this subelement. There is UK expertise but it has either not yet been applied to offshore wind or only applied to a limited degree.
- High = There are synergies with offshore wind for this subelement for a significant fraction of the value of products or services in this subelement. There is UK expertise and it has been applied to offshore wind.

Size of the UK opportunity

This considers how much of the value in the completed products and services could realistically be generated in the UK (the potential UK expenditure) as a percentage of the lifetime cost of the wind farm. In making the assessments for each subelement, we drew on an analysis, updated where necessary, which derived a cost breakdown for each component in a wind farm and within that showed the proportion that related to "Labour", "Materials" or "Other" costs, using the definitions in Table 2.2.[4] This criterion has been included to help enabling organisations prioritise their activities. Even those subelements with low scores provide significant opportunities for suppliers.

For subelements with two or more technology options (foundations and electrical systems), in calculating the size of the opportunity, no consideration has been given to the market share of that technology. The size of the opportunity of all foundation and substation technology options is therefore the same.

For simplicity, the same component costs have been provided for all technology options. In reality this would not be the case; however, if the costs used for, for example, monopiles and non-monopile steel foundations were different, this would affect the percentage cost of other components.

[4] *Value Breakdown for the Offshore Wind Sector*, A report commissioned by the Renewables Advisory Board, BVG Associates, February 2010, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48171/2806-value-breakdown-offshore-wind-sector.pdf, last accessed December 2013

Table 2.1 Scoring for each supply chain criterion.

Criterion	Score	Description
UK supply track record	1	No UK supply to date
	2	UK supply but only to projects less than 200MW
	3	One UK-based supplier that has supplied 200MW or more in total
	4	Two or more UK-based suppliers that have supplied 200MW or more in total
Market readiness of suppliers for commercial scale projects	1	Investment plans are not in existence or are at an early stage
	2	Companies have investment plans that are pending final investment decision that would enable them to supply a 500MW wind farm or larger
	3	One company has made the final investment decision on an investment in new capacity that will enable it to supply a 500MW wind farm or larger
	4	Two or more companies have made the final investment decision on an investment in new capacity that will enable them to supply a 300MW wind farm or larger
Investment risk	1	Investments in the UK can only be made with long-term confidence in the offshore wind market and with public sector financial support
	2	Investments in the UK needs long-term confidence in the market
	3	Investment in the UK can be triggered by a framework contract or two or more orders of500MW or more
	4	Investment in the UK can be made with a single order of 500MW of more
Logic of UK supply	1	There is no significant logic for UK supply for UK projects
	2	There is a limited logic for UK supply for UK projects
	3	There is a good logic for UK supply for UK projects
	4	There is strong logic for UK supply for UK projects
Availability of UK expertise	1	The UK has no significant industrial expertise
	2	The UK has relevant industrial expertise but is unlikely to be competitive in offshore wind
	3	The UK has strong expertise in relevant parallel sectors but would require a shift in relevant company strategies to enter the offshore wind market
	4	The UK has world class expertise in sectors analogous to offshore wind that can be readily exploited in offshore wind or is already applying significant expertise to offshore wind
Size of the UK opportunity	1	Size of the UK opportunity is <2% of undiscounted lifetime expenditure on a wind farm at current prices
	2	Size of the UK opportunity is 2 to<4% of undiscounted lifetime expenditure on a wind farm at current prices
	3	Size of the UK opportunity is 4 to<6% of undiscounted lifetime expenditure on a wind farm at current prices
	4	Size of the UK opportunity is ≥6% of undiscounted lifetime expenditure on a wind farm at current prices

Table 2.2 Definitions of terms used for cost breakdowns.

Cost	Definition
Labour	Direct and indirect labour of suppliers that could realistically be in the UK given appropriate industry and market conditions.
Materials	Raw materials, steel, components, consumables including fuel, equipment, plant and buildings and non-UK labour associated with their supply.
Other	Services, rent, insurance and any remaining costs.

With an understanding of the total expenditure on Labour, Materials and Other for each subelement, and an assessment of the first five criteria described above, the potential UK expenditure can be estimated, as illustrated in Figure 2.1. The justification for these judgements is presented in the discussion of each subelement.

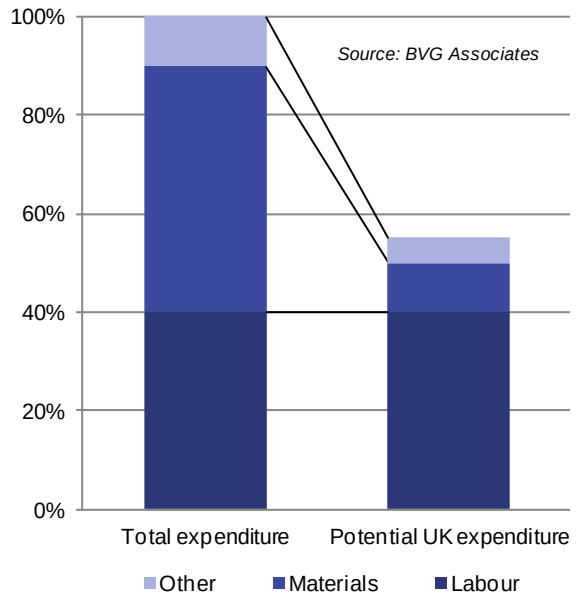

Figure 2.1 Illustrative graph showing the breakdown of subelement expenditure and the potential UK expenditure. The relative size of the opportunity for each subelement is a product of the potential UK expenditure and the percentage of lifetime wind farm expenditure on that subelement.

For each subelement, the size of the UK opportunity is calculated by multiplying the potential UK expenditure with the percentage lifetime cost breakdown shown in

The results of these analyses are expressed in the form of the example table below. The figures are rounded, recognising that the cost breakdowns for wind farms can differ markedly between projects and over time and that the potential UK expenditure used here has been derived relatively simply.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
X%	Y%	X% multiplied by Y%

For each of the elements listed above, the most significant subelements have been identified for further analysis as shown in Figure 2.2. This means that the sum of the percentages of lifetime cost do not add up to 100%. In Figure 2.2, the remaining areas are shown as subelement “other” under each element.

For operational expenditure (OPEX), a 20-year life has been assumed. We understand that some developers are modelling lifetime costs on the basis of an extended life for the wind farm. Where this occurs, the proportion of OPEX in the lifetime expenditure will be higher.

Decommissioning is likely to be a significant cost at the end of a wind farm’s life. The process is likely to have similar supply chain requirements as installation and commissioning; however, since no offshore wind farms have been decommissioned, and the decommissioning of large scale offshore wind farms is not expected for at least 15 years there is a lot of uncertainty about costs and methodologies and so decommissioning is not considered in this analysis.

Lifetime costs are analysed on the basis of 2013 prices and are undiscounted to ensure that the business opportunities throughout the wind farm’s life are given equal weighting.

Full-scale test facilities are discussed to reflect their importance to the development of a UK supply chain. Since the costs will ultimately be reflected in the cost of the components, the costs are not itemised in the breakdown shown in Figure 2.2 and hence the size of the opportunity is not quantified. Although the remaining criteria are discussed, they have not been scored.

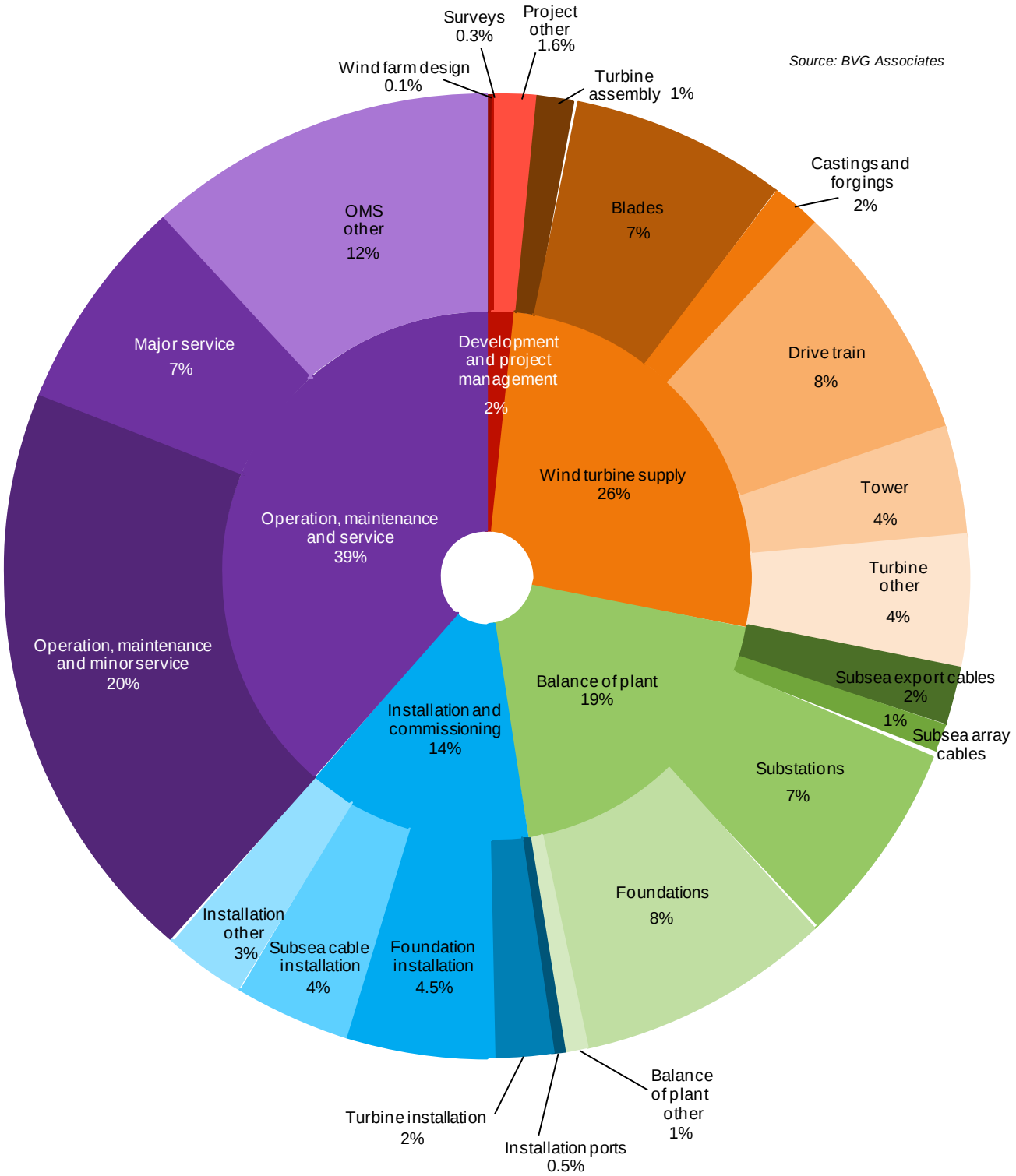

Figure 2.2 Breakdown of undiscounted capital and operational costs of a typical offshore wind farm. These are based on a 500MW wind farm using 6MW turbines and jacket foundations using a combination of real project and modelled data. In some cases percentages have been rounded to fewer significant figures than those in the main text of the report.

3. Development and project management

This section covers the development and project management of the offshore wind farm from the point of signing a lease exclusivity agreement to the construction works completion date. This includes the internal engineering studies and project management work, and managing external contracts for engineering studies, planning applications, environmental impact assessments (EIAs), site investigations, environmental services and construction contract management activities.

Much of the project development and management is undertaken internally by the developer and many of the services may be contracted out to companies in the same country as that of the development team. Most developers have a significant UK presence. Although wind farm design and surveys represent only a small fraction of development and project management expenditure (see Figure 3.1), these are typically contracted out and have therefore been chosen for analysis.

Source: BVG Associates

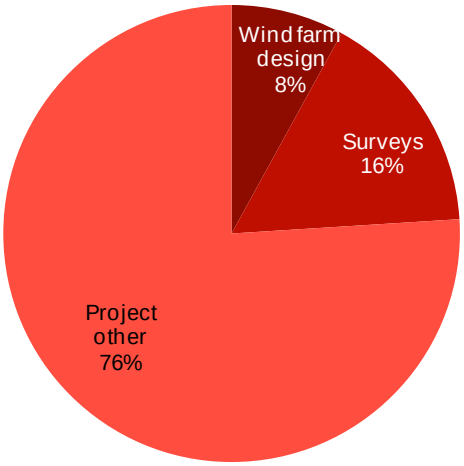

Figure 3.1 Breakdown of project development and management costs.

3.1. Wind farm design

Wind farm layout, support structure choice and design, electrical architecture and installation methods for each element of each wind farm are developed through an iterative engineering process typically taking around two years. The process involves various engineering teams and organisations. Most commonly for utility developers, the initial concept is developed in-house during the pre-front end engineering and design (pre-FEED) stage, also incorporating a constraints analysis and study of wind conditions.

The constraints analysis defines the available areas for development within the lease area, based on the activities of other sea users, such as the shipping and fishing industries, the presence of sea bed infrastructure such as oil and gas pipelines, and telecommunication cables, and geological features such as sand banks.

The study of wind conditions is used to generate an initial turbine array layout, considering basic array shape, spacing and orientation. Detailed design and optimisation occurs during FEED studies that are delivered via a mix of developer in-house expertise and contracted services.

UK supply track record (4)[5]

UK companies have designed most UK wind farms. The UK contribution to the in-house design work of developers is typically high for UK utilities but lower for overseas utilities. UK companies have been successful in supplying UK utilities for several reasons:

- There is a strong presence of specialist wind energy consultancies
- The UK footprint of global high voltage engineering companies is significant
- The growth in industrial scale offshore wind farms started in the UK, giving UK companies a first-mover advantage, and
- Local knowledge and relationships are beneficial.

Market readiness of UK suppliers for commercial scale projects (4)

UK companies have invested in the capacity required for developing Round 3 projects. In general, UK companies have the technical capacity to deliver to commercial scale projects having invested incrementally with the growth of the offshore wind industry. Companies reported that they have had difficulty in recruiting individuals with engineering design skills from the UK. In high voltage engineering, for example, companies have had to recruit globally to meet demand.

UK investment risk (4)

The investment required is primarily in human resource. This can be made incrementally providing that skilled individuals are available. In most cases, notwithstanding any specific skills shortages, recruitment can be matched to demand. Feedback from electrical system suppliers has been that a significant amount of work is requested ahead of contract award. For some Round 3 projects, there may be a number of years between this initial design work and the project final investment decision (FID).

[5] The figure in brackets refers to the score assigned to this criterion, as defined in Table 2.1

Logic of UK supply (4)

Locally based design teams enable close collaboration with the development team. While externally undertaken wind farm design can in theory be undertaken anywhere. In practice, however, a close relationship with developers is considered valuable and this can be sustained best through regular contact.

UK staffs are most likely to be familiar with UK statutory requirements and environmental conditions. Specific UK knowledge is a benefit where there are interfaces with existing infrastructure, either onshore or offshore.

For non-UK projects, there is little benefit for developers to undertake work in the UK. Developers will tend to use in-house teams and established consultancies in their home markets. Nevertheless many UK companies have developed a significant track record which could provide them with a competitive advantage.

Availability of UK expertise (4)

The UK has historical strengths in parallel sectors. The UK companies in these sectors have made the transition to offshore wind as a result of the UK's position as market leader and its long-standing strength in engineering, and marine and offshore services. In particular, companies that previously undertook cable and umbilical route design for the oil and gas industry have been able to make the transition to offshore wind, although the problems that have been associated with cable installation suggest that this process has not been straightforward.

Table 3.1 Synergies of parallel sectors with wind farm design and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	Jee, KBR, Pelagian, Red7 Marine, Red Penguin
Rail	Low	None

Size of the UK opportunity (1)

The cost of wind farm design work has a high labour content. Figure 3.2 shows that the potential UK expenditure is about 90% of total expenditure on wind farm design. For contracts awarded to UK consultancies, the only value that could be generated outside the UK is the acquisition of design tools and consumables. Although it has a big impact on the project, the cost of wind farm design makes a small contribution to the lifetime cost of the wind farm, however, and hence the size of the UK opportunity is correspondingly low.

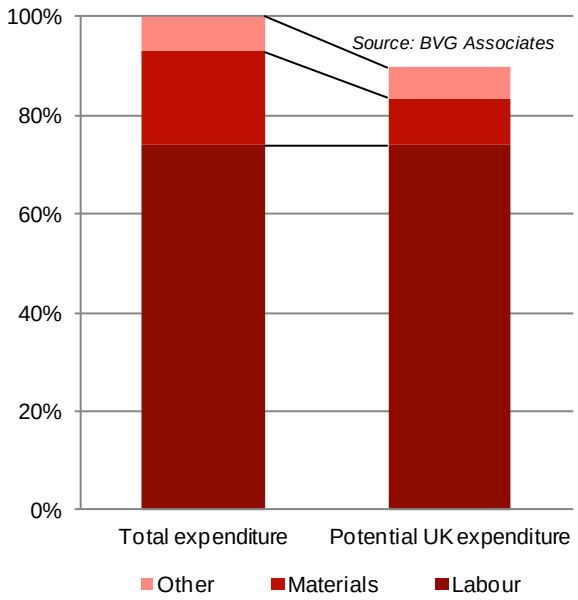

Figure 3.2 Breakdown of total wind farm design expenditure and potential UK expenditure.

Wind farm design forms about 8% of development and project management cost and 0.14% of wind farm lifetime cost. With a potential UK expenditure of 90%, it creates a UK opportunity of 0.12%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
0.14%	90%	0.12%

Summary

Source: BVG Associates

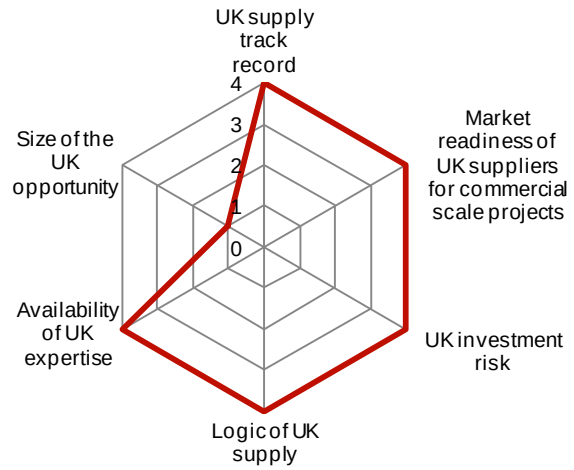

Figure 3.3 Summary of considerations concerning wind farm design.

3.2. Surveys

Surveys account for about one tenth of wind farm development costs and are contracted by the wind farm developer to specialist data acquisition companies. Depending on the survey type, the contract may involve both data collection and analysis, such as geotechnical surveys, or data collection only, where analysis is performed by the developer in-house, for example, metocean data.

Environmental surveys, geotechnical and geophysical sea bed surveys and data collection start five years or more before the planned operation of the wind farm. EIA requirements determine critical path items such as ornithological surveys, where a minimum of two years of data is needed in the UK as part of best practice guidelines developed with input from the regulators and statutory consultees.

Wind resource data is generally captured using meteorological stations. These are generally fixed structures ("met masts") with some use of floating buoys fitted with remote sensing technology (LiDAR). The work is usually contracted as a single package with subcontracts awarded for the design of the station, the mast, foundation, installation and operation.

UK supply track record (4)

UK companies are among the market leaders in undertaking survey work for UK wind farms. UK companies have benefitted from the pre-eminence of the UK offshore wind market (see Table 3.3).

Market readiness of UK suppliers for commercial scale projects (4)

Investments have been made to provide the necessary capacity. For later Round 2 and Round 3 projects located further from shore, the need is for ocean going survey vessels and a concern from developers has been that this has not always been reflected in the choice of vessels included in the bids from UK contractors. Leading suppliers such as Fugro and Gardline have made suitable investments.

UK investment risk (3)

Suppliers will make investments if they have a pipeline of future work. Investments in vessels are smaller than required for installation activities. They may involve significant conversions such as Gardline's conversion of the Ocean Reliance in 2012, which took three years, or the upgrading of offshore installation support vessels to add surveying capacity, which could take six months. In both cases, the investment is unlikely to be borne by a single project.

For wildlife surveys, the vessel requirements are less exacting than for site investigation work and significant investments in new capacity for the industry as a whole are unnecessary, even for work far from shore. Increasingly bird surveys are being undertaken using light aircraft that are widely available.

Logic of UK supply (3)

For environmental surveys UK companies have an advantage. Developers benefit from suppliers with a knowledge of the local environment and the local availability of suitable vessels and teams of staff.

For met mast supply to UK projects, there are benefits in awarding the main contract to UK suppliers but there is no significant advantage for UK suppliers in winning subcontracts for the mast, foundation and installation. As the use of floating LiDAR increases, due to the lower cost of deployment, the logic of local supply increases. UK companies have also been at the forefront of the development of floating LiDAR for wind resource measurement.

Availability of UK expertise (4)

The UK has a long-standing strength in offshore surveying. This comes from the involvement of companies such as Calecore, Fugro, Gardline and Wood Group Kenny in oil and gas and other marine operations. As Table 3.3 shows, a significant number of UK survey companies are already active in the offshore wind industry.

UK shipyards are well placed to undertake vessel modifications. Several UK shipyards have the competitive expertise to undertake survey ship modifications, including Cammell Laird, Dunston and Harland and Wolff.

Table 3.2 Synergies of parallel sectors with surveys and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	Calecore, Fugro, Gardline, Wood Group Kenny
Rail	Low	None

Size of the UK opportunity (1)

Although many of the main survey vessels used will not have a UK origin, the potential UK expenditure on a given supply contract is high. Figure 3.4 incorporates the fact that although many of the vessels (classified as "other") will have originally been constructed overseas, their modification can be undertaken in the UK.

Overall, the potential UK expenditure is about 70% of total expenditure on surveys but because the subelement represents a small part of lifetime wind farm cost, surveys provide a small opportunity for the UK.

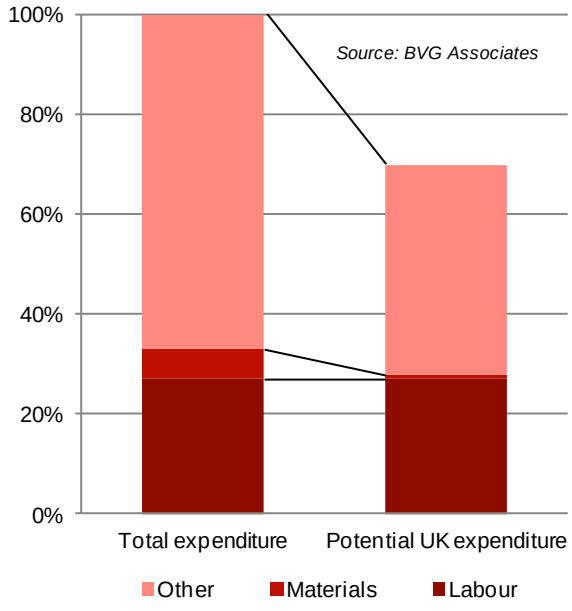

Figure 3.4 Breakdown of total survey expenditure and potential UK expenditure.

Surveys form about 16% of development and project management cost and 0.2% of lifetime cost. With a potential UK expenditure of 70%, it creates a UK opportunity of 0.15%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
0.30%	70%	0.2%

Summary

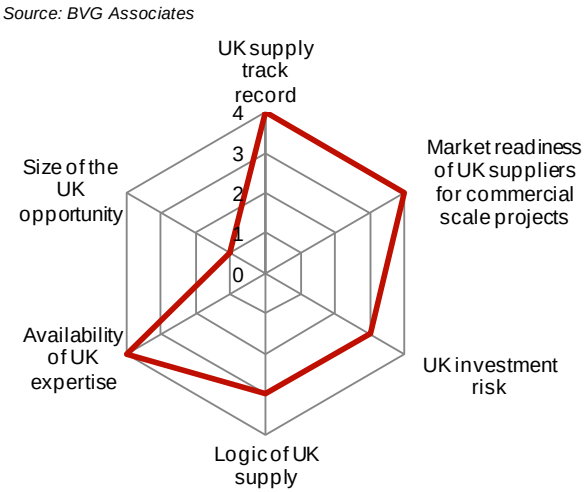

Figure 3.5 Summary of considerations concerning surveys.

Table 3.3 Summary of conclusions on wind farm design and surveys.

Criterion	Wind farm design	Surveys
UK proven expertise (supplied greater than 200MW equivalent)	Wind farm array design: Garrad Hassan, Natural Power, RES, Sgurr Foundation design: Atkins, Garrad Hassan, Ramboll UK Cable route: Intertek, Pelagian, Royal HaskoningDHV Power system: ABB, Alstom Grid, Siemens Energy Transmission Substation design: Atkins, Wood Group Kenny Installation engineering: Jee, K2 Management, ODE, Red Penguin In house capacity within developers and other suppliers	Benthic and pelagic: ESS Ecology, Fugro, Gardline Coastal processes: ABPMer, HR Wallingford Geotechnical and geophysical: Calecore, Coastline Surveys, Fugro, Gardline Met masts: Kona, Radius Tech, SeaRoc, SLP Engineering, Wood Group Kenny Onshore: Apem, ESS Ecology, Thomson Ecology Ornithological: Apem, ESS Ecology, HiDef, Thomson Ecology Sea mammal: ESS Ecology, Fugro, Gardline
Additional future UK expertise	Incremental investment by existing suppliers; new suppliers of specific design services	New investment by existing suppliers; further entrants from parallel sectors
UK supply track record	UK companies have designed most UK wind farms	UK companies are among the market leaders in undertaking survey work for UK wind farms
Market readiness of UK suppliers for commercial scale projects	UK companies have invested in the capacity required for developing Round 3 projects	Investments have been made to provide the necessary capacity
UK investment risk	The investment required is primarily in human resource	Suppliers will make investments if they have a pipeline of future work
Logic of UK supply	Locally based design teams enable close collaboration with the development team UK staff are most likely to be familiar with UK statutory requirements and environmental conditions For non-UK projects, there is little incentive for developers to undertake work in the UK	For environmental surveys UK companies have an advantage
Availability of UK expertise	The UK has historical strengths in parallel sectors	The UK has a long-standing strength in offshore surveying UK shipyards are well placed to undertake vessel modifications
Size of the UK opportunity	The cost of wind farm design work has a high labour content	Although many of the main survey vessels used will not have a UK origin, the potential UK expenditure for a given supply contract is high

4. Turbine supply

Turbine supply involves the manufacture, assembly and system-level functional test of all electrical and mechanical components and systems that make up a wind turbine, including the nacelle, rotor and normally the tower.

The wind turbine manufacturer is a system integrator, designing the overall system and many components, then assembling the components, which it may manufacture in-house or source from others.

The nacelle components typically include the nacelle bedplate, drive train, power take-off, control system, yaw system, yaw bearing, nacelle auxiliary systems and fasteners, housed within the nacelle cover.

The rotor components include the blades, hub casting, blade bearings, pitch system, hub cover (spinner), rotor auxiliary systems, fabricated steel components and fasteners.

The tower components generally include steel, personnel access and survival equipment, any tuned damper, electrical system, tower internal lighting and fasteners.

Of the turbine components, this section will focus on the following, most significant areas:

Turbine nacelle assembly. This involves the completed product, including whole system design, assembly and system-level functional test of all of the items below.

Blades. Almost all blades for current offshore wind turbines are currently manufactured in-house by wind turbine manufacturers. As the final assembly of blades to the rest of the turbine only happens at the installation port or on the wind farm site and the transport of blades is a significant consideration, it is relevant to consider blade manufacture as distinct from turbine nacelle assembly and other main component manufacture. It can be carried out efficiently at a separate coastal location.

Castings and forgings. These items include the hub, main shaft (where used), main frame (in some cases), gearbox casings (where used), forged rings for bearings, gears (where used) and tower flanges.

Drive train. This includes gearboxes, large bearings and direct drive generators. All offshore turbines installed in commercial projects to date use gearboxes, but there is a strong trend towards the use of low-ratio gearboxes coupled with mid-speed generators or direct-drive (gearless) drive trains.

Bearings are used in the gearbox as well as in nacelle and hub sub-assemblies.

Towers. As for blades, towers need not meet other turbine components until they reach the offshore site, so they can be manufactured at a separate location. Again, logistics become critical for very large offshore designs, requiring a move to coastal manufacture. In some onshore markets, towers have been procured by the developer (to the turbine manufacturer's design), but the pattern offshore currently remains for the wind turbine manufacturer to source supply against their own design.

Turbine other. This comprises a significant number of nacelle components and includes large items such as nacelle and hub covers, transformer, main electrical panels, control panels, on-board cranes and smaller component such as auxiliary heating and cooling systems and anemometry.

The installation of turbines, including the work undertaken by turbine manufacturers is considered in Section 6.4.

A breakdown of turbine supply costs in shown in Figure 4.1.

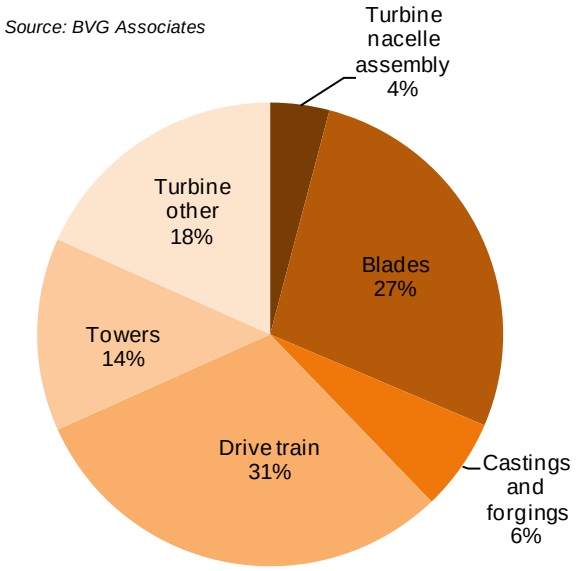

Figure 4.1 Breakdown of turbine supply costs. Based on a 6MW turbine with 147m rotor

4.1. Turbine nacelle assembly

This section will consider the UK's capability and opportunity to undertake nacelle assembly.

UK supply track record (2)

Turbines of up to 2MW have been assembled in the UK. Vestas assembled in the UK the 30 V80 2MW turbines for the Scroby Sands Offshore Wind Farm in 2004 and previously series-assembled sub-MW turbines for the onshore market. No turbines greater than 2MW have been assembled in the UK since those for Scroby Sands and it is unlikely that any UK-headquartered companies will enter the market as a new wind turbine manufacturer.

Market readiness of UK suppliers for commercial scale projects (2)

Several overseas wind turbine manufacturers have developed plans for UK integrated manufacturing and installation facilities. These include the potential

investments by Samsung Heavy Industries (SHI) in Methil and Siemens Wind Power in Hull. Areva Wind, Gamesa and Mitsubishi Heavy Industries (MHI) have also made public announcements of their interest in UK manufacturing, although it is not known how MHI's joint venture with Vestas, announced in September 2013, will affect its plans. Areva and Gamesa also announced a joint venture in January 2014 which will have implications for their investment plans. In order to commit to these investments, manufacturers need firm early orders and greater clarity on Government commitment to the industry beyond 2020.

UK investment risk (1)

The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry. The size of the next generation turbine means that new, sufficiently large waterside locations are needed to enable efficient logistics. To provide such facilities in the UK requires investment and a commitment to the long leases sought by the owners of suitable port sites, which are mainly private companies. The extent to which these hurdles prevent locating in the UK depends largely on confidence in market volume, the relative advantages in logistics and flexible labour market and the level of public sector support.

Investment in new UK turbine nacelle assembly facilities is a strategic decision for a manufacturer. The decision has long-term significance. In the future UK and European market projected in this study, some of the demand can be met from existing facilities used for the onshore and offshore markets or from those with funding committed. Although existing nacelle assembly facilities, such as those of Siemens Wind Power and Vestas at Lindø on Denmark's east coast, are primarily for use in assembling prototype and early series turbine assembly, and not ideally located or capable of efficiently handling the larger turbines, they can be used to serve current market demand temporarily and so delay investment decisions in new facilities if growth in demand is low. In making an investment decision, turbine manufacturers are sensitive to political support. Several manufacturers have overseas facilities from which they can supply the UK market and a decision to invest in the UK is not a simple equation. The location of assembly also opens the potential of associated investment, possibly with a partner in drive train components, blades and towers.

Logic of UK supply (3)

Nacelle assembly with waterside access enables nacelles to be transported directly from quayside to wind farm site. In the projection used for this study, the UK market will remain the largest European market lead and so locating a turbine assembly in the UK is a logical choice for a new investment, despite some higher UK site costs, because of lower logistics costs and project risks. Our analysis shows that a UK east coast integrated manufacturing facility has the potential to save up to £14 million on total turbine logistics costs for every GW installed in the four main UK Round 3 zones in the North Sea compared with a similar facility in Continental Europe.

A UK nacelle assembly facility is especially politically attractive. While nacelle assembly is a small part of total turbine cost, the presence of a nacelle assembly facility is politically desirable as the import of turbines from elsewhere is highly visible. From experience elsewhere, coupled with the right local support, it also has a significant impact on the eventual local manufacture of a range of nacelle components.

Land is available that allows component manufacturing to co-locate with nacelle assembly activity. Locations that enable clustering are expected to encourage greater levels of engagement and collaboration between companies and attract additional funding and resources. Co-location can also enable the efficient use of new facilities and lower handling and transport costs.

Availability of UK expertise (3)

The UK has a good track record of efficient final assembly in parallel sectors. Similar types of assembly are undertaken in the UK particularly in rail, aerospace and low-volume automotive. There are examples of wind turbine manufacturers with significant rail operations. Alstom Transport has UK rail manufacturing and Hitachi has committed investment to a new rail manufacturing facility near Durham. Low volume automotive manufacturing is undertaken in the UK by Caterpillar and JCB and aircraft large component assembly by Airbus and Bombardier.

These specific operations demonstrate the availability of expertise in the UK but are likely to have little direct significance to offshore wind turbine nacelle assembly.

Table 4.1 Synergies of parallel sectors with turbine nacelle assembly and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Medium	None
Automotive	Medium	None
Composites	Medium	None
Nuclear	Low	None
Oil and gas	Low	None
Rail	Medium	None

The UK has a good track record in research, development and demonstration (RD&D). An example is the National Composites Centre which has links with the

aerospace industry and includes Vestas among its members.

Size of the UK opportunity (1)

A high proportion of nacelle assembly cost is Labour. There is a significant expenditure on Labour by turbine manufacturers and their main suppliers that could be located in the UK (see Figure 4.2).

A UK nacelle assembly facility opens up further UK component supply. The size of the UK opportunity for nacelle assembly alone is small (see Figure 4.1); however, UK assembly presents a significant opportunity from the supply of a large number of components that fall into the "turbine other" category.

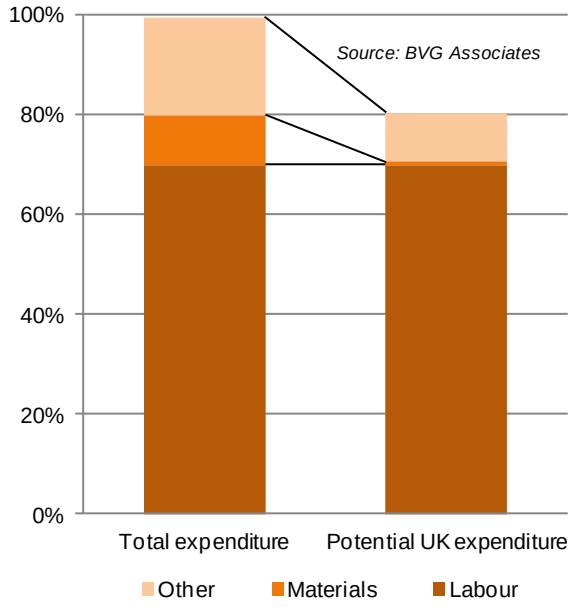

Figure 4.2 Typical breakdown of total turbine nacelle assembly expenditure and potential UK expenditure.

Turbine nacelle assembly forms about 4% of turbine supply cost and 1.0% of wind farm lifetime cost. With a potential UK expenditure of 80%, it creates a UK opportunity of 0.8%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
1.0%	80%	0.8%

Summary

Source: BVG Associates

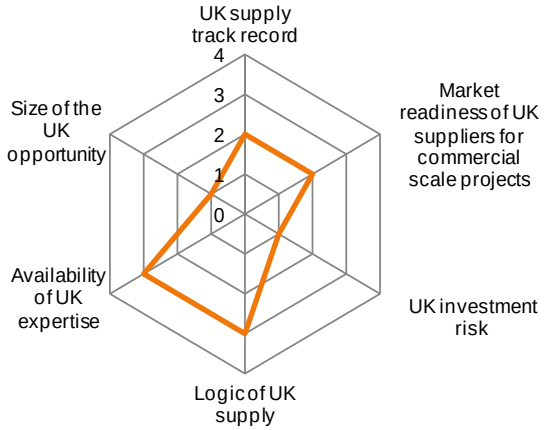

Figure 4.3 Summary of considerations concerning turbine nacelle assembly.

4.2. Blades

Blades are manufactured and then brought together with the nacelle and tower during installation. About 60% of blades for the global wind industry are manufactured in-house by turbine manufacturers and this fraction is higher still for offshore wind. All blades used on Areva, Siemens and Vestas turbines offshore have been manufactured in house. Of the key players, only Senvion (formerly Repower) has purchased blades from an external supplier, the global market leader in independent blade supply, LM Wind Power, although it has also developed in-house capacity through its PowerBlades subsidiary.

This trend for in-house supply will change with the new entrants to the offshore wind turbine market. Alstom Power has an agreement with LM Wind Power to manufacture blades at Cherbourg, France. Euros has supplied blades for the MHI Sea Angel prototype and plans to build series production facilities at Rostock, Germany. Gamesa and SHI may also outsource at least some of their blade supply. There are a number of independent blade manufacturers, though only the market leader LM Wind Power has significant experience with the largest of blades for offshore wind. Smaller suppliers with interesting technology may be acquired by turbine manufacturers seeking to take benefit of such technology whilst managing risk. .

UK supply track record (1)

Blades for the onshore market have been manufactured in the UK. Vestas manufactured MW-scale blades on the Isle of Wight for export until 2009. In closing the facility, Vestas extended its technology presence on the island, and established its global R&D centre for rotor technology in UK. Here it is manufacturing 80m prototype blades for the V164 turbine and is able to series manufacture low volumes.

The UK has supplied composites materials to the wind industry. This primarily meets the demand from the aerospace, automotive and boatbuilding industry but there is some supply to the wind industry. For example, PPG Industries and Gurit provide materials for blades manufactured overseas.

Market readiness of UK suppliers for commercial scale projects (1)

Turbine manufacturers and independent blade suppliers have developed plans for UK blade manufacture. For turbine manufacturers, a UK blade manufacturing facility may either be part of a larger investment in an integrated manufacturing facility or a stand-alone investment that addresses the logistics challenges of manufacturing and transporting blades from its existing non-coastal facilities on the continent. An independent blade supplier may look to locate close to key customers, as LM Wind Power plans to with Alstom Power in France, but it will also be mindful of the opportunity to supply additional turbine manufacturers.

The lead time from an investment decision on a site with planning consent to an operating factory is about two years so there remains just sufficient time for investments to be made so that facilities are ready for the projected increase in the UK market in 2017.

UK investment risk (2)

Investment in a new blade manufacturing facility is a strategic decision for a manufacturer. The long-term decision is similar to that for nacelle assembly.

Independent manufacturers can supply more than one customer. By supplying more than one wind turbine manufacturer albeit probably with a different product, the investment risk is reduced.

The onshore wind market can also be supplied from new coastal facilities. There is currently no UK blade manufacture for the onshore market which is expected to require a further 8GW by 2020. The facilities and workforce required for offshore wind can also be used for smaller onshore blade production provided they are well located for road transportation (unrestricted access to the UK motorway system, ideally close to the “centre of gravity” of the onshore market, so in Northern England.

Logic of UK supply (4)

Blade manufacture as part of an integrated manufacturing facility has logistics benefits. The capacity projection used in this analysis has the UK as the dominant European offshore wind market. UK blade supply therefore offers lower logistics costs and reduces project risks and the probability of damage during transportation.

Well located UK sites are available. Blades do not need to be assembled with other turbine components until at the offshore site. This increases the number of potential sites for blade manufacture.

The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry. The dimensions of the next generation blades mean that new waterside locations are needed that are big enough to manufacture and store significant quantities of blades. To provide such facilities in the UK requires investment and the owners of suitable port sites, which are mainly private companies, want long leases if they are to displace their existing customers or develop new facilities.

Availability of UK expertise (4)

The UK has a good track record in other composites sectors. The UK has a track record in onshore blade manufacture and has an established composites supply chain also serving the boat building, aerospace and automotive industries. The transition from these sectors is not straightforward. Cost is a bigger driver in offshore wind than in sectors such as aerospace and high end automotive, where weight and performance have resulted in the widespread use of carbon fibre. The same is also true of parts of the marine sector. For example, Portsmouth-based Magma Structures has manufactured carbon fibre masts over 60m for the “superyacht” sector. Composites expertise in the oil and gas industry can be applied in the manufacture of walkways and in blast protection

Table 4.2 Synergies of parallel sectors with blades and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Medium	None
Automotive	Medium	None
Composites	High	Gurit, PPG Industries
Nuclear	Low	None
Oil and gas	Medium	None
Rail	Low	None

Size of the UK opportunity (2)

A high proportion of blade expenditure is available to UK suppliers. Given the presence of a significant composites supply chain, the potential UK expenditure is about half of total cost, made up of all Labour, most Materials and a significant part of Other cost (see Figure 4.4). The potential UK expenditure is about 50%.

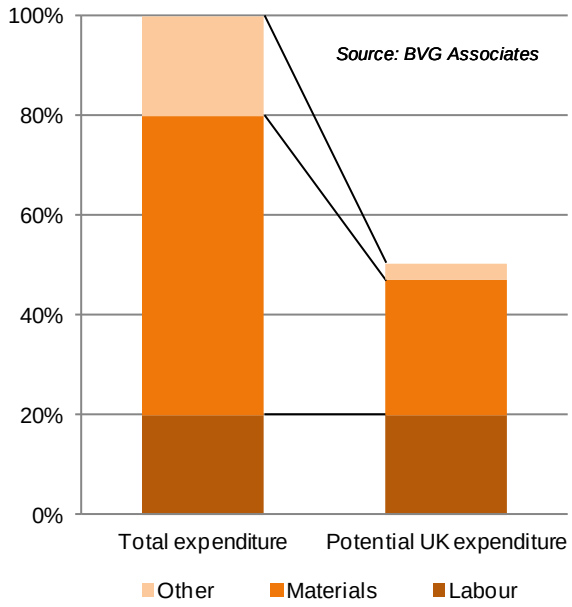

Figure 4.4 Typical breakdown of total blade supply expenditure and potential UK expenditure.

Blades form about 27% of turbine supply cost and 7.3% of wind farm lifetime cost. With a potential UK expenditure of 50%, they create a UK opportunity of 3.6%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
7.3%	50%	3.6%

Summary

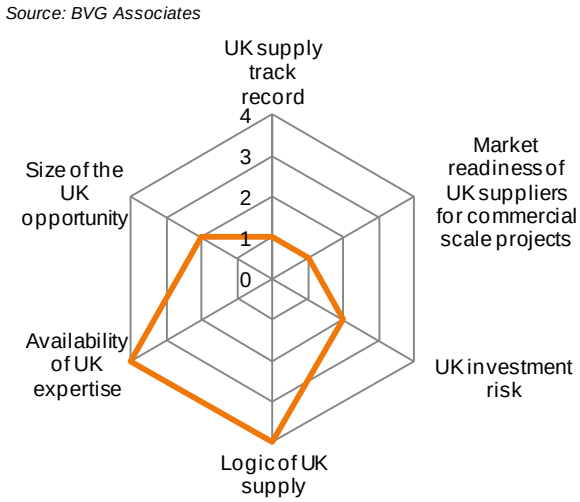

Figure 4.5 Summary of considerations concerning blades.

4.3. Castings and forgings

Spheroid graphite iron castings are used for the following components:

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

Steel forgings have greater strength and ductility than cast iron and can be reliably welded. They are used in the following components:

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

The challenge for a supplier is to produce the larger components for the next generation of turbines, if the products cannot be produced within its existing production facilities, and produce them in sufficient volume.

UK supply track record (2)

There is currently no serial manufacture of large castings or forgings for the wind industry in the UK. David Brown Wind UK sourced the castings for their gearbox test rig and the casing for the prototype gearboxes from Coupe Foundry in Preston for SHI's 7MW turbine.

Market readiness of UK suppliers for commercial scale projects (1)

Foundry investment plans are at an early stage. Some plans have been developed for investments in new UK foundry output, both by existing UK foundries and inward investors.

Large rings are forged in the UK but for aerospace, not wind. There is reluctance to adapt manufacture to the different quality and quantity requirements of wind due to reduced margins.

UK investment risk (2)

New facilities will need to serve multiple sectors. To justify a new foundry or rolling mill, suppliers need to make a significant investment and serve sectors such as nuclear, oil and gas and low volume automotive as well as offshore wind.

A new facility would need to supply more than one offshore wind customer. Suppliers will need to have confidence they can supply two or more wind turbine manufacturers to enable timely investment. Wind turbine manufacturers will accept their supplier supplying

competitors as it lowers their supply risk and enables increased volumes.

Any investment depends on decisions by wind turbine manufacturers to locate nacelle assembly in the UK. Sourcing from a UK supplier new to offshore wind is a risk for a turbine manufacturer and it is only likely to be considered following investment in a UK nacelle assembly facility. Most forgings would be supplied to a turbine component manufacturer that would also need to have committed to UK supply in order to facilitate reasonable logistics costs.

Logic of UK supply (2)

Large castings and forgings can only be moved by road at low volumes. For the largest products, UK supply to a UK nacelle assembly facility will have logistics benefits, but these are less than for offshore blade and tower supply, where transport on public roads is impractical, particularly in production rates of two or more a week.

Availability of UK expertise (3)

There is low volume supply of iron castings up to 10t for a range of industries. There are a number of companies with relevant experience and strong metals innovation expertise, supplying gearbox and generator housings and products for the aerospace, rail, oil and gas, and construction markets. Russell Ductile Castings can make castings up to 6t and David Brown Wind UK has received an AMSCI offer to support new investment for supply of gearbox casings for the SHI 7MW gearboxes. Coupe Foundry made the 30t casting for David Brown Wind UK's test rig. The challenge for suppliers in parallel sectors is to supply competitively in volume.

Table 4.3 Synergies of parallel sectors with castings and forgings and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	High	None
Automotive	High	Coupe Foundry
Composites	Low	None
Nuclear	Medium	Coupe Foundry
Oil and gas	High	None
Rail	Low	None

Size of the UK opportunity (1)

Manufacture is energy intensive and the Labour content is relatively high. Machining and painting of castings typically take place close to the foundry. The potential UK expenditure for a product is about 60%, capturing the Labour and some of the material and Other costs (see Figure 4.6).

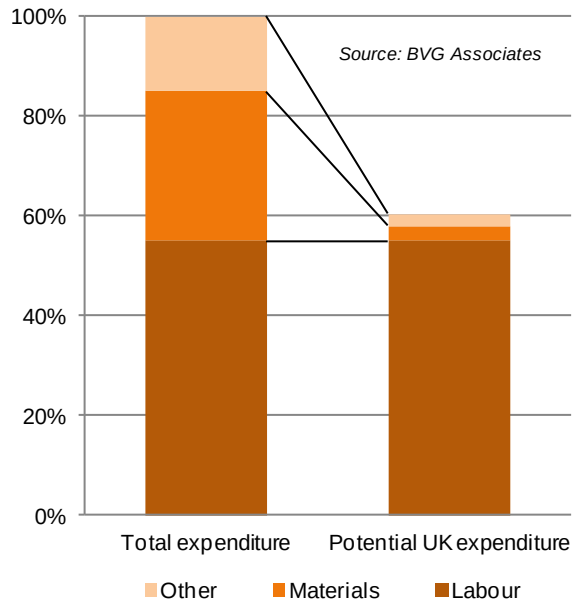

Figure 4.6 Typical breakdown of total castings and forgings supply expenditure and potential UK expenditure.

Castings and forgings form about 6% of turbine cost and 1.7% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 1.1%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
1.7%	60%	1.1%

Summary

Source: BVG Associates

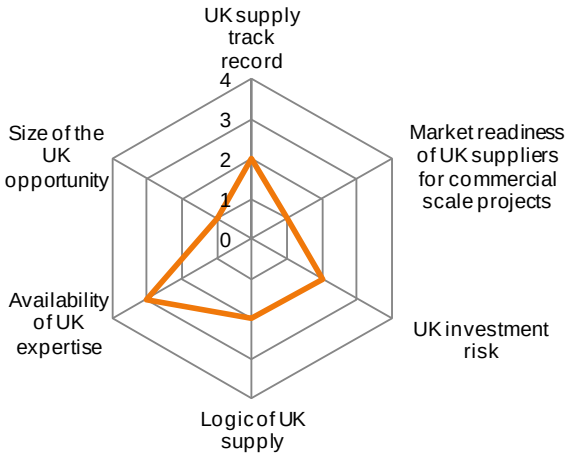

Figure 4.7 Summary of considerations concerning castings and forgings.

Table 4.4 Summary of conclusions on offshore wind turbines, blades, and castings and forgings.

Criterion	Turbine nacelle assembly	Blades	Castings and forgings
UK proven expertise (supplied greater than 200MW equivalent)	None	None	None
Additional future UK expertise	Areva Wind, Gamesa, Mitsubishi Heavy Industries, Samsung Heavy Industries and Siemens Wind have made public announcements of their plans to invest in UK wind turbine assembly facilities	Wind turbine manufacturers and independent blade suppliers such as Blade Dynamics and LM Wind Power	Castings: Bradken, Coupe Foundry, PMT Industries, RGR Foundry, Russell Ductile Castings Forgings: Doncasters, VulcanSFM
UK supply track record	Turbines of up to 2MW have been assembled in the UK	Blades for the onshore market have been manufactured in the UK The UK has supplied composites materials to the wind industry	There is currently no serial manufacture of large castings or forgings for the wind industry in the UK
Market readiness of UK suppliers for commercial scale projects	Several overseas wind turbine manufacturers have developed plans for UK integrated manufacturing and installation facilities	Turbine manufacturers and independent blade suppliers have developed plans for UK blade manufacture	Foundry investment plans are at an early stage Large rings are forged in UK but for aerospace, not wind
UK investment risk	The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry Investment in new UK turbine nacelle assembly facilities is a strategic decision for a manufacturer	Investment in a new blade manufacturing facility is a strategic decision for a manufacturer Independent manufacturers can supply more than one customer The onshore wind market can also be supplied from new coastal facilities	New facilities will need to serve multiple sectors A new facility would need to supply more than one offshore wind customer Any investment depends on decisions by wind turbine manufacturers to locate nacelle assembly in the UK
Logic of UK supply	Nacelle assembly with waterside access enables nacelles to be transported directly from quayside to wind farm site	Blade manufacture as part of an integrated manufacturing facility has logistics benefits	Large castings and forgings can only be moved by road at low volumes

Criterion	Turbine nacelle assembly	Blades	Castings and forgings
	A UK nacelle assembly facility is especially politically attractive Land is available that allows other manufacturing to co-locate with nacelle assembly activity	Well located UK sites are available The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry	
Availability of UK expertise	The UK has a good track record of efficient final assembly in parallel sectors The UK has a good track record in research, development and demonstration	The UK has a good track record in other composites sectors	There is low volume supply of iron castings up to 10t for a range of industries
Size of the UK opportunity	A high proportion of nacelle assembly cost is Labour A UK nacelle assembly facility opens up further UK component supply	A high proportion of blade expenditure is available to UK suppliers	Manufacture is energy intensive and the labour content is relatively high

4.4. Drive train

The drive train consists of the shaft(s), gearbox (if part of the design), generator and converter(s) most of which have different sources of supply.

Almost all of the next generation offshore turbines under development have drive trains that are either mid speed or direct drive. These replace the largely standard drive trains used in most turbines commercially deployed, onshore and offshore, which typically have a high speed three-stage gearbox driving a doubly-fed induction generator running at 1,500 rpm.

This approach has been taken to improve reliability and maintainability for offshore turbines, where turbine downtime and vessel costs can exceed the cost of replacing the large components. Gearbox failures in particular have been high profile and, although faults occur less frequently than for many other turbine components, any main drive train component failure requires significant external intervention. Technical trends have focused on reducing the number of drive train components and driving up reliability through holistic system design and thorough verification. A further innovation is the development of hydraulic drive trains, for example, the UK technology company Artemis was acquired by MHI and its digital displacement transmission is in the MHI prototype next generation turbine.

The diversity of approaches means that drive train technology is increasingly product specific, which has implications for the availability of supply since it takes a long time to establish a new supplier for a bespoke component.

UK supply track record (3)

The UK has significant suppliers of converters and gearboxes to the offshore wind industry. GE Power Conversion is a market leader in the supply of power convertors and large electrical machines. It has also supplied prototype direct-drive and intermediate speed generators at the 6MW-scale for about half of the known offshore wind prototypes. David Brown Wind UK has supplied the gearboxes for SHI's prototype 7MW turbines.

Market readiness of UK suppliers for commercial scale projects (2)

Supply of only small quantities is possible from existing facilities. New waterside facilities for assembly or full manufacture will enable efficient logistics. Plans are in development, but decisions depend on customers' commitments to the market.

UK investment risk (2)

The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry. The scale of the next generation gearboxes and mid speed or direct drive generators make waterside locations adjacent to their customer's nacelle assembly facility particularly desirable, although it is likely to be a lower priority for turbine manufacturers than for towers or blades. To provide such facilities in the UK requires investment and the owners of suitably scaled coastal sites who are mainly private companies seeking long lease lengths. The extent to which this hurdle is a barrier to locating in the UK depends largely on confidence in market volume and the relative advantages in logistics and labour laws compared to other countries.

Investment in new gearbox or generator production facilities is a strategic decision for a manufacturer. The investment risk is high for such large component supply when tied to the success of one turbine manufacturer. Manufacturers would prefer to have more than one wind industry customer but product design is now closely aligned to the specific turbine drive train configuration. Also, gearbox and generator supply is typically a "design win" with manufacturers retaining intellectual property and it is difficult for a new supplier to replace an incumbent.

Logic of UK supply (2)

Drive train components can be moved by road but efficiency is low at high volumes. Given sufficient volume, better efficiency is achieved by their final assembly at a waterside facility co-located with nacelle assembly. David Brown Wind UK has plans for a gearbox assembly facility close to SHI's proposed facility at Methil, Scotland, for example.

The logic of local supply is illustrated by GE Power Conversion's proposed facility at St Nazaire (France) to manufacture its 6MW direct drive generator alongside Alstom Power's new nacelle assembly facility.

We understand that a turbine manufacturer considering a UK nacelle assembly facility would give a priority to the co-location of its generator supplier.

Large coastal land areas are available that allow co-location with nacelle assembly activity. Locations that enable clustering are expected to encourage greater levels of engagement and collaboration between companies and attract additional funding and resources. It can also enable efficient shared use of new facilities such as a quayside and thus improve their investment case.

Availability of UK expertise (3)

The UK has a strong expertise in drive train engineering. In David Brown Wind, Romax and Ricardo, the UK has globally competitive designers of wind turbine drive trains and gearboxes.

Artemis Intelligent Power, acquired by MHI in 2010, has developed a drive train, based on its "Digital Displacement" hydraulic technology. A 7MW offshore version has been rig tested and is scheduled to be erected in a prototype 7MW SeaAngel wind turbine at SSE's Hunterston demonstration site in 2014.

Table 4.5 Synergies of parallel sectors with drive train and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	High	David Brown, Ricardo, Romax
Composites	Low	None
Nuclear	Low	None
Oil and gas	Medium	David Brown, GE Power Conversion
Rail	High	David Brown

The UK has a strong expertise in drive train manufacturing. This is only partially exploited in wind, though there are few suppliers of the scale needed for offshore wind. In addition to supplying generators and converters to the wind industry, GE Power Conversion deploys that same technology competence in supplying motors for the shipbuilding industry, mining, steelmaking, test installations and the oil and gas sector, and generators for hydro generation, marine renewables, offshore oil and gas power supplies, merchant and military shipping and gas turbine power stations.

Size of the UK opportunity (3)

Manufacture of drive train components has a high Labour content. About 50% of the total expenditure is Labour cost. Most Materials and Other expenditure is unlikely to be in the UK and the overall potential UK expenditure is about 60%, although this depends on the level of automation in the factory (and hence labour content).

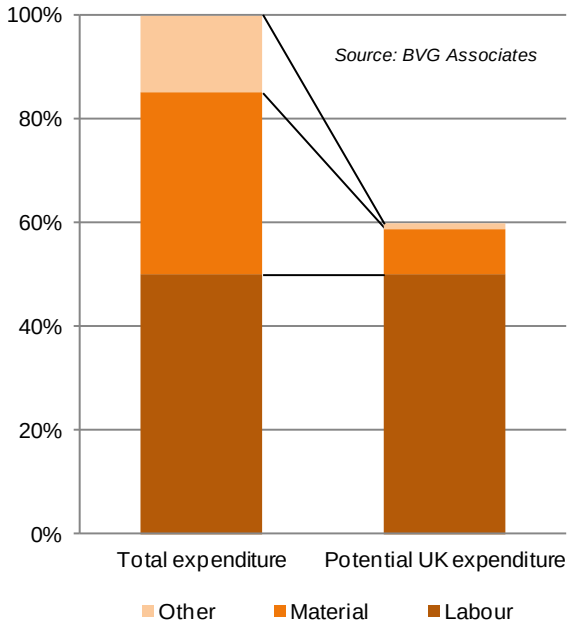

Figure 4.8 Typical breakdown of total drive train component expenditure and potential UK expenditure.

Drive train components account for about 31% of turbine supply cost and 8.2% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 4.9%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
8.2%	60%	4.9%

Summary

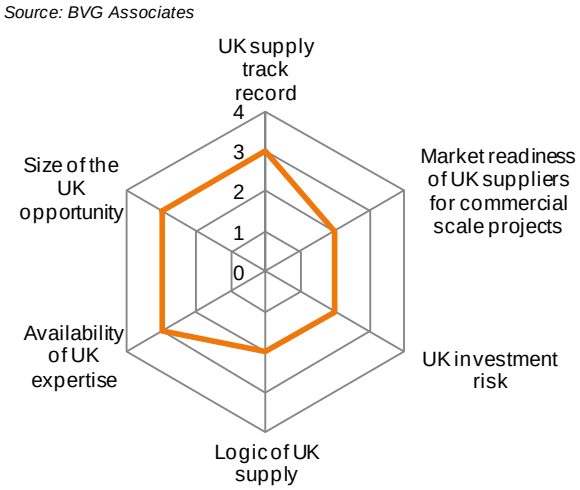

Figure 4.9 Summary of considerations concerning the drive train.

4.5. Tower

All offshore turbines towers installed to date are tapered tubular steel structures, as mainly used onshore. These are manufactured by rolling sheet steel into tapered cylindrical cans, which are welded together to form tubular sections of length typically 30 to 40m. Flanges are welded to each end of these before they are shot-blasted and surface-finished inside and out and internal components are installed. Towers, consisting of two or three sections are then generally pre-assembled at the installation port before installation.

For 3-4MW turbines, towers have a base diameter of between 4 and 5m. Larger turbines require longer and larger diameter towers with thicker sections to carry the increased loads and provide the required structural stiffness. Towers for the next generation of turbines will have a base diameter of between 5m and 7.5m. Such an increase in size means that inland production requiring the use of public roads for delivery will not be possible and the towers will need to be manufactured at a waterside facility and loaded directly onto a vessel.

As well as fulfilling its main structural role, the tower also houses electrical switchgear, control panels, personnel access systems and lifting equipment. In some turbines, the transformer and power take-off system may also be in the tower.

Towers are mainly manufactured by independent suppliers.

UK supply track record (2)

The UK has provided towers for the onshore wind market but only in low volume for offshore wind. The UK has two operating tower manufacturing facilities: at Chepstow by Mabey Bridge, and at Campbeltown by Wind Towers Scotland. The Mabey Bridge site has no waterside access and has supplied towers for the onshore wind market and provided pin piles for offshore wind. Wind Towers Scotland has produced a small number of towers for offshore turbines at London Array but is currently constrained by quayside logistics. Tata Steel has supplied steel plate for turbine towers from its UK facilities at Scunthorpe and at Motherwell for both export and domestic markets.

Market readiness of UK suppliers for commercial scale projects (2)

Some tower manufacturers are negotiating with owners of coastal sites but no investment plans have been announced that would enable the supply of offshore towers in large quantity. Any further investment for the offshore market by the UK's two tower suppliers would need to be either at a new coastal location or for quayside access improvements by Wind Towers Scotland and there have been no announcements of such plans. The lead time in factory construction is about two years so there is enough time for investments to be made for facilities to be ready for the projected increase in the UK market in 2017.

UK investment risk (3)

There is a flexible UK labour market in fabrication. UK workers are used to the varying demands of shipbuilding and oil and gas fabrication and UK labour laws enable companies to respond to uneven demand quicker than in some other European countries.

Low margins may deter investment. Towers are considered by some turbine manufacturers as commodity items and fabrication has been associated with low margins, which has been compounded by oversupply for the onshore wind market. Any investment case for a tower manufacturer will need to be focused on supply for offshore wind where there is a limited coastal manufacturing capacity in Europe.

A new tower facility would need to supply more than one offshore wind customer. Suppliers will need to have confidence they can supply two or more wind turbine manufacturers to enable investment. By supplying more than one wind turbine manufacturer, the investment risk for the supplier is reduced. Wind turbine manufacturers will also see value in their supplier supplying other companies as this enables them to benefit from shared learning, greater economies of scale and they have greater assurance that the supplier is more stable financially.

Logic of UK supply (4)

Tower production requires waterside access and there are logistics benefits of a UK location. If the UK remains the dominant market, UK manufacture means lower logistics costs and also lower project risk. A location near a nacelle assembly facility is desirable to reduce logistics costs because towers will be loaded onto the same installation vessel as the nacelle.

Large coastal land areas are available that allow the co-location with nacelle assembly activity. Locations that enable clustering are expected to encourage greater levels of engagement and collaboration between companies and attract additional funding and resources. It can also enable the efficient use of new facilities such as a quayside and thus improve their investment case. Towers do not need to be assembled with other turbine components until loading on to installation vessels with nacelles and blades. This increases the number of potential sites for tower manufacture.

Availability of UK expertise (4)

Fabrication yards exist that can be used or brought back into production. Existing coastal yards are available, making the investment needed relatively low and there are UK companies with the expertise to make towers efficiently.

The UK has engineering and manufacturing skills in metal handling, joining and process design. These are mainly deployed in the oil and gas and construction industries. A significant UK entrant to onshore tower manufacturing is Mabey Bridge, which has diversified from steel bridge construction.

The UK has internationally competitive steel production. Tata Steel Europe is an established supplier of steel to the wind industry.

Table 4.6 Synergies of parallel sectors with towers and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Medium	None
Oil and gas	High	Tata Steel
Rail	Low	None

Size of the UK opportunity (2)

Manufacture has a low labour content and high raw material and tooling costs. The potential UK expenditure is about 60% but this figure can only be achieved if there is UK supply of steel and a significant UK supply of internals such as lifts, platforms and ladders. As a significant contributor to lifetime costs, towers represent a significant UK opportunity.

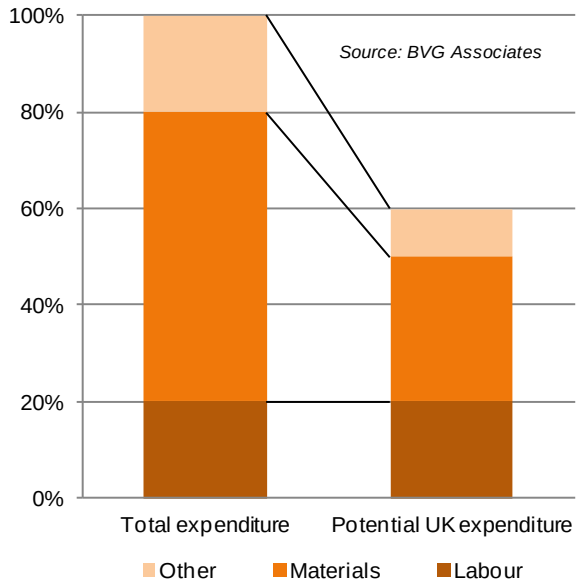

Figure 4.10 Typical breakdown of total tower supply expenditure and potential UK expenditure.

Towers form about 14% of turbine supply cost and 3.5% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 2.1%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
3.5%	60%	2.1%

Summary

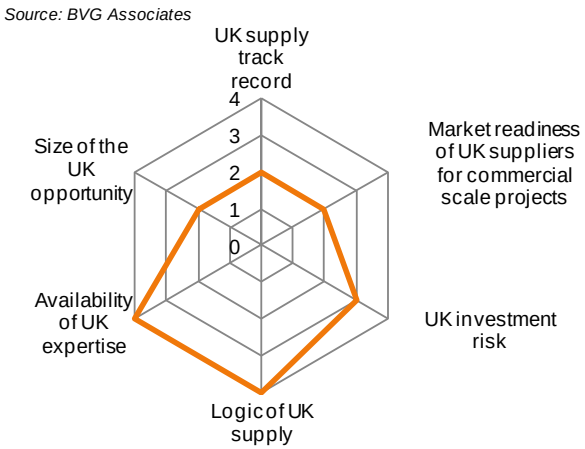

Figure 4.11 Summary of considerations concerning towers.

Table 4.7 Summary of conclusions on drive train and towers.

Criterion	Drive train	Tower
UK proven expertise (supplied greater than 200MW equivalent)	Power convertors: GE Power Conversion	None
Additional future UK expertise	Gearboxes: David Brown Generators: Cummins Generator Technologies, GE Power Conversion Hydraulic transmission: MHI (Artemis) Inward investment by established supplier	Burntisland Fabrications (BiFab), Mabey Bridge, TAG Energy Solutions, Wind Towers Scotland Investment by established supplier
UK supply track record	The UK has significant suppliers of converters and gearboxes to the offshore wind industry	The UK has provided towers for the onshore wind market but only in low volume for offshore wind
Market readiness of UK suppliers for commercial scale projects	Supply of only small quantities is possible from existing facilities	Some tower manufacturers are negotiating with owners of coastal sites but no investment plans have been announced that would enable the supply of offshore towers in large quantity
UK investment risk	The private ownership of many UK waterside facilities may limit their cost-effective availability to the offshore wind industry Investment in new gearbox or generator production facilities is a strategic decision for a manufacturer	There is a flexible UK labour market in fabrication Low margins may deter investment A new tower facility would need to supply more than one offshore wind customer Independent manufacturers can supply more than one customer
Logic of UK supply	Drive train components can be moved by road but efficiency is low at high volumes Large coastal land areas are available that allow co-location with nacelle assembly activity	Tower production requires waterside access and there are logistics benefits of a UK location Large coastal land areas are available that allow the co-location with nacelle assembly activity
Availability of UK expertise	The UK has a strong expertise in drive train engineering The UK has a strong expertise in drive train manufacturing	Fabrication yards exist that can be used or brought back into production The UK has engineering and manufacturing skills in metal handling and joining and process design The UK has internationally competitive steel production
Size of the UK opportunity	Manufacture of drive train components has a high Labour content	Manufacture has a low labour content and high raw material and tooling costs

5. Balance of plant supply

Balance of plant includes all aspects of the supply of cables, turbine foundations, and offshore and onshore substations. Of these, this section will focus on the following, most significant areas:

Subsea cables. Array cables connect turbines to local offshore substations generally at medium voltage (MV). Export cables operate at high voltage (HV) and connect offshore substations to shore and collector stations to HVDC offshore substations. Export cables can either be HV alternating current (HVAC) or HV direct current (HVDC). The supply of export cables (and especially HVDC export cables) is more specialised, so there are fewer suppliers in that market. Subsea export cables and subsea array cables are considered separately.

Definitions of MV and HV vary. For this study, MV is used to describe voltages from 1kV to 69kV and HV is greater than 69kV.

AC and DC substations. Depending on the specific design used, AC systems incorporate HV transformers, reactors, switchgear and associated power electronics, control and auxiliary systems. DC systems also incorporate HVDC converters. Although a number of major suppliers of HV electric components produce both AC and DC equipment, the HVDC market is less mature and is considered separately. An HVDC system will generally have offshore AC collector substations, which receive power from a number of turbine arrays, step up the voltage and feed the offshore HVDC converter substation.

Offshore substation electrical systems are mounted on platforms. The fabrication expertise for these platforms (topsides) exists in the oil and gas sector and foundations for these platforms are usually similar to those of turbines. Far fewer foundations are required compared to the number of turbine foundations so the availability of steelwork fabrication for offshore substation foundations is not considered a concern.

Steel and concrete foundations. Foundations support the turbine above the sea bed. Designs are driven by a combination of wind and wave loading and structural dynamic requirements. Steel monopile foundations currently dominate the market but with larger turbines and with deeper water sites, non-monopile steel foundations such as jackets are increasingly likely to be used. Another material for offshore foundations is concrete. Since the supply issues are distinct, concrete foundations are considered separately here, along with hybrid designs that also have steel structural elements.

There is uncertainty about future technology choices. By 2020, the greater mass and rotor diameter of the next generation of larger turbines, combined with the development of projects in greater water depths, could mean that structural dynamic, 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, large diameter "XL" monopiles, concrete designs and even floating foundations in deeper water sites as these technologies are proven.

In Figure 5.1, the cost breakdown is based on a project using non-monopile steel foundations.

Source: BVG Associates

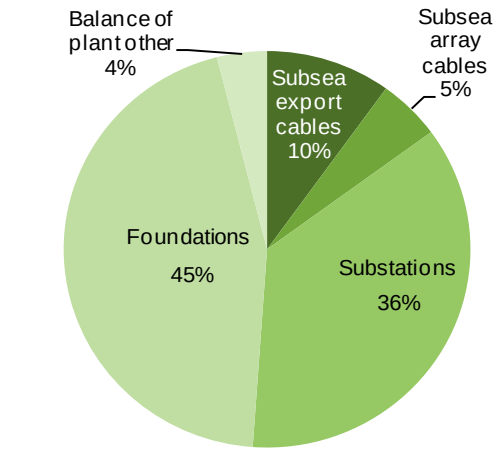

Figure 5.1 Breakdown of balance of plant supply costs.

Installation is considered in Section 6. Similarly, the work undertaken in the OMS of balance of plant is covered in Section 7.

5.1. Subsea array cables

Subsea array cables connect turbines to offshore substations or AC collector substations for a DC grid connection. Almost all array cables used to date have been MVAC cross-linked polyethylene (XLPE) products rated at 33kV.

Array cable supply has usually been contracted separately from installation, but developers are now increasingly looking to combine the supply and install packages to reduce the number of contractual interfaces. Where a supply and install contract is awarded, it is most likely that the main contractor is the cable supplier, most of which have some internal cable-laying expertise. Even if separate packages are awarded, feedback is that developers will make a contractual obligation on suppliers to work together.

An important trend expected to take place over the next 10 years is the large scale adoption of higher voltage array cables. Increasing the voltage of array cables to about 66kV has the potential to reduce electrical losses and preserve the number of turbines in each "string" connected

to the substation as turbine ratings increase. In some circumstances, this innovation also means it becomes cost effective to install turbines on ring circuits from the offshore substation which allows the turbines to continue generating electricity in the event of a single cable or switchgear fault.

UK supply track record (4)

A UK manufacturer has supplied around 40% of array cable length used in UK wind farms up to the end of 2012. JDR Cable Systems (JDR) is the only current UK manufacturer of subsea cables for the offshore wind industry. It supplied around 200km of array cable for both the Greater Gabbard and London Array projects combined, giving JDR about a 40% share in the total length of cable supplied to UK projects. JDR has also been successful also in exporting to the German offshore wind market.

AEI Cables supplied several early UK wind farms from its former Gravesend facility but has since withdrawn from the subsea MV cable market.

The UK has no capacity to manufacture cable cores for subsea cables. Cable cores (conductors) represent about 40% of cable cost. JDR currently imports these from continental Europe.

Market readiness of UK suppliers for commercial scale projects (3)

JDR would need to make further investment to increase capacity and enable the supply of higher voltage array cable. JDR opened its facility in Hartlepool in 2009 and is capable of supplying significant lengths of cable. JDR has invested in R&D activities relating to higher voltage cable but further investment is required to manufacture such cable.

New entrants are considering UK manufacturing options. Feedback was that there are overseas suppliers considering manufacturing cables in the UK. At least one UK manufacturer of oil and gas umbilicals is also believed to be considering the offshore wind array cable market.

UK investment risk (1)

New investments can be made with a pipeline of orders. Feedback was that current order lead times were about nine months for 33kV array cables and the ramp-up time to increase factory capacity was six to eight months, assuming no planning restrictions. Framework agreements between developers and suppliers can provide suppliers with confidence to invest, although the only current known example is that between DONG Energy and Nexans signed in August 2011.

Facilities can be used to manufacture cables for other sectors. Investment risk is reduced as the production capacity used for offshore wind array cables can also be used to serve other sectors, such as umbilical and power cables for oil and gas applications, which are typically associated with higher profit margins.

There is competition for coastal land. Subsea cable manufacturing facilities are typically located on the coast due to the need to transport cables via the sea. As discussed in Section 4, new facilities and extensions of current facilities will compete with alternative users of coastal land.

Logic of UK supply (3)

There is a preference for local supply because of the high logistics costs. Due to the cost of transporting cables, supply from the UK, particularly the east coast, would be logical in a strong, growing market, but manufacturers will be wary of diluting the technical and management expertise at existing facilities in establishing new facilities.

Existing subsea cable manufacturing facilities are based close to areas of high historical demand. There are several factories in the Nordic countries, due to the historical demand for subsea interconnector cables in the region. They are therefore not necessarily well located to serve most offshore wind markets, and the UK in particular. Industry feedback was that transporting cables is costly as it requires specialist vessels.

The UK is an attractive destination for cable manufacturers currently without a European presence. Overseas manufacturers, particularly those in Asia, may seek to set up manufacturing facilities in Europe to avoid the high cost of transporting cables and to gain better access to the UK and European markets. Investment in the UK as the largest market would be a logical decision. Industry feedback was that the market is such that only one manufacturer is likely to make this move.

Availability of UK expertise (3)

The UK has power cable and umbilical manufacturing expertise for other sectors. There is power cable manufacturing capacity at lower voltage for subsea cables (AEI Cables) and for MV and HV onshore cables (Prysmian). Umbilicals are manufactured by Oceaneering and Technip Umbilical Systems (Duco) and these skills can be readily applied to subsea cable manufacture. The oil and gas sector has also sustained UK expertise in cable ancillaries such as terminations and hang-offs.

Table 5.1 Synergies of parallel sectors with subsea array cables and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	JDR Cables, Pipeline Engineering, Tekmar, WT Henley
Rail	Low	None

Size of the UK opportunity (1)

Most of the potential UK expenditure generated in array cable supply lies in core production and cable assembly. Figure 5.2 shows that the Labour cost in cable manufacture is low. Cores are a significant part of the material cost and JDR currently imports these from continental Europe. ”Other” includes factory overheads and much of this is UK supply expenditure. The potential UK expenditure is about 60% and includes the UK supply of cores.

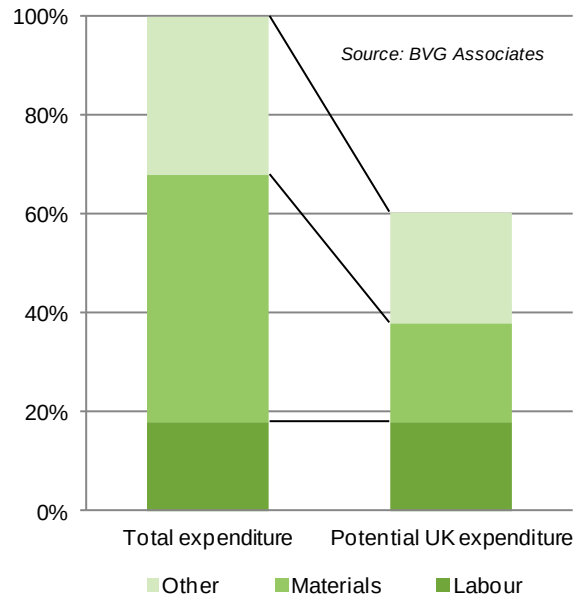

Figure 5.2 Breakdown of total subsea array cable supply expenditure and potential UK expenditure.

Subsea array cables form about 5% of balance of plant cost and 1.0% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 0.6%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
1.0%	60%	0.6%

Summary

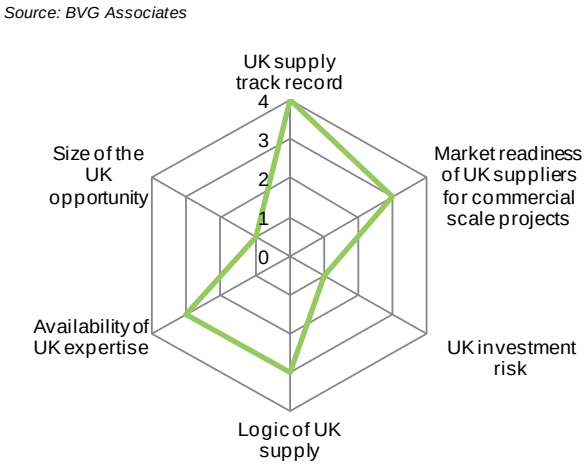

Figure 5.3 Summary of considerations concerning subsea array cables.

5.2. Subsea export cables

Subsea export cables are HV cables that connect the offshore and onshore substations and, for a project using HVDC transmission, that connect the AC collector platforms and the main DC converter platform.

AC export cables have typically been three-core extruded XLPE cables rated between 132kV and 245kV. DC export cables are used for projects located further offshore as HVDC systems allow more power to be carried efficiently by less cable at higher voltages over long distances compared with HVAC systems. HVDC cables can be either extruded XLPE or mass impregnated (MI) designs although all the offshore wind HVDC cables installed to date have been the former. HVDC cables for offshore wind have so far been rated at between 150kV and 320kV.

As with array cables, the supply and installation of export cables has typically been contracted separately. Feedback was that developers were increasingly looking to combine the supply and install packages to reduce the number of contractual interfaces.

UK supply track record (1)

There has been no UK supply of subsea export cables to offshore wind to date. Prysmian has supplied HV underground cables for several offshore wind projects from its facility in Wrexham.

Market readiness of UK suppliers for commercial scale projects (1)

JDR has made steps towards the manufacture of HVAC subsea cables. It has received a £2 million UK Government grant to assist in HV subsea cable development.

New entrants to the offshore wind market are considering UK manufacturing options. Feedback was that there are overseas companies interested in manufacturing cables in the UK and that any inward investment is likely to involve both MV and HV subsea cable supply.

UK investment risk (2)

The lead time for new investments is longer than typical order lead time. The investment lead time for a new factory by an existing supplier is about four years, and about two years for an extension to an existing facility. Investments must therefore be made ahead of confirmed supply contracts for specific projects. As with array cable supply, there is an appetite for investment as long as there is a sufficient pipeline of orders.

Investment costs for an export cable manufacturing facility are higher than for an array cable facility. Although there are plans by UK suppliers and overseas players for UK HV cable production facilities, there are additional costs associated with HV cable manufacturing investment.

The supply of HV cables is constrained and there is less competition in the HV cable market than for the MV cable market. Feedback is that there are long lead times for HV cable supply and limited supply options, with the result that there is demand for new HV cable manufacturing capacity.

There are synergies with the subsea interconnector market. Where expertise for HV XLPE cable manufacture exists, both DC and AC products can be manufactured at the same facility. A UK HV cable factory could be used to supply both the HV interconnector and offshore wind markets, thereby lowering the risk of investment.

There is competition for coastal land. Subsea cable manufacturing facilities are typically located on the coast due to the need to transport cables by sea. This is more important for export cables than for array cables as ideally they need to be transported as single lengths to avoid joints, which are a potential source of failure. As discussed in Section 4, new facilities and extensions of current facilities will compete with alternative uses of coastal land.

Logic of UK supply (4)

A strong UK market will create a preference for UK supply because of the logistics costs. Due to the cost of transporting cables, supply from the UK, particularly the east coast, would be logical in a strong, growing market, but cable manufacturers will be wary of diluting the technical and management expertise at existing facilities in establishing new facilities.

Existing subsea cable manufacturing facilities are based close to areas of high historical demand. There are several factories in the Nordic countries, due to the historical demand for subsea interconnector cables in the region. They are therefore not necessarily well located to serve most offshore wind markets, the UK in particular. Industry feedback was that transporting cables is costly as it requires specialist vessels.

The UK is an attractive destination for cable manufacturers currently without a European presence. Overseas manufacturers, particularly those in Asia, may seek to set up manufacturing facilities in Europe to avoid the high cost of transporting cables and to gain better access to the UK and European markets. Investment in the UK as the largest market would be a logical decision. Industry feedback was that the market is such that only one manufacturer would be likely to make this move.

Availability of UK expertise (3)

The UK has cable manufacturing capacity for other sectors. The UK has cable manufacturing capacity for MV subsea cables, for MV and HV onshore cables, and for oil and gas umbilicals, all relevant to the supply of subsea HV cables.

Table 5.2 Synergies of parallel sectors with subsea export cables and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	Medium	None
Rail	Low	None

Size of the UK opportunity (1)

Most of the potential UK expenditure generated in export cable supply lies in core production and cable assembly. Figure 5.4 shows that the Labour cost in tier 1 cable manufacture is low. Cores are a significant part of the material cost. Other includes factory overheads and much of this will be sourced in the UK. The potential UK expenditure is about 60% and includes the UK supply of cores.

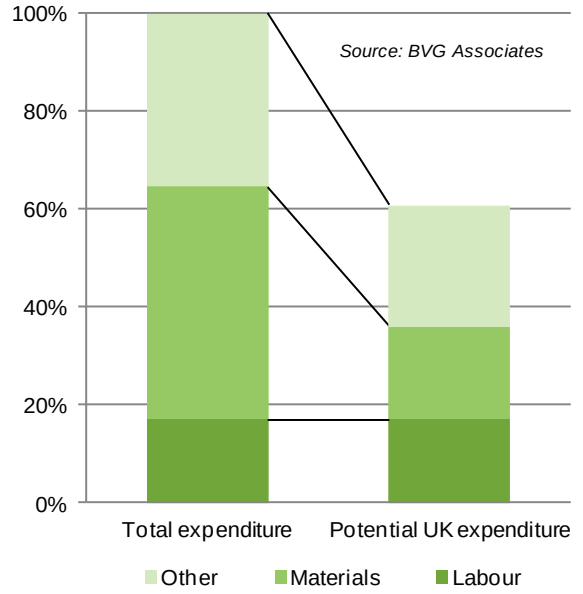

Figure 5.4 Breakdown of total subsea export cable supply expenditure and potential UK expenditure.

Subsea export cables form about 10% of balance of plant cost and 1.9% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 1.1%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
1.9%	60%	1.1%

Summary

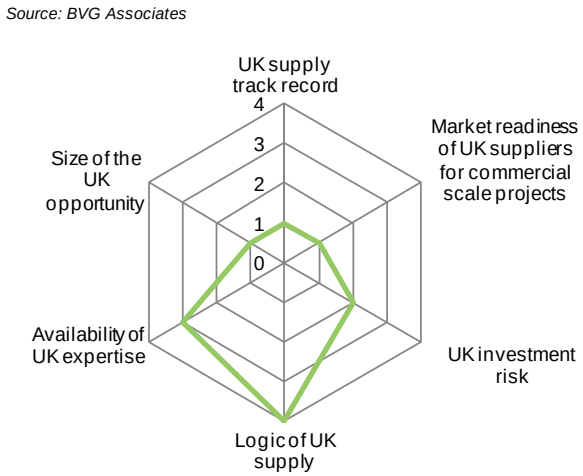

Figure 5.5 Summary of considerations concerning subsea export cables.

Table 5.3 Summary of conclusions on subsea array cables and subsea export cables.

Criterion	Subsea array cables	Subsea export cables
UK proven expertise (supplied greater than 200MW equivalent)	JDR Cable Systems	None
Additional future UK expertise	Oceaneering, Technip Umbilical Systems (Duco) Inward investor	JDR Cable Systems Inward investor
UK supply track record	A UK manufacturer has supplied around 40% of array cable length used in UK wind farms up to the end of 2012 The UK has no capacity to manufacture subsea cable cores	There has been no UK supply of subsea export cables to offshore wind to date
Market readiness of UK suppliers for commercial scale projects	JDR would need to make further investment to increase capacity and enable the supply of higher voltage array cable New entrants are considering UK manufacturing options	JDR has made steps towards the manufacture of HVAC subsea cables New entrants to the offshore wind market are considering UK manufacturing options
UK investment risk	New investments can be made with a pipeline of orders Facilities can be used to manufacture cables for other sectors There is competition for coastal land	The lead time for new investments is longer than typical order lead time Investment costs for an export cable manufacturing facility are higher than for an array cable facility The supply of HV cables is constrained and there is less competition in the HV cable market than for the MV cable market There are synergies with the subsea interconnector market There is competition for coastal land
Logic of UK supply	There is a preference for local supply because of the high logistics costs Existing subsea cable manufacturing facilities are based close to areas of high historical demand The UK is an attractive destination for cable manufacturers currently without a European presence	A strong UK market will create a preference for UK supply because of the logistics costs Existing subsea cable manufacturing facilities are based close to areas of high historical demand The UK is an attractive destination for cable manufacturers currently without a European presence
Availability of UK expertise	The UK has subsea power cable and umbilical manufacturing capacity for other sectors	The UK has cable manufacturing capacity for other sectors
Size of the UK opportunity	Most of the potential UK expenditure generated in array cable supply lies in core production and cable assembly	Most of the potential UK expenditure generated in array cable supply lies in core production and cable assembly

5.3. HVAC substations

With the exception of a small number of early projects that were connected to the grid without offshore substations, commercial UK offshore wind projects completed to date have incorporated one or two offshore HVAC substations and a new, or extended, onshore substation. Substation supply can be divided into the supply of electrical systems and the supply of the structures.

AC electrical systems, onshore and offshore, comprise transformers, reactors switchgear, power electronics, cables within the substation and control and auxiliary systems.

Offshore substation structures include the offshore platform and associated structures for access and accommodation, and the substation foundation. The mass of an HVAC offshore platform is usually between 1,000t and 2,000t. Both monopile and jacket foundations have been used to support these.

Onshore substations for offshore wind farms do not differ significantly from substations for other electrical transmission projects. They can be new substations or extensions to those that already exist. For a commercial scale offshore wind farm, the footprint of the substation may be several hectares and gas-insulated switchgear is generally preferred to air-insulated switchgear as it requires less space.

Most substation supply has been awarded through engineer, procure and construct (EPC) contracts for both onshore and offshore substations. The main exception has been for projects developed by DONG, which has used an in-house engineering team and sourced the electrical and structural components from different sources, effectively providing an in-house EPC service.

UK supply track record (4)

Most HVAC substations installed in the UK have been designed and built in the UK. The UK market has been dominated by Alstom Grid and Siemens Energy Transmission, which both have a significant footprint in the UK, primarily at their Stafford and Manchester sites respectively. Other suppliers are ABB and CG Power, both of which have a significant UK presence.

Electrical components are usually sourced internally by the EPC suppliers from facilities around the world. Components used for offshore wind substations are used for power transmission projects across the world for a range of sectors. In the UK, the main manufacturing capacity is at Alstom Grid's facility at Stafford where HV transformers are produced.

The UK has a good track record of supplying substation platforms and foundations. Most UK projects have used platforms made in the UK by BiFab, Harland and Wolff, Heerema Hartlepool or McNulty Offshore. Where jacket foundations for the substations have been used, BiFab and McNulty Offshore have been among the suppliers.[6]

Currently, the potential UK expenditure on AC electrical substation component supply and fabrication is about 30% for UK projects. For non-UK projects, electrical design work is usually undertaken in the relevant home market, although Siemens Energy Transmission has built its Renewable Energy Engineering Centre in the UK and draws on UK teams for non-UK projects. Harland and Wolff made the jacket foundation for the Bard 1 substation but otherwise no fabrication work for non-UK projects has been undertaken in the UK.

Market readiness of UK suppliers for commercial scale projects (4)

Two suppliers have invested in the UK in anticipation of the offshore wind market growth. In 2012, Siemens Energy Transmission opened its Renewable Energy Engineering Centre, Manchester and has created 200 new jobs. Alstom Grid's Stafford centre has delivered onshore and offshore transmission connections for UK projects such as Sheringham Shoal and Ormonde, as well as four German projects. Both are major suppliers capable of delivery of large projects.

There are potential new UK suppliers of substation platforms and foundation fabrication. There are established facilities on Tyneside (OGN Group), at Nigg, Cromarty Firth (Global Energy Group) and Rosyth (Babcock). Global Energy Group has submitted a planning application for upgrades to the quayside at Nigg, which would be suitable for substation fabrication.[7] Due to the small number of units required, all are capable of delivering for commercial scale projects.

UK investment risk (3)

For the main EPC suppliers, the principal UK investment is in teams of HV electrical engineers. This recruitment can be undertaken incrementally, although suppliers fed back that developers have asked for initial design work as part of the contracting process for Round 3 projects and they have had to commit resource to offshore wind projects with the potential business some years away.

[6] McNulty Offshore went into administration in February 2012 and its yard on Tyneside was acquired by the Port of Tyne.

[7] *£37M development for Nigg Energy Park*, news release by the Global Energy Group. Available online at http://gegroup.com/media-centre/latest-news/37m-development-for-nigg-energy-park, last accessed August 2013

Suppliers of electrical systems reported difficulty in appointing UK nationals as HV electrical engineers, and these have had to be recruited from overseas.

The work undertaken by substation fabricators is similar to that for offshore oil and gas platforms and nuclear power station modules. Any investment in infrastructure, such as that proposed by Global Energy Group at the Nigg Energy Park, can be used for each of these markets.

Logic of UK supply (2)

Offshore wind farm electrical systems are bespoke and suppliers benefit from locating engineering teams close to their customers. Alstom Grid's Stafford facility and the Siemens Renewable Energy Engineering Centre in Manchester are existing centres of excellence. ABB has yet to win a UK offshore wind substation contract, although it was the preferred bidder for Dudgeon before its acquisition by Statoil and Statkraft. ABB has supplied a number of non-UK projects and has a substantial UK footprint which is active in other power sectors.

The UK market is insufficient to stimulate investment in new UK component manufacturing capacity. Component manufacturing investment decisions are based on the global demand for electrical systems or where there are centres of technical excellence. The UK offshore wind market is not large enough to influence suppliers' manufacturing strategy. Even the comparatively large investment in UK infrastructure by National Grid in recent years has had little impact on the UK supply chain.

There are benefits from substation construction close to the wind farm site. Although substation installation is a one-off activity, the process is highly weather dependent and the heavy lift vessels needed for this work are typically more expensive than other installation vessels and double-handling at a local marshalling yard is also inefficient.

Availability of UK expertise (4)

The UK HV engineering sector has traditional strengths in the north west of England. This "M6 corridor" cluster has developed to supply transmission infrastructure for power generation projects and grid infrastructure. As well as the facilities already mentioned, the National Grid High Voltage Research Centre is based at the University of Manchester.

The offshore oil and gas sector has sustained a supply base for offshore platform construction. This provides a strong heavy engineering expertise but its availability to the offshore wind industry depends on the demand from an industry that has, to date, operated with margins higher than offshore wind. The demand from offshore wind is currently more intermittent than oil and gas with the result that wind industry customers may be less valued and suppliers may choose not to tender for some offshore wind projects.

Table 5.4 Synergies of parallel sectors with HVAC substations and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	ABB, Alstom Grid, BiFab, Harland & Wolff, Siemens Energy Transmission, Heerema, Wood Group
Rail	Low	None

Size of the UK opportunity (3)

Apart from some electrical components, most of the components and services can be supplied from the UK. The potential UK expenditure on an HVAC substation is about 70% (see Figure 5.6). This figure is highly dependent on whether a UK fabricator is used for the platform and foundations. Most substation platforms at UK offshore wind farms were built in the UK.

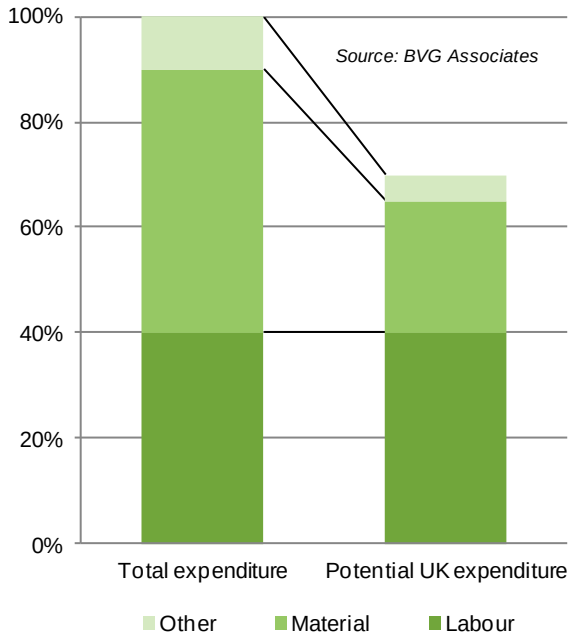

Figure 5.6 Breakdown of total HVAC substation supply expenditure and potential UK expenditure.

For projects using HVAC substations, they form about 37% of balance of plant cost and 7% of wind farm lifetime cost. With a potential UK expenditure of 70%, they create a UK opportunity of 4.9%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
7%	70%	4.9%

Summary

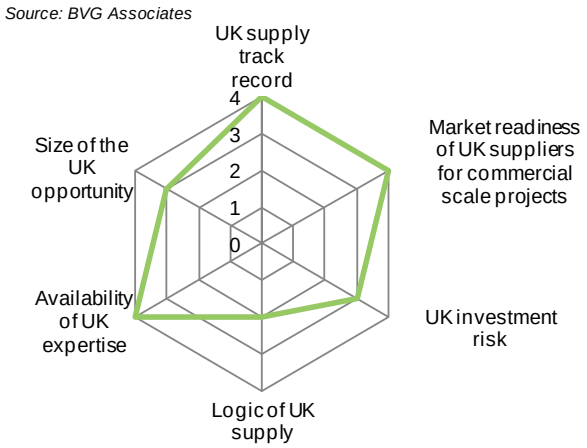

Figure 5.7 Summary of considerations concerning HVAC substations.

5.4. HVDC substations

HVDC systems allow more power to be carried by less cable at higher voltages and with lower electrical losses over long distances, but with higher substation costs compared with HVAC systems. HVDC substations will typically be used for wind farms with grid connections (onshore and offshore) longer than about 80km.

HVDC systems have been in commercial use since the 1950s but the most widely used designs use current source converters (CSC). CSC systems, like HVAC systems, require reactive compensation components, which account for over 40% of the footprint of a substation and preclude the economic use of CSC technology for use in offshore wind farms. Offshore wind farms therefore use the newer voltage source converter (VSC) technology, which was first developed in the early 1990s by ABB. VSC systems have a lower mass and a smaller footprint than CSC systems. There are currently three suppliers: ABB, Alstom Grid and Siemens Energy Transmission.

HVDC substations are bigger than HVAC platforms. For example, the DolWin Alpha 800MW DC offshore substation, fully commissioned in autumn 2013, has a platform mass of 9,300t, about five times the mass of a large HVAC substation platform. Platform fabrication can be undertaken by the suppliers of oil and gas platforms provided they have the space at their facilities.

The onshore substation for an HVDC system using VSC technology comprises a AC-DC converter facility and an AC transformer facility. Although the substation does not have the same requirement for reactive compensation, the area of an HVDC substation is likely to be about 50% larger than a substation for an HVAC system.

UK supply track record (1)

HVDC substations for German projects have been designed in the UK. To date, three HVDC substations have been installed in Europe for the offshore wind industry, none of these in UK. The DolWin Gamma substation will be designed and project managed in Stafford, Alstom Grid's global centre for HVDC.

Substation transformers and converter modules are manufactured in the UK. Alstom Grid has a factory in Stafford that manufactures transformers and VSC modules.

There has been no UK fabrication of HVDC substation platforms and foundations. Suppliers have been limited to Drydocks World in Dubai, Heerema Fabrication Group (from its Zwijndrecht facility in the Netherlands) and Nordic Yards (from its Warnemünde facility in Germany).

There is UK RD&D in DC systems. Alstom Grid's Stafford Research and Technology Centre has an HVDC demonstration facility. GE Power Conversion undertakes RD&D in DC systems considering MVDC arrays and HVDC offshore grids.

Market readiness of UK suppliers for commercial scale projects (3)

There are three UK suppliers with the expertise to supply offshore wind HVDC systems. The three main suppliers (ABB, Alstom Grid and Siemens Energy Transmission) have UK teams to deliver UK offshore wind projects. ABB UK recently delivered the East-West Interconnector between Ireland and the UK which uses VSC technology. All are major suppliers that have the expertise to deliver large projects.

Two suppliers have invested in the UK in anticipation of the growth of the offshore wind market. As well as Siemens' Renewable Energy Engineering centre, Manchester, Alstom Grid's Stafford facility is expanding with the award of the German DolWin 3 substation.

The UK has limited fabrication capacity for HVDC structures. Feedback from industry was that unlike for smaller HVAC structures, only one UK fabricator currently has the capacity to build a HVDC substation structure.

UK investment risk (2)

The European demand for HVDC transmission will be lower than for HVAC. Feedback from suppliers was that future demand from offshore wind would remain at a low level over the next decade and be intermittent, making it difficult to sustain specialist design teams.

Fabricators of HVDC substation platforms have suffered delays and significant cost overruns. For any new entrant to the offshore wind market, there would be a steep learning curve which could deter investment.

Logic of UK supply (2)

Offshore wind farm electrical systems are bespoke and suppliers benefit from locating engineering teams close to their customers. Alstom Grid's Stafford facility and the Siemens Renewable Energy Engineering Centre in Manchester are existing centres of excellence. ABB has yet to win a UK offshore wind substation contract, although it has delivered from the UK the world's largest operational VSC HVDC system (the East-West Interconnector) linking Ireland and the UK which went live in 2013 and so has comparable capacity to that of Siemens Energy Transmission and Alstom Grid.

The UK market is insufficient to stimulate investment in new component manufacturing capacity. Component manufacturing investment decisions are based on the global demand for electrical systems or where there are centres of technical excellence. The UK offshore wind market is not large enough to influence suppliers' manufacturing strategy. While new UK investment in major components such switchgear and transformers is therefore unlikely, the UK's strength in HVDC technology makes it a logical place for investment for specialist components.

There are benefits from substation construction close to the wind farm site. Although substation installation is a one-off activity, the process is highly weather dependent and heavy lift vessels are typically more expensive than other installation vessels.

Availability of UK expertise (3)

The UK HV engineering sector has traditional strengths in the north west of England. A cluster around the "M6 corridor" has developed to supply transmission infrastructure for power generation projects and grid infrastructure.

Facilities with a track record in supplying HVAC substation platforms and foundations will be well placed to win HVDC contracts. Feedback from industry was that a track record in supplying the offshore industry was valued highly.

The offshore oil and gas sector has sustained a supply base for offshore platform construction. This provides strong expertise but its availability to the offshore wind industry depends on the demand from an industry that has operated with margins higher than offshore wind. Babcock, Global Energy Group and OGN Group have expertise in oil and gas platforms which could that could, with investment, be used for HVDC offshore wind substation platform fabrication but the size of facilities needed for HVDC substation structures may limit the application of this expertise.

Table 5.5 Synergies of parallel sectors with HVDC substations and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	None
Rail	Low	None

Size of the UK opportunity (3)

Apart from some electrical components, most of the components and services can be supplied from the UK. The potential UK expenditure on an HVDC substation is about 70% (see Figure 5.8). This figure is highly dependent on whether a UK fabricator is used for the platform and foundations. Most substation platforms at UK offshore wind farms were built in the UK.

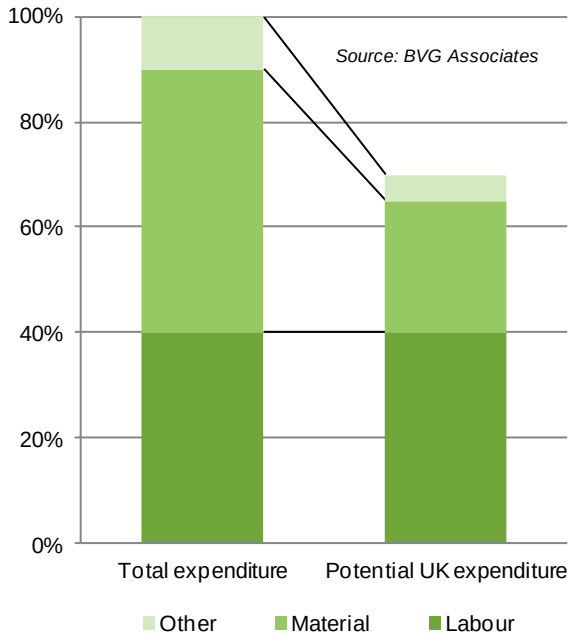

Figure 5.8 Breakdown of total HVDC substation supply expenditure and potential UK expenditure.

For projects using HVDC substations, they form about 37% of balance of plant cost and 7% of wind farm lifetime cost. With a potential UK expenditure of 70%, they create a UK opportunity of 4.9%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
7%	70%	4.9%

Summary

Source: BVG Associates

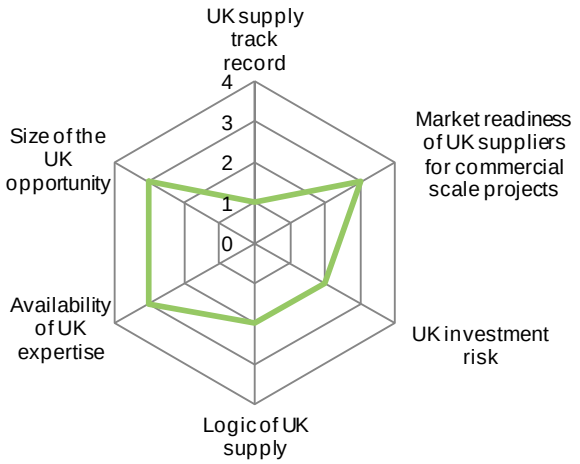

Figure 5.9 Summary of considerations concerning HVDC substations.

Table 5.6 Summary of conclusions on HVAC substations and HVDC substations.

Criterion	HVAC substations	HVDC substations
UK proven expertise (supplied greater than 200MW equivalent)	Electrical systems: Alstom Grid, Siemens Energy Transmission Structures: Harland and Wolff, Heerema, SLP Sembmarine	Electrical systems: None Structures: None
Additional future UK expertise	Electrical systems: ABB, CG Power Structures: Babcock, BiFab, Cammell Laird, Global Energy Group, OGN Group	Electrical systems: ABB, Alstom Grid, Siemens Energy Transmission Structures: Babcock, Global Energy Group, OGN Group
UK supply track record	Most HVAC substations installed in the UK have been designed and built in the UK Electrical components are usually sourced internally by the EPC suppliers from facilities around the world The UK has a good track record of supplying substation platforms and foundations	HVDC substations for German projects have been designed in the UK Substation transformers and converter modules are manufactured in the UK There has been no UK fabrication of HVDC substation platforms and foundations There is UK RD&D in DC systems
Market readiness of UK suppliers for commercial scale projects	Two suppliers have invested in the UK in anticipation of the offshore wind market growth There are potential new UK suppliers of substation platforms and foundation fabrication	There are three UK suppliers with the expertise to supply offshore wind HVDC systems Two suppliers have invested in the UK in anticipation of the growth of the offshore wind market The UK has limited fabrication capacity for HVDC structures
UK investment risk	For the main EPC suppliers, the principal UK investment is in teams of HV electrical engineers The work undertaken by substation fabricators is similar to that for offshore oil and gas platforms and nuclear power station modules	The European demand for HVDC transmission will be lower than for HVAC Fabricators of HVDC substation platforms have suffered delays and significant cost overruns
Logic of UK supply	Offshore wind farm electrical systems are bespoke and suppliers benefit from locating engineering teams close to their customers The UK market is insufficient to stimulate investment in new component manufacturing capacity There are benefits from substation construction close to the wind farm site	Offshore wind farm electrical systems are bespoke and suppliers benefit from locating engineering teams close to their customers The UK market is insufficient to stimulate investment in new component manufacturing capacity There are benefits from substation construction close to the wind farm site
Availability of UK expertise	The UK HV engineering sector has traditional strengths in the north west of England The offshore oil and gas sector has sustained a supply base for offshore platform construction	The UK HV engineering sector has traditional strengths in the north west of England Facilities with a track record in supplying HVAC substation platforms and foundations will be well placed to win HVDC contracts The offshore oil and gas sector has sustained a supply base for offshore platform construction
Size of the UK opportunity	Apart from some electrical components, most of the components and services can be supplied from the UK	Apart from some electrical components, most of the components and services can be supplied from the UK

5.5. Monopile foundations

More than three quarters of installed European offshore wind projects to date have used steel monopile foundations, with most of the remainder using concrete gravity base designs. Monopile technology is tried and tested by the industry for 3MW to 4MW turbines and there is existing manufacturing and installation capacity in the market. Monopiles have now also been used for 6MW turbines, though in relatively shallow water and with relatively small rotors for that rated power.

The most common design has been a cylindrical pile that is first driven into the sea bed, with cylindrical transition piece mounted over it and grouted into position. The purpose of the transition piece is to provide access arrangements (these welded appurtenances would not survive the piling activity) and levelling of the tower base interface. Industry has suffered significant issues relating to the grouted connection and various solutions have since been used. The principle of the monopile foundation itself, however, is proven.

For larger turbines and in deeper water, the cost of monopile supply increases significantly because of the increased steel demand in order to give sufficient stiffness, especially with heavier nacelles and larger, heavier, slow-rotating rotors. Together with the increased installation costs of larger monopiles (see Section 6.2), this means that there is a point at which the total installed cost of using monopiles outweighs the cost of other designs. Previous industry feedback has been that that this tipping point is 30m to 35m water depth for projects using turbines with a rated capacity of 4MW or less and about 20m for turbines with a rated capacity of around 6MW. In the last two years, however, effort has been put in to stretch the envelope of use of monopiles to larger turbines in deeper water. These large monopiles (frequently referred to as “XL monopiles”) have a diameter greater than 7.5m. Recent feedback was the tipping point was now likely to be a water depth of about 35m for turbines with rated capacities 6MW.

UK supply track record (1)

UK companies have captured a small share of activity to date. The only project to use all UK-sourced monopiles so far has been the shallow-water Scroby Sands project of 3MW turbines which was completed in 2004. The supply contract for the 30 relatively small monopiles (4.2m diameter) for this project was split between Cambrian Engineering with supply from its facility in Arnish on the Isle of Lewis (now owned by BiFab), and Isleburn Mackay and Macleod (now part of Global Energy Group) with supply from its facility at Nigg Yard in the Cromarty Firth. All other projects have been supplied by Continental suppliers.

In 2012, TAG Energy Solutions (TAG) on Teesside delivered one monopile for the German Riffgat project and, in 2013, it was awarded the contract for 16 out of 73 monopiles and transition pieces for E.ON’s Humber Gateway project.

Metal fabricators MTL Group has also successfully worked with UK and Continental fabricators on projects using monopiles in the UK (Humber Gateway) and overseas (Meerwind), providing secondary steel items including personnel platforms and boat landing systems.

UK companies have supplied monopile foundations for met masts, including Steel Engineering for the East Anglia zone and Harland and Wolff for the Dogger Bank zone.

Market readiness of UK suppliers for commercial scale projects (3)

There are UK suppliers with the capacity to supply to large projects, including XL monopiles. Investment has been made by a number of companies but they are still in the process of building up industry track record and securing long term orders. These companies have indicated their ability to expand to meet market demand but this will require sustained growth and long term commitment in a challenging and uncertain market.

TAG started operations in its Teesside facility in 2011 following a £20 million investment programme that included £3 million of public funding. Its supply to the offshore wind industry has been on a limited scale but it is anticipated that the award of a fraction of the foundation supply for the Humber Gateway project will help to give the company the track record needed to give developers confidence to commit to purchase all foundations for large projects. TAG has the manufacturing and logistics expertise to supply XL monopiles.

Steel Engineering has invested £3.5 million in new equipment at its Renfrew facility to give it the capacity to produce about 35 XL monopiles and transition pieces a year. With additional investment, the company reported that it could double this capacity. BiFab’s Arnish facility has the capacity to roll XL monopiles but it is likely that the company will seek to use much of this capacity to guarantee its own supply of pin piles for its jackets as well as its oil and gas activity.

No steel plate for monopiles is currently sourced from the UK although development plans are in place. The leading supplier of steel in the UK, Tata, indicated that it was considering the investment needed to deliver the plate weight required for monopiles, including XL products. As material cost is the dominant contribution to total product cost, the supply of UK steel is a significant factor in achieving the potential UK expenditure on monopiles.

UK investment risk (3)

Investment risks are lower than for a turbine nacelle assembly and component manufacturing because of the availability of parallel market activity. All of the UK monopile suppliers also serve the oil and gas industry and are able to redirect production capacity between sectors to

maximise factory utilisation. This lowers investment risk but means that companies are more likely to invest in more flexible tooling. A disadvantage of this approach is that production facilities will be less optimised for offshore wind activities and may therefore not be able to achieve the full level of cost reduction that is possible.

Most fabricators will not invest in significant infrastructure speculatively. None of the UK companies with expertise to undertake monopile fabrication are large corporations with the financial strength to invest speculatively in an uncertain market.

There is uncertainty about which foundation designs will be used in the long term. The industry trend towards larger turbines and sites in deeper waters means that there is uncertainty about which foundation concepts will dominate in the long term, as all concepts are still evolving. As a result, companies may delay and eventually cancel investment plans in new monopile manufacturing facilities.

There is a strong existing supply chain on the Continent with a strong track record and plans for expansion. The two market-leading consortia, SIF Group with Smulders Group, and EEW with Bladt Industries, have both developed strong track records in project delivery. As well as giving confidence to potential customers, this gives them advantages in production experience and streamlining and the confidence to invest in optimised tooling.

Logic of UK supply (2)

The main supplier of steel for monopiles is located in western Germany with close proximity to the existing monopile suppliers. The leading supplier of heavy steel plate to the monopile market is Dillinger Hütte which is located in Saarland near the north east French border, making it well placed deliver to the main fabricators in Belgium, the Netherlands, Denmark and Germany.

There are unlikely to be significant logistic savings from local supply of monopiles and transition pieces. Although the existing supply chain is not located in the UK, this has not proved a problem in project delivery and monopiles can be transported using relatively low cost vessels. For example, the monopiles for a number of UK east coast projects as far north as Teesside have involved shipping units made by Sif and Smulders using the Dutch port of Vlissingen on coaster vessels and then undertaking a vessel-to-vessel transfer to the jack-up installation vessel in sheltered waters.

Availability of UK expertise (3)

Offshore wind can draw on existing UK expertise in steel fabrication. The UK has a strong pedigree in large-scale steel fabrication, in particular for the North Sea oil and gas and nuclear industries. This means that UK fabricators can draw on a pool of experience in designing and building large offshore structures. There is a risk that increased demand in these other sectors will limit the availability of yard capacity and workforce.

Table 5.7 Synergies of parallel sectors with monopile foundation supply and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Medium	None
Oil and gas	High	TAG Energy
Rail	Low	None

Size of the UK opportunity (4)

The lack of a UK supplier of heavy plate steel limits the potential for UK expenditure. Figure 5.10 shows that about 30% of monopile cost is “Materials”, and while Tata is considering plans to develop capacity, this would take time to realise and would be dependent on demand. The potential UK expenditure includes UK supply of steel plate.

The production process for monopiles is largely automated. This means that the number of jobs associated with this activity is less than for other foundation concepts, such as steel jackets or concrete gravity base foundations.

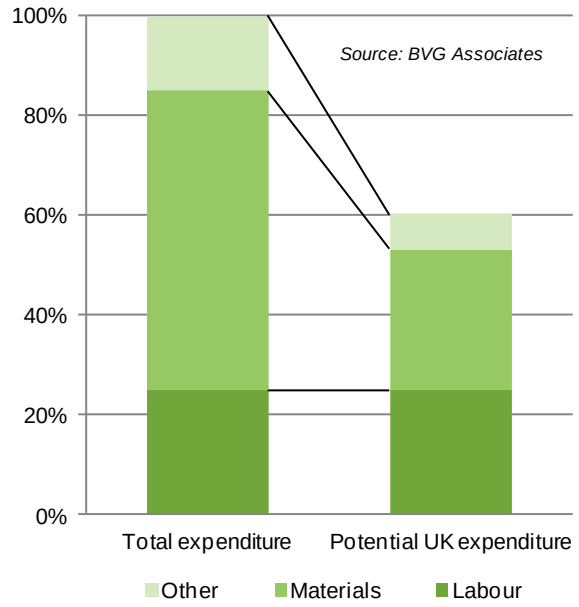

Figure 5.10 Breakdown of total monopile foundation supply expenditure and potential UK expenditure.

For projects using monopile foundations, they form about 42% of balance of plant cost and 8.7% of wind farm lifetime cost. With a potential UK expenditure of 60%, they create a UK opportunity of 5.3%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
8.7%	60%	5.3%

Summary

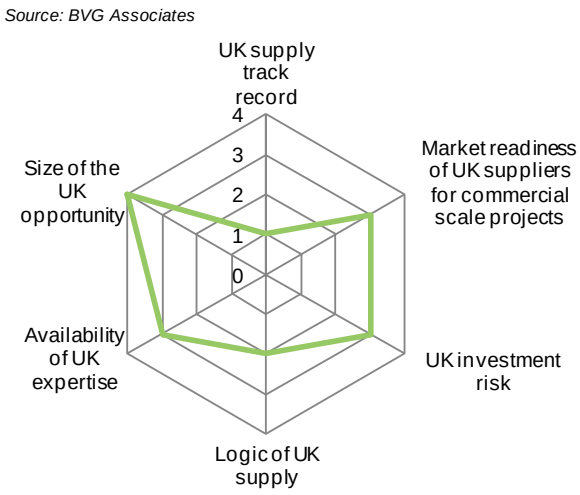

Figure 5.11 Summary of considerations concerning monopile foundations.

5.6. Non-monopile steel foundations

There are several non-monopile steel foundation concepts being considered for projects for which monopiles are not a feasible option. There is uncertainty, however, about which ones are likely to predominate in the long term.

Industry feedback was that the most common “deeper water, larger turbine” foundation design would be the four-legged steel jacket (a cross-braced, welded, space-frame structure using steel tubes) but other steel designs, such as tripods and tri-piles, 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 sea bed connection, and jacket variants with designs of three or six legs or twisted structures. Floating foundations are currently at the demonstration but are not considered here as they are unlikely to be deployed commercially in UK projects before 2020.

These designs have been grouped together for consideration here as many of the issues faced by potential suppliers and customers are similar.

UK supply track record (3)

The UK has one leading market player with a track record of delivery at a commercial scale. BiFab is a leading fabricator of jackets having built the first offshore wind jacket for the Beatrice Demonstrator project. It has also produced six units for the German Alpha Ventus demonstrator project and 30 for Ormonde, the first commercial-scale project to use this foundation type.

In MTL Group, the UK has a successful supplier of secondary steel work for projects in the UK (Ormonde) and overseas (Borkum West and Nordsee Ost).

There are UK companies that have supplied foundations for demonstration projects. Steel Engineering in Renfrew has been responsible for the shallow water jacket foundation for the SHI prototype turbine at Methil which was installed in 2013. Belfast-based Harland and Wolff has built the four “Universal Foundation” suction bucket units used for meteorological masts on the Dogger Bank and Firth of Forth zones.

Market readiness of UK suppliers for commercial scale projects (2)

Companies are waiting for firm orders before investing in efficient large-quantity production capacity. UK companies, including BiFab in Methil, OGN Group in Wallsend on the Tyne and Global Energy Group at Nigg Yard in the Cromarty Firth, have investment programmes for production facilities with capacities of up to 150 units a year. Uncertainty about the scale of the market and the foundation concept choices that developers will make has meant that any investment at this stage would be quite speculative. It will be possible for these companies to make

rapid progress in developing facilities once they have firm orders but there is a risk that in the meantime, the companies decide to reallocate land or resources to serve other sectors.

Investment has been made by a UK supplier in the tooling required to produce finished tubes for jackets. In 2012, Tata invested £2 million at its Hartlepool Offshore Processing Centre. The investment in automated cutting equipment enables the company to create accurate profiles at the ends of tubes for specific designs ahead of final fabrication by a fabricator. This equipment gives the company the capability to produce the tubes for up to 150 jackets per year, for both the UK and export markets.

UK investment risk (3)

Investment risks are lower than for a turbine nacelle assembly and component manufacturing because of the availability of parallel market activity. As with monopiles, all of the existing and prospective UK fabricators of jackets also supply the oil and gas industry and are able to share production capacity between sectors to maximise factory utilisation. This will lower investment risk although it also means that companies are likely to invest in more flexible tooling that can be used in a number of applications and this may not facilitate realising maximum efficiency for offshore wind.

Most fabricators will not invest in significant infrastructure speculatively. None of the companies known to be planning to develop jacket fabrication facilities in the UK are large corporations with the financial strength to invest speculatively in an uncertain market. Feedback was that plans will only go ahead once a company has secured a sufficiently large pipeline of work. The market certainty required will vary between companies depending on the level of investment in infrastructure and tooling that is required. This may vary from an order for single commercial-scale project to orders spanning several years over a number of wind farms. Investments by Bladt and Smulders were made following the award of supply contracts for EnBW Baltic 2 and Thornton Bank II and III respectively.

There is uncertainty about which foundation designs will be used in the long term. The uncertainty about which foundation concepts will dominate in the long term affects all foundation manufacturers.

There is a strong existing supply chain on the Continent with a strong track record and plans for expansion. Bladt Industries, Smulders Group and Weserwind have developed track records in project delivery. As well as giving confidence to potential customers, this gives them advantages in production experience and streamlining and the confidence to invest in optimised tooling.

Logic of UK supply (3)

Local supply of steel tubes is a significant advantage. If tubes are supplied to UK fabricators by Tata from its Offshore Processing Centre in Hartlepool, there will be lower logistic costs and less risk of delays in deliveries than if steel tubes are imported.

The UK offers more flexible and cheaper labour than some other northern European countries. Being used to the variable throughput of the oil and gas industry, UK manufacturers are able to quickly expand their workforce to cope with increased demand. Feedback was that the UK was considered relatively low cost compared to other Northern European countries. This is significant because the production process for jackets has a higher proportion of Labour, accounting for 60% of cost compared to only 25% for monopiles. The UK still has to compete with low cost countries in Eastern Europe and further afield such as Korea and China, say, but offers a good combination of cost, logistics benefits and industry track record.

High transportation costs and concerns about quality control may to deter developers from sourcing from Asia. There has been interest from shipyards in China, Korea and Singapore in fabricating jackets and shipping them to the European market. The lower labour costs in these locations mean that it may be possible to cut the fabrication costs but industry feedback was that any benefit would be offset by the high costs of transporting completed structures over such long distances and the additional complexity of addressing quality issues, especially if only discovered on delivery in Europe. An option is to transport jacket sections that can be loaded in vessels more efficiently for final fully assembly in Europe.

Another concern voiced by industry was that long distance supply constrained communication between the developer, designer and fabricator so problems can take longer to address and opportunities for cost reduction could be missed. Any delays in delivery will have significant cost implications if installation vessels contracted for the work are idle.

Scotland has a support programme that aims to secure a commitment to establishing production facilities. In 2013, Scottish Enterprise launched it Scottish Innovative Foundation Technologies (SIFT) fund. This is a £15 million programme to support the demonstration of foundations for water depths of 30m or more in return for an assurance that manufacturers will set up production facilities in Scotland.

Availability of UK expertise (3)

Offshore wind can draw on the expertise in parallel sectors. The UK has a strong pedigree in large scale steel fabrication, in particular through the North Sea oil and gas, shipbuilding and nuclear industries. This means that fabricators can draw on a strong pool of welding skills. There is a risk that increased demand in these other

sectors will limit the availability of yard capacity and workforce.

Table 5.8 Synergies of parallel sectors with non-monopile steel foundation supply and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Medium	None
Oil and gas	High	BiFab, SLP, Steel Engineering
Rail	Low	None

Size of the UK opportunity (4)

The production process for jackets is more labour intensive than that for monopiles. The production of tubes is highly automated but the final assembly of jackets involves a range of manual or semi-mechanised processes. Figure 5.12 shows that over 60% of jacket cost is spent on Labour undertaken by the fabricator. With UK steel supply, the potential UK expenditure can reach 80%.

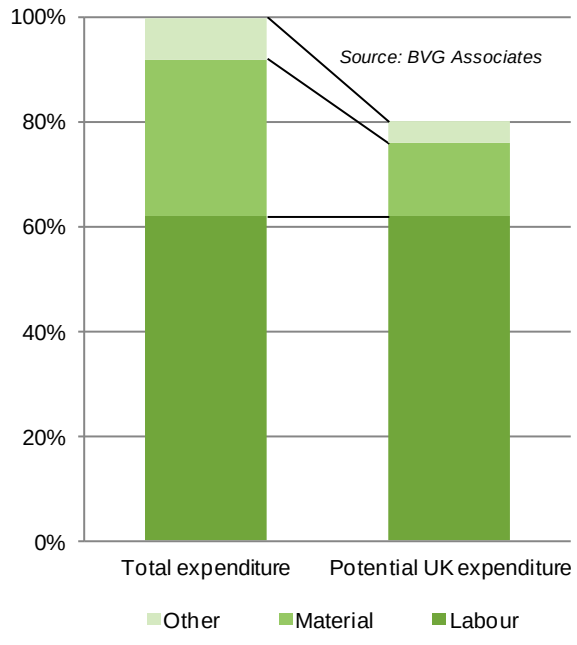

Figure 5.12 Breakdown of total non-monopile steel foundation supply expenditure (based on jacket manufacture) and potential UK expenditure.

For projects using non-monopile steel foundations, they form about 45% of balance of plant cost and 8.7% of wind farm lifetime cost. With a potential UK expenditure of 80%, they create a UK opportunity of 7.1%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
8.7%	80%	7.1%

Summary

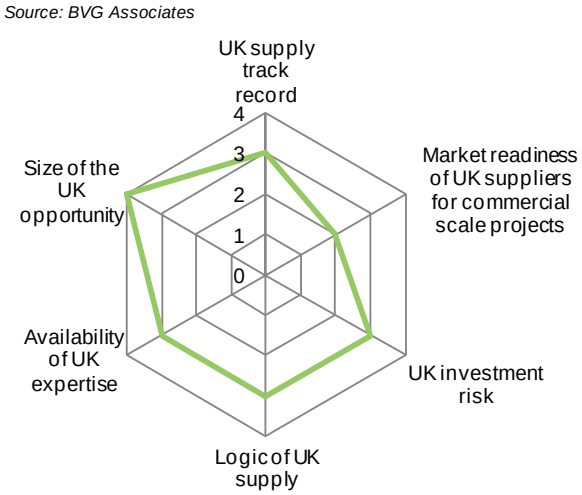

Figure 5.13 Summary of considerations concerning non-monopile steel foundations.

5.7. Concrete foundations

Concrete gravity base foundations have been used extensively in shallow, generally calm water sites in the Baltic Sea, most recently at Kårehamn in Sweden, but only once at Thornton Bank I in exposed, deeper water North Sea conditions. Benefits include reduced exposure to relatively volatile steel prices and removing the need for sea bed piling, which is likely to be a significant constraint for some projects.

The installation method used in the Baltic Sea cannot be applied cost effectively for deeper water, harsher North Sea conditions. In order to address this issue, "next generation" concrete (including concrete-steel hybrid) designs have been developed. These new designs do not need the costly heavy lift crane vessels needed for existing concrete foundations and for piled steel foundations.

There are two main approaches: non-buoyant designs that use a bespoke vessel to transport them to site, and buoyant designs that are towed to site and ballasted to sink them to the sea bed. The non-buoyant designs have typically been designed to allow the complete installation of the turbine on the foundation at the quayside before it is delivered to site, a solution likely to take longer to commercialise but offering the prospect of greater savings in the long run. Neither approach has yet been applied at full scale in offshore wind, even on a single demonstrator.

UK supply track record (1)

No offshore wind projects have used concrete foundations made in the UK. The UK has no wind farms

with concrete foundations and for one-off projects, concrete foundations have typically been made close to the wind farm site. For example, for Thornton Bank I the foundations were made at a temporary facility at the Port of Oostende and for Middelgrunden, a dry dock in Copenhagen was used. Large concrete foundations such as the Maureen articulated loading column for the oil and gas sector, installed in 93m water depth have been manufactured in the UK.

The UK is leading research to address the barriers to the commercial-scale use of concrete foundations. The Concrete Centre (part of the Mineral Products Association) has formed the Interest Group for Gravity Foundations that includes companies involved in the design, construction and installation of concrete gravity base foundations. This group addresses industry-wide challenges that could restrict or prevent the use of concrete designs.

A concrete gravity base foundation design (the GBF concept developed by Gifford (now Ramboll), BMT Nigel Gee and Freyssinet) was also one of the four finalists to be supported by the Carbon Trust Offshore Wind Accelerator programme.

Market readiness of UK suppliers for commercial scale projects (1)

A number of consortia involving UK-based companies have developed concrete gravity base foundation concepts. These include Gravitas (a joint venture of Arup, Hochtief and Costain), Skanska (in collaboration with SMIT Marine Projects and Grontmij) and the GBF consortium. All have well developed plans for commercialisation.

A lack of economically viable demonstration opportunities is a key challenge that is delaying and may prevent the adoption of concrete designs on commercial projects. Although the long term behaviour of gravity base structures is well understood, there is still uncertainty about the proposed installation strategies that involve floating the structure to site and lowering it to the sea bed. While prospective suppliers may highlight similar practice in parallel sectors (such as bridge building), most developers are expected to require large scale demonstration of the installation of multiple units before placing a contract for a complete commercial wind farm as they recognise logistics risks in repeating such a process for a commercial project far from shore.

UK investment risk (2)

Prospective suppliers are unlikely to make speculative investments in infrastructure. The cost associated with a production facility and the uncertainty about whether concrete foundation will be widely adopted means that companies are unlikely to invest speculatively. As with non-monopile steel foundation production facilities, feedback was that plans would only go ahead once a company has secured a sufficiently large pipeline of work against which it can invest. Depending on a company's investment needs, a sufficient pipeline could be a single commercial-scale project or orders spanning several years and for a number of wind farms.

There is uncertainty about which foundation designs will be used in the long term. The uncertainty about which foundation concepts will dominate in the long term affects all foundation manufacturers.

Logic of UK supply (3)

There are suitable port facilities in the UK that can accommodate large-scale production facilities. Ports such as Ardersier, Killingholme (Able Marine Energy Park) and Kishorn can, with investment, offer large land areas, heavy lift quayside and deep water alongside the quays and in the approach channels. The ports are also near sheltered offshore areas that can be used for the wet storage of completed units.

The UK may offer flexible and cheaper labour than other northern European countries. As with jackets, the high labour content of concrete foundations means this is likely to be an important consideration for prospective suppliers. The UK will still not be able to compete with low cost countries in Eastern Europe and further afield, such as Poland and China, but offers a good combination of cost, logistics benefits and industry track record.

Scotland has a support programme that could aims to secure a commitment to establishing production facilities. As with jacket foundations, the Scottish Enterprise SIFT fund is expected to be a significant incentive for Scottish fabrication.

Availability of UK expertise (3)

The UK aggregates industry is aware of the opportunity. The potential to source concrete and aggregates from nearby onshore or offshore sources should be a strong benefit for potential investors.

UK civil contractors have experience of fabricating and installing large concrete marine structures. These companies are well placed to work in partnership with prospective suppliers to set up strong supply chains and establish workforces. Facilities developed to produce the much larger concrete structures used for North Sea oil and gas are well suited to production of units for offshore wind.

There is UK expertise to manufacture steel sections for hybrid concrete-steel designs. Fabricators with a expertise to produce monopiles or jackets are well place to produce the upper steel sections required as part of some designs.

Table 5.9 Synergies of parallel sectors with concrete foundation supply and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	Medium	None
Rail	Low	None

Size of the UK opportunity (4)

A high proportion of the Materials for concrete foundations can be supplied from the UK. Aggregates and steel rebar can be readily sourced from the UK for UK manufacture and local suppliers providing significant opportunities for local content. Labour value is concentrated at the manufacturing facility and this activity has a lower skills threshold than the welding requirement associated with jacket production, enabling a high degree of local content.

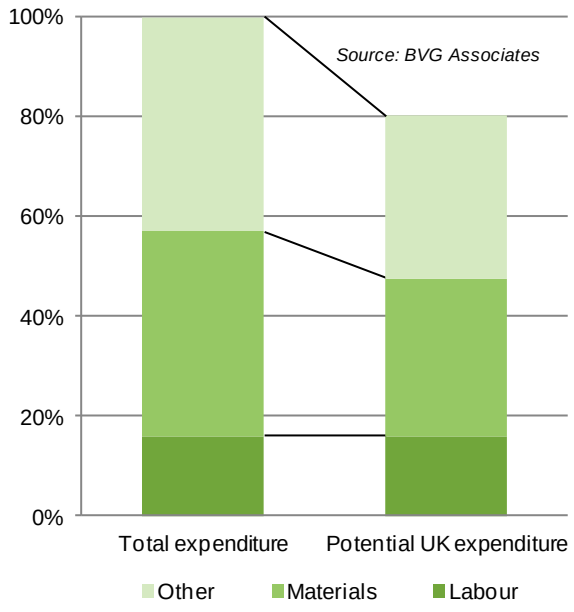

Figure 5.14 Breakdown of total concrete foundation supply expenditure and potential UK expenditure.

For projects using concrete foundations, they form about 45% of balance of plant cost and 8.7% of wind farm lifetime cost. With a potential UK expenditure of 80%, they create a UK opportunity of 7.1%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
8.7%	80%	7.1%

Summary

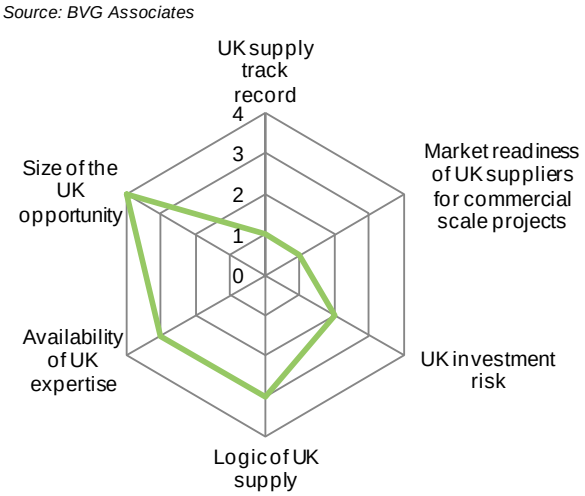

Figure 5.15 Summary of considerations concerning concrete foundations.

Table 5.10 Summary of conclusions on monopile foundations, non-monopile steel foundations and concrete foundations.

Criterion	Monopile foundations	Non-monopile steel foundations	Concrete foundations
UK proven expertise (supplied greater than 200MW equivalent)	None	BiFab	None
Additional future UK expertise	Steel Engineering, TAG Energy	Harland and Wolff, OGN Group, Steel Engineering	BAM/Van Oord, Concrete Marine Solutions, Gravitas, MT Højgaard/Seatower, Skanska/SMIT/Grontmij, Strabag, Vici Ventus, Vinci, Xanthus
UK supply track record	UK companies have captured a small share of activity to date	The UK has one leading market player with a track record of delivery at a commercial scale There are UK companies that have supplied foundations for demonstration projects	No offshore wind projects have used concrete foundations made in the UK The UK is leading research to address the barriers to the commercial-scale use of concrete foundations
Market readiness of UK suppliers for commercial scale projects	There are UK suppliers with the capacity to supply to large projects, including XL monopiles No steel plate for monopiles is currently sourced from the UK although development plans are in place	Companies are waiting for firm orders before investing in efficient large-quantity production capacity Investment has been made by a UK supplier in the tooling required to produce finished tubes for jackets	A number of consortia involving UK-based companies have developed concrete gravity base foundation concepts A lack of economically viable demonstration opportunities is a key challenge that is delaying and may prevent the adoption of concrete designs on commercial projects
UK investment risk	Investment risks are lower than for a turbine nacelle assembly and component manufacturing because of the availability of parallel market activity Most fabricators will not invest in significant infrastructure speculatively There is uncertainty about which foundation	Investment risks are lower than for a turbine nacelle assembly and component manufacturing because of the availability of parallel market activity Most fabricators will not invest in significant infrastructure speculatively There is uncertainty about which foundation	Prospective suppliers are unlikely to make speculative investments in infrastructure There is uncertainty about which foundation designs will be used in the long term

Criterion	Monopile foundations	Non-monopile steel foundations	Concrete foundations
	designs will be used in the long term There is a strong existing supply chain on the Continent with a strong track record and plans for expansion	designs will be used in the long term There is a strong existing supply chain on the Continent with a strong track record and plans for expansion	
Logic of UK supply	The main supplier of steel for monopiles is located in western Germany with close proximity to the existing monopile suppliers There are unlikely to be significant logistics savings from local supply of monopiles and transition pieces	Local supply of steel tubes is a significant advantage The UK offers more flexible and cheaper labour than some other northern European countries High transportation costs and concerns about quality control may to deter developers from sourcing from Asia Scotland has a support programme that aims to secure a commitment to establishing production facilities	There are suitable port facilities in the UK that can accommodate large-scale production facilities The UK may offer flexible and cheaper labour than other northern European countries Scotland has a support programme that could aims to secure a commitment to establishing production facilities
Availability of UK expertise	Offshore wind can draw on existing UK expertise in steel fabrication	Offshore wind can draw on the expertise in parallel sectors	The UK aggregates industry is aware of the opportunity UK civil contractors have experience of fabricating and installing large concrete marine structures There is UK expertise to manufacture steel sections for hybrid concrete-steel designs
Size of the UK opportunity	The lack of a UK supplier of heavy plate steel limits the potential for UK expenditure The production process for monopiles is largely automated	The production process for jackets is more labour intensive than that for monopiles	A high proportion of the Materials for concrete foundations can be supplied from the UK

6. Installation and commissioning

Installation and commissioning covers work on all balance of plant as well as turbines. It can be broken down into the following areas: transport of completed assemblies from manufacturing facilities; installation port facilities; foundation installation; turbine installation and commissioning; array and export cable installation; offshore substation installation; and sea-based support. Of these, this section will focus on the following, most significant areas:

Installation ports. While a number of ports have been used to date for offshore installation, the scale of Round 3 developments will in some cases require ports with larger lay-down areas, particularly for turbines. The costs to wind farm owners and their contractors include infrastructure upgrades undertaken specifically for the project, harbour dues and rental of quayside-associated land.

Foundation installation. This includes transport to the wind farm site and installation, including any piling, scour protection, transition piece installation and grouting. The section will focus on steel foundations as it is likely that future concrete foundations will be installed either with standard tugs or with bespoke vessels supplied by the manufacturer.

Subsea cable installation. This includes the transport and laying of both array and export cables and their termination at the turbines and at the offshore substation.

Turbine installation. This includes transport to the wind farm site and the installation and commissioning of turbines. It includes the work of the turbine manufacturer during installation. With few exceptions the principal vessels used for installation have been specifically designed for the offshore wind industry and in all cases these are self-propelled jack-up vessels.

Installation other. Beyond the areas listed above, there are significant additional costs relating to substation installation, onshore cable installation and a large number of smaller activities that support the installation and commissioning process more generally such marine warranty surveyors, navigation aids and weather forecasting services.

Source: BVG Associates

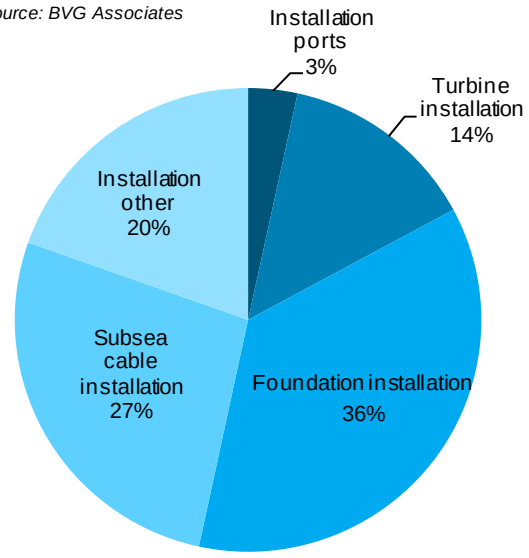

Figure 6.1 Breakdown of installation and commissioning costs.

6.1. Installation ports

The availability of waterside (port) infrastructure is a prerequisite for much of the necessary new coastal manufacturing, assembly and installation infrastructure to deliver the anticipated growth in European demand. Facilities may either be developed for manufacturing and installation activities or as standalone installation facilities. The term installation port is used here to describe the location where the main wind farm components are stored and pre-assembly completed before being loaded onto an installation vessel. The reason for setting up an installation port (as opposed to taking components straight from their manufacturing location to site) is to lower the logistics risks of a project by storing components closer to the wind farm site. Since the UK's supply of finished wind farm components is still relatively low, there is a greater need for installation ports in UK than in Germany, Denmark and France.

Most UK ports are operated privately and make investment decisions on purely commercial factors. In contrast many Continental ports are in public ownership and their investment decisions can consider the wider local economic benefits of a project, as well as the direct port revenue.

UK supply track record (4)

A number of UK ports have been used for the installation of UK wind farms. There is a distinction between the role played by ports on the east and west coasts of the UK. For west coast projects such as Robin Rigg and Rhyl Flats, the long sailing distance from manufacturing locations in Continental Europe has meant significant areas of land have been needed closer to the site in the UK for storage, in these cases at Harland and Wolff in Belfast and the Port of Mostyn respectively. The

UK's first purpose-built installation port, also in Belfast, was used by DONG for the first time for the West of Duddon Sands in 2013. For east coast projects, in the absence of nacelle assembly facilities the purpose of installation ports has been to buffer supply and transfer components from transportation vessels to installation vessels, such as was the case at Harwich for Greater Gabbard and Great Yarmouth for Sheringham Shoal. In general, the UK the availability of ports has been sufficient, even if some of the logistics have been suboptimal.

Market readiness of UK suppliers for commercial scale projects (3)

UK ports have already supported the installation of commercial scale wind farms over 500MW. The port of Harwich was used for the installation of both Greater Gabbard and London Array, and the Port of Mostyn and Cammell Laird were chosen for the installation of Gwynt y Môr.

Several UK ports have developed master plans that incorporate offshore wind installation facilities. DECC published a prospectus for UK ports for offshore wind in 2009, reflecting a concern at the time within the wind industry that there was little space at UK ports available at reasonable cost.[8] Since then a number of UK ports have been promoted successfully to the wind industry and in most cases without needing significant investment. The most significant investment in a port for offshore wind installation has been at Belfast Harbour for use for DONG's Irish Sea projects.

A number of east coast ports have sought to attract turbine manufacturers to set up integrated manufacturing and installation ports. Notable among these are at Hull, Killingholme (south Humberside), Leith and Methil. In December 2013, the Able Marine Energy Park at Killingholme was given planning consent to develop what would be the largest such facility in the UK and Strabag has announced its interest in constructing concrete gravity bases. No investment at the site has been committed to date, however.

The status of publically stated UK port investment for offshore wind installation is shown in Table 6.1.

UK investment risk (1)

The short-term revenue from a single project is insufficient to justify a significant investment. Unlike many Continental ports, privately owned UK ports make investment decisions on purely commercial grounds relating to the port infrastructure, rather than wider economic considerations.

The investment needed for different ports will differ significantly but taking Belfast Harbour as an example, the £50 million that has been invested can be amortised over a decade because DONG Energy has an interest in six offshore wind projects over this period in the Irish Sea. It was reported that RWE will pay about £5 million for the use of Cammell Laird for three years for the construction of Gwynt y Môr, a figure that would be insufficient to fund significant investment in quayside infrastructure.[9]

It is likely that as multi-phase Round 3 projects advance, their developers will look to secure port space. Indeed, for possibly the first of these, East Anglia, its developers have already signed MOUs with ports at Great Yarmouth and Lowestoft, with reports that Harwich is also being considered.[10]

Several Continental ports have already invested in facilities for offshore wind. Speculative investment of public funds in Germany and Netherlands has enabled the establishment of facilities suitable for offshore wind. This competition will weaken the business case for investment at some east coast UK ports.

[8] *UK Ports for the Offshore Wind Industry: Time to Act*, BVG Associates for the Department of Energy and Climate Change, February 2009, available online at http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file49871.pdf, last accessed September 2013

[9] '*RWE npower renewables awards multi-million pound Gwynt y Môr engineering contract to Merseyside's Cammell Laird',* Press release, RWE npower renewables, 5 October 2011, available online at www.rwe.com/web/cms/mediablob/en/1265390/data/1203864/1/rwe-innogy/sites/wind-offshore/under-construction/gwynt-y-mr/latest-news-and-information/05-10-11-RWE-npower-renewables-awards-multi-million-pound-Gwynt-y-Mr-engineering-contract-to-Merseysides-Cammell-Laird.pdf. Last accessed August 2013

[10] Wind Farm Developers Investigate Potential Of East Anglian Ports, *East Anglia Offshore Wind Ltd*, 31 October 2012, available online at www.eastangliawind.com/news-view.aspx?newsID=15. Last accessed August 2013

Table 6.1 The status of publically announced investments for offshore wind installation ports.

Port	Function	User	Status
Able Marine Energy Park (Killingholme)	Manufacturing and installation	Strabag	Consent awarded "Preferred location" for Strabag
Belfast Harbour	Installation	DONG Energy	Operational (for West of Duddon Sands)
Cammell Laird (Birkenhead)	Installation	RWE npower renewables	Operational (for Gwynt y Môr)
Dundee	Manufacturing and installation	SSE Renewables	MOU signed
Great Yarmouth (Eastport)	Installation	East Anglia Offshore Wind, Scira (Statkraft/Statoil)	Operational (for Sheringham Shoal) MOU signed (for East Anglia)
Green Port Hull (ABP)	Manufacturing and Installation	Siemens Wind Power	Pending FID
Harwich	Installation	DONG, East Anglia Offshore Wind, SSE Renewables	Operational for Gunfleet Sands and Greater Gabbard Consent awarded for Bathside Bay development MOU signed (for East Anglia)
Leith (Forth Ports)	Manufacturing and installation	Gamesa	MOU signed
Lowestoft (ABP)	Installation	East Anglia Offshore Wind	MOU signed
Methil	Manufacturing and installation	Samsung Heavy Industries	MOU signed
Mostyn	Installation	RWE npower renewables	Operational (for Gwynt y Môr)
Sheerness (Peel Ports)	Manufacturing and installation	Vestas	Option agreement (now lapsed)

Logic of UK supply (3)

There are logistics benefits in using local UK ports but some Continental ports may offer a lower cost option for east coast UK projects if manufacturing is also on the Continent. In theory, logistics analysis would favour an installation port within a few hours sailing of the wind farm site to minimise the transit time of installation vessels, even taking into account the costs of double-handling. In reality, the equation is more complex and depends on the relative cost of using UK ports which includes completion from other users, and the location of the manufacturing facility.

UK installation ports are most efficient when combined with turbine or balance of plant manufacturing facilities. Integrated facilities, such as those considered by most offshore turbine manufacturers, offer more efficient logistics than separate facilities.

Availability of UK expertise (2)

The UK has an efficient port sector. In general, a port handles a range of traffic. At the Port of Mostyn, for example, the offshore wind sector benefited from quayside infrastructure developed to handle the shipping of Airbus wings from a nearby manufacturing facility in north Wales.

The infrastructure requirements for container ports is similar to that used for offshore wind farms and the offshore wind-related plans at Great Yarmouth and Green Port Hull have both evolved from container port developments.

Private ownership has stimulated competition and created an incentive to maximise revenue by attracting a business from number of sectors. If there are no synergies with these parallel sectors, this can create a problem for the offshore wind industry, for which investments usually offer lower rates of return than other sectors.

There is sufficient coastal land and infrastructure in the UK for the offshore wind industry. There has been a perception that there is limited land available for offshore wind customers. There is likely to be a shortage of *unoccupied* developed coastal land as UK port owners have been successful in maximising the utilisation of their assets. UK ports can meet the needs of the industry, however, if mutually agreeable terms can be reached by port owners and wind industry users.

Table 6.2 Synergies of parallel sectors with installation ports and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	Port of Mostyn
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	None
Rail	Low	None

Size of the UK opportunity (1)

The value generated at ports is derived from land rental and from services provided by the port during operation. Although expenditure in ports is a relatively small part of project capital expenditure and there are considerable differences between projects, a high proportion of this cost is potential UK expenditure.

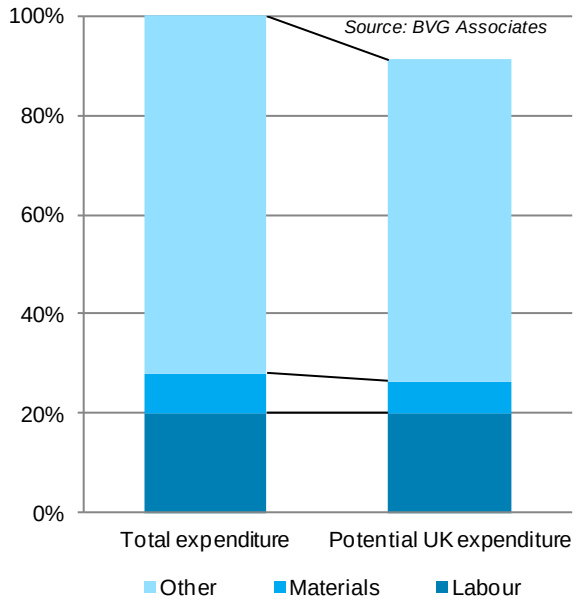

Figure 6.2 Breakdown of total installation port expenditure and potential UK expenditure.

Installation ports costs are about 3% of installation and commissioning costs and 0.5% of wind farm lifetime costs. With a potential UK expenditure of 90%, they create a UK opportunity of 0.45%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
0.5%	90%	0.45%

Summary

Source: BVG Associates

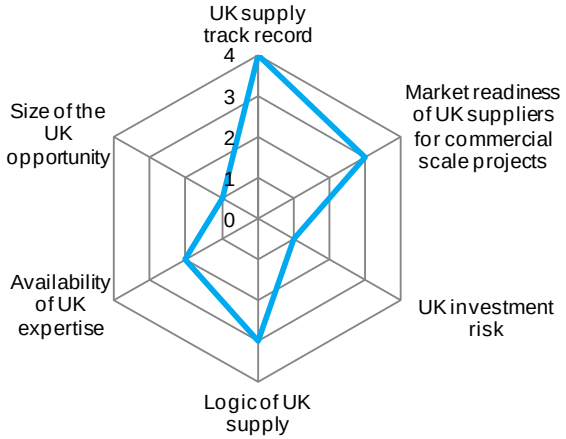

Figure 6.3 Summary of considerations concerning installation ports.

6.2. Foundation installation

There are two main vessel options for steel foundation installation: a jack-up vessel, most of which are also used for turbine installation; or a floating vessel, often with components fed using a separate floating vessel. The installation vessels used for steel foundations can be usefully divided the foundations into five groups, based on the type and size of the foundations to be installed:

- Standard monopiles
- XL monopiles (defined here as requiring a crane with lifting capacity greater than 1,200t)
- Jackets or tripods (space frames) with either piled or suction bucket sea bed connection
- Monopods with a suction bucket sea bed connection, and
- Concrete gravity base foundations.

For a jack-up vessel, its efficiency for space frame installation depends on the number of foundations it can fit on its deck. This is because the transfer of foundations from a feeder vessel requires another jack-up, which is likely to be uneconomic because the charter rate of a jack-up feeder vessel is high and the component transfer time long because of the jacking up time. An optimum jack-up specification for space frame installation is considered to be one that has a crane with at least 1,000t capacity and can carry at least five foundations. The optimum number of foundations for a vessel to carry will depend not only on the cost of the vessel but also the speed with which foundations can be fabricated and readied for loading.

A floating vessel has less need for deck space as foundations can be more readily transferred from a floating feeder vessel or floated out with tugs. Space frames have been installed using the sheerleg crane vessel *Rambiz* but its sensitivity to weather (it cannot operate when there is a significant wave height greater than 0.75m) means that it cannot be considered to be an optimal solution unless it is brought in for short projects or to complement other vessels during the summer months. It is assumed that monopiles cannot be installed efficiently from a sheerleg crane vessel.

Suction buckets are an alternative method of sea bed connection to piles. These can be used for both space frames and monopods, and installation vessels are fitted with vacuum pumps to create the negative pressure in the suction bucket to pull it into the substrate.

The concrete gravity base foundations for operational wind farms have typically been installed using a sheerleg crane vessel. Operational sheerleg cranes do not have the capacity to lift next generation concrete foundations and they are also highly sensitive to wave conditions, which would lead to significant weather downtime for large projects (and therefore installation programmes that extend beyond the summer months). Next generation concrete foundations are therefore likely to be installed using standard tugs or a bespoke vessel provided by the manufacturer.

A range of vessels have been used for monopile installation, including jack-ups, heavy lift vessels (such as the *Stanislav Yudin*) and crane vessels (notably the *Svanen*). Jack-ups are likely to be the efficient in most cases but their charter rates are typically lower than for heavy lift vessels and their ability to install turbines means that they can be used flexibly and are therefore attractive for long-term charter by developers. The current trend for larger XL monopiles will reduce the available installation fleet as few jack-ups have cranes with the capacity to lift monopiles greater than 1,000t (which typically require a crane with a 1,200t lifting capacity)

UK supply track record (4)

The UK has competitive operators in the offshore wind foundation installation market. MPI Offshore and Seajacks specialise in the sector, operating several purpose-built jack-ups, and are competitive with overseas contractors. There has been UK supply of installation support vessels, notably by Sealion Shipping, which operates a fleet of offshore installation vessels which have been used to transport monopiles to site.

There is little economic capacity for large vessel construction in Western Europe. The vessels operated by Seajacks and MPI Offshore were built in Asia. The UK has shipyards with the expertise to build installation vessels, as demonstrated by their use for the construction of military vessels. It would be difficult, however, for them to compete with shipyards in China and Korea in particular unless there are over-riding political considerations. The only European shipyards known to have made wind farm installation vessels are Crist in Poland and Sietas in Germany, which has faced financial difficulties in recent years. In addition, DBB Jack-Up Services has

commissioned an OMS jack-up vessel from Nordic Yards in Germany.

There are UK suppliers of foundation installation equipment. Pile handling equipment, such as templates and upending tools, has been supplied by UK-based companies such as IHC Sea Steel, LDD and Houlder.

Market readiness of UK suppliers for commercial scale projects (4)

UK contractors have a proven expertise to deliver large projects. Companies such as MPI Offshore and Seajacks have proven expertise to deliver foundation installation contracts on large commercial projects, including London Array and Meerwind.

UK vessel operators have made large investments in new capacity. Both MPI Offshore and Seajacks have put new build vessels into service since the beginning of 2012 in anticipation of increased demand for large jack-up vessels. Seajacks ordered a further vessel in May 2013 which will be well equipped for the installation of XL monopiles and space frames.

MPI Offshore has developed a specialist space frame installation jack-up concept. This is one of several space frame installation vessels under development in Europe for which operators are waiting for clearer demand before ordering.

New UK entrants could be potential EPC contractors that currently lack their own installation fleet. There are over 10 operators of offshore wind installation vessels. Feedback from industry was that the current lull in the market may trigger acquisitions by EPC contractors, such as Bechtel, Subsea7 and Technip, as specialist vessel operators seek to exit the market.

UK investment risk (1)

The investment risk in installation vessels is lowered by their use in other sectors. Although floating foundation installation vessels are likely to be more cost-effective than jack-ups, as they can work more quickly without the need to jack up, they may have fewer other applications. Jack-ups can be used for turbine installation for projects anywhere in Europe, as well as for offshore oil and gas applications.

Logic of UK supply (1)

Vessel operators typically provide services globally. Installation vessels can operate equally efficiently anywhere in the world.

Local suppliers can form long-term relationships with their customers that can help optimise project logistics. Feedback from industry was that project learning has not been retained for subsequent wind farms. Long term relationships between operators and developers, often involving extended charters, provide an opportunity to optimise installation strategies and reduce costs. With the UK as the leading market, this presents an advantage to UK-based operators.

Availability of UK expertise (4)

UK vessel operators compete successfully in the oil and gas industry. The origins of UK operators in offshore wind are typically in oil and gas operations and these have drawn on expertise in developing new vessel concepts and applying offshore installation expertise, for example in the use of dynamic positioning systems. Both MPI Offshore and Seajacks have built on experience gained in the oil and gas sector. To be successful they have recognised the different culture in wind and adjusted to the lower profit margins. There are UK-based EPC contractors now working in oil and gas looking to enter the market, a notable example being Subsea7, which forms part of SSE's offshore wind alliance.

The UK also has specialist expertise in areas such as structural grouting and scour protection around the base of support structures.

Table 6.3 Synergies of parallel sectors with foundation installation and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	MPI Offshore, Seajacks, Sealion Shipping
Rail	Low	None

Size of the UK opportunity (2)

About half the value of an installation contract is the charter or depreciation of the cost of the vessel. Figure 6.4 shows that over 60% of the cost of foundation installation goes on "Other", which in this case is mostly the depreciation or charter cost of the vessel. A UK operator will primarily use a British crew and is likely to mobilise and demobilise the vessel in a UK port. The potential UK expenditure is about 50%.

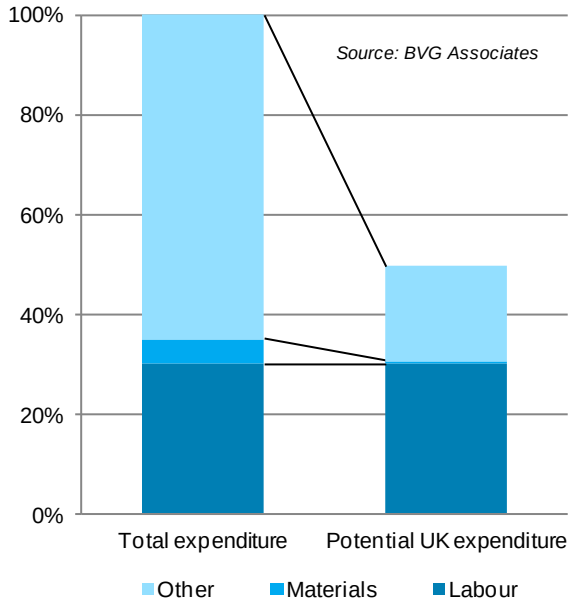

Figure 6.4 Breakdown of total steel foundation installation expenditure and potential UK expenditure.

Steel foundation installation accounts for 36% of installation and commissioning costs and 5.0% of wind farm lifetime costs. With a potential UK expenditure of 50%, it creates a UK opportunity of 2.5%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
5.0%	50%	2.5%

Summary

Source: BVG Associates

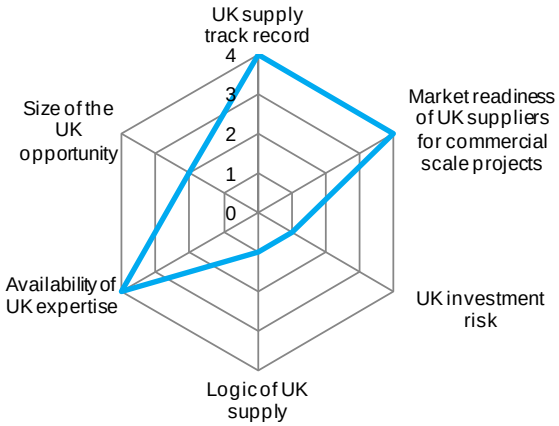

Figure 6.5 Summary of considerations concerning foundation installation.

Table 6.4 Summary of conclusions on installation ports and foundation installation.

Criterion	Installation ports	Foundation installation
UK proven expertise (supplied greater than 200MW equivalent)	Belfast, Birkenhead, Great Yarmouth, Harwich, Mostyn, Ramsgate	Vessel manufacture: None Operation: MPI Offshore, Seajacks
Additional future UK expertise	Dundee, Hartlepool, Holyhead, Hull	Operation: Bechtel, Subsea7, Technip
UK supply track record	A number of UK ports have been used for the installation of UK wind farms	The UK has competitive operators in the offshore wind foundation installation market There is little economic capacity for large vessel construction in Western Europe There are UK suppliers of foundation installation equipment
Market readiness of UK suppliers for commercial scale projects	UK ports have already supported the installation of commercial scale wind farms over 500MW Several UK ports have developed master plans that incorporate offshore wind installation facilities	UK contractors have a proven expertise to deliver large projects UK vessel operators have made large investments in new capacity New UK entrants could be potential EPC contractors that currently lack their own installation fleet
UK investment risk	The revenue from a single project is insufficient to justify a significant investment Several Continental ports have already invested in facilities for offshore wind	The investment risk in installation vessels is lowered by their use in other sectors
Logic of UK supply	There are logistics benefits in using local UK ports but some Continental ports may offer a lower cost option for east coast UK projects if manufacturing is also on the Continent UK installation ports are most efficient when combined with turbine or balance of plant manufacturing facilities	Vessel operators typically provide services globally Local suppliers can form long-term relationships with their customers that can help optimise project logistics
Availability of UK expertise	The UK has an efficient port sector There is sufficient coastal land and infrastructure in the UK for the offshore wind industry	UK vessel operators compete successfully in the oil and gas industry
Size of the UK opportunity	The value generated at ports is derived from land rental and from services provided by the port during operation	About half the value of an installation contract is the charter or depreciation cost of the vessel

6.3. Subsea cable installation

Subsea cable installation can be undertaken using either a single lay and burial process with a plough or using a separate surface lay with subsequent burial, using a jetting tool operated from a remotely operated vehicle (ROV). Both approaches have their advantages, depending on site conditions.

Array cable laying is considered a more technically challenging process than export cable-laying due to the large number of operations that are involved and the cable pull-in interface at each foundation. Export cable-laying vessels tend to be larger with cable carousels with a higher capacity to enable a single length of cable to be laid from substation to shore, where possible.

Cable installation has long been an area of concern for the industry due to the number of problems that have been encountered, and developers have cited the lack of credible suppliers as the greatest source of problems. A constraint is the lack of availability of experienced staff and crews to execute the works. Installation contractors on their part have reported that many problems could have been avoided with their early engagement in a project and that inadequate sea bed surveys and inflexible burial requirements have added risk to projects.

There are signs, however, that the industry is maturing and the work is increasingly being undertaken with well-backed companies with a good track record.

UK supply track record (4)

A small number of vessels have been made in the UK and some vessel modification has been undertaken in the UK. Unlike turbine installation, cable installation does not demand purpose built vessels and the cable installation fleet is mostly made up of older vessels built in shipyards around the world. A small number were built in the UK and are still in operation, notably the barges AMT Explorer and AMT Discoverer built in the 1980s. More recently, in 2010, the *Nexans Skagerrak* was lengthened at the Cammell Laird yard. The UK has successful naval architects, for example BMT Nigel Gee and Houlder.

The UK has world-class expertise in cable installation equipment. The UK, through Aquatic, Forum Energy Technologies, Modus Seabed Intervention, IHC Engineering Business, Saab Seaeye, SMD and Sparrows Baricon, has experience in the manufacture of remotely operated vehicles and cable ploughs. A number of cable carousels and cable handling equipment have also been made in the UK by Caley Ocean Systems and Fraser Hydraulic Power.

The UK has competitive operators. There are several UK-based cable installation contractors, notably Canyon, DeepOcean, Prysmian Powerlink, Reef Subsea and Technip Offshore Wind. Several cable laying companies have ceased trading in recent years following problems on offshore wind farms. Many of the UK cable installers now have greater financial backing than has been the case previously.

Market readiness of UK suppliers for commercial scale projects (3)

UK contractors have a proven expertise to deliver large projects. UK based companies such as DeepOcean, Prysmian Powerlink Services (formerly Global Marine Energy), Reef Subsea and Technip Offshore Wind have installed cables on commercial scale wind farms.

Cable installers have developed plans for new vessels which are pending an investment decision. The vessels operated by cable installers fall into three categories:

- Vessels that are owned and operated by the same company
- Vessels that are on long-term charter, and
- Vessels that are chartered for individual projects.

Cable installers operate a combination of vessels from these categories to give them flexibility and a high vessel utilisation. New investments will be made for wholly owned and long-term chartered vessels and UK operators have investment plans that are pending a pipeline of orders. Most have developed plans awaiting more favourable market conditions.

UK investment risk (3)

Cable installers have been hesitant to invest in new equipment specifically for offshore wind. Although there are potential cost reductions from using a bespoke offshore wind cable vessel, an investment in such a vessel is a high risk for an independent cable installation contractor. Cable manufacturers with an installation capability such as Prysmian, which acquired Global Marine Energy in 2012, and Nexans favour bespoke installation vessels dedicated to power cable installation as these offer greater efficiencies and lower costs. The same may be true for EPC contractors, such as Van Oord, which has ordered a new-build cable vessel for offshore wind projects due for delivery in 2014.

Logic of UK supply (1)

Vessel operators typically provide services globally. An objective for operators is to maintain high utilisation rates for vessels and this typically requires operators to work globally and they have offices in key markets to support this.

Local suppliers can form long-term relationships with their customers that can help to optimise project logistics. Feedback from industry was that project learning has not been retained for subsequent wind farms. Long term relationships between operators and developers, often involving extended charters, provide an opportunity to optimise installation strategies and reduce costs. With the

UK as the leading market, this presents an advantage to UK-based operators.

Availability of UK expertise (3)

The UK expertise in offshore wind cable-laying is based on historical strengths in offshore telecoms and oil and gas industries. A number of UK companies have sought to diversify into offshore wind. A concern from industry has been that the specific requirements of offshore wind, notably the large number of operations over a large area for array cable installation, has meant that the transfer of expertise from these sectors has been less straightforward than anticipated.

Table 6.5 Synergies of parallel sectors with subsea cable installation and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	DeepOcean, Reef Subsea, Technip Offshore Wind
Rail	Low	None

Size of the UK opportunity (2)

About half the value of an installation contract is the charter or depreciation of the cost of the vessel. Figure 6.6 shows a similar cost breakdown to foundation installation. There is additional potential UK expenditure from cable-laying equipment with the result that the potential UK expenditure is about 60%.

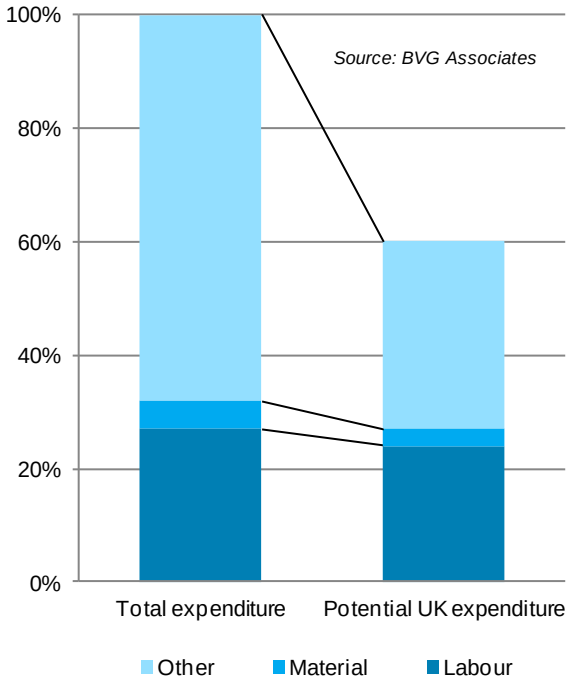

Figure 6.6 Breakdown of total subsea cable installation expenditure and potential UK expenditure.

Subsea cable installation forms about 27% of installation cost and 3.7% of wind farm lifetime costs. With a potential UK expenditure of 60%, it creates a UK opportunity of 2.2%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
3.7%	60%	2.2%

Summary

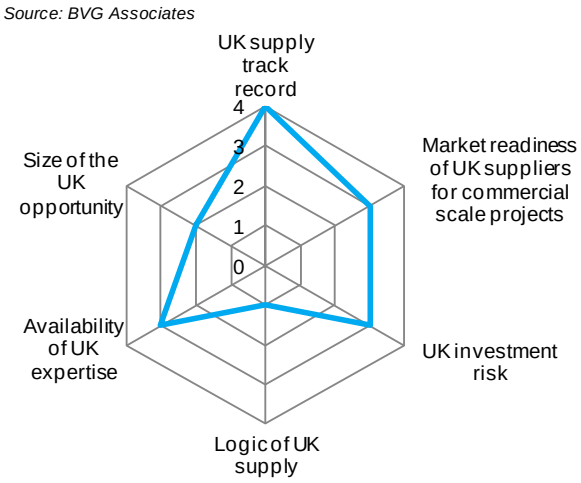

Figure 6.7 Summary of considerations concerning subsea cable installation.

6.4. Turbine installation

Turbine installation on all existing commercial-scale projects to date has been undertaken by a jack-up vessel as to give sufficient stability for the nacelle and rotor lifts. In early projects, a number of self-propelled jack-ups, leg-suspended vessels (such as A2SEA's *Sea Power*) and general purpose jack-up barges were employed. These vessels are generally unable to operate in water depths greater than 25m and only have deck capacities for a small number of turbine component sets. For projects built since 2010, most developers have used vessels purpose built for offshore wind.

UK supply track record (4)

The UK has competitive operators in the offshore wind turbine installation market. MPI Offshore and Seajacks, both of which specialise in the sector, operate several purpose-built jack-ups and are competitive with overseas contractors.

There is little economic capacity for large vessel construction in Western Europe. The vessels operated by Seajacks and MPI Offshore were built in Asia. The UK has shipyards with the expertise to build installation vessels, as demonstrated by their use for the construction of military vessels. It would be difficult, however, for them to compete with shipyards in China and Korea in particular unless there are over-riding political considerations. The only European shipyards known to have made wind farm installation vessels are Crist in Poland and Sietas in Germany, which has faced financial difficulties in recent years. In addition, DBB Jack-Up Services has commissioned an OMS jack-up vessel from Nordic Yards in Germany.

Market readiness of UK suppliers for commercial scale projects (4)

UK contractors have a proven expertise to deliver large projects. MPI Offshore and Seajacks have undertaken the foundation installation on a number of UK and non-UK projects.

UK vessel operators have made large investments in new capacity. Both MPI Offshore and Seajacks have put new build vessels into service since the beginning of 2012 in anticipation of increased demand for large jack-up vessels. Seajacks ordered a further vessel in May 2013.

New UK entrants could be potential EPC contractors that currently lack their own installation fleet. There are over 10 operators of turbine installation vessels. Feedback from industry was that the current lull in the market may trigger acquisitions by EPC contractors as specialist vessel operators seek to exit the market.

UK investment risk (2)

The investment risk in installation vessels is lowered by their use in other sectors. Although floating vessels are likely to be more cost-effective, jack-ups can be used for foundation installation for projects anywhere in Europe, as well as for offshore oil and gas applications.

Large jack-up vessels can also be used in other offshore sectors as accommodation or logistics bases.

Logic of UK supply (1)

Vessel operators typically provide services globally. Such is the dominance of the European offshore wind market that the focus of operators has been in this region. With only one exception (Gulf Marine Services), the vessel operators have all been European companies. The growth of the US and Asian offshore wind industries may lead to contractors operating on a more global basis. The formation of Seajacks Japan in 2013 may be the first sign of this trend.

Local suppliers can form long-term relationships with their customers that can help to optimise project logistics. Feedback from industry was that project learning has not been retained for subsequent wind farms. Long term relationships between operators and developers, often involving extended charters, provide an opportunity to optimise installation strategies and reduce costs. With the UK as the leading market, this presents an advantage to UK-based operators.

Availability of UK expertise (4)

The oil and gas industry is the origin of UK expertise in turbine installation. Many of the vessels used for early projects came directly from the oil and gas market. As the offshore wind industry has matured, the vessels used have become increasingly bespoke and many are exclusively used in offshore wind. Despite this, there is a strong offshore skills base available to offshore wind, notwithstanding the higher salaries and margins in offshore oil and gas.

Table 6.6 Synergies of parallel sectors with turbine installation and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	MPI Offshore, Seajacks
Rail	Low	None

Size of the UK opportunity (1)

About half the value of an installation contract is the depreciation in the cost of the vessel. Figure 6.8 shows

that over 60% of the cost of foundation installation goes on Other, which in this case is mostly the depreciation or charter cost of the vessel. A UK operator will primarily use a British crew and is likely to mobilise and demobilise the vessel in a UK port. The potential UK expenditure is about 50%.

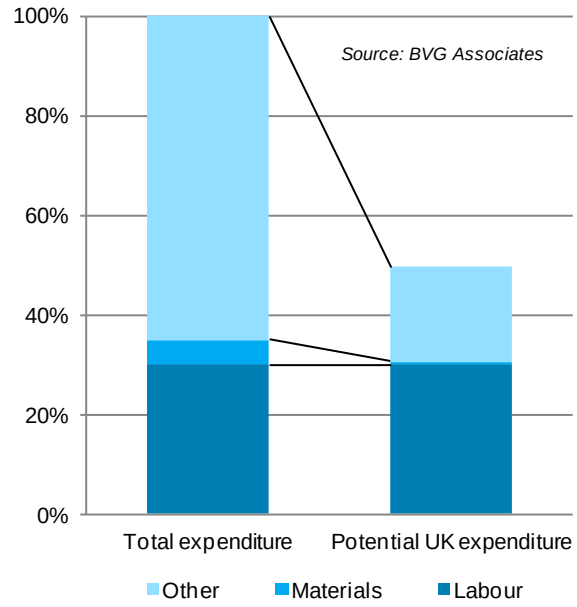

Figure 6.8 Breakdown of total turbine installation expenditure and potential UK expenditure.

Turbine installation forms about 14% of installation and commissioning costs and 1.9% of wind farm lifetime costs. With a potential UK expenditure of 50%, it creates a UK opportunity of 1.0%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
1.9%	50%	1.0%

Summary

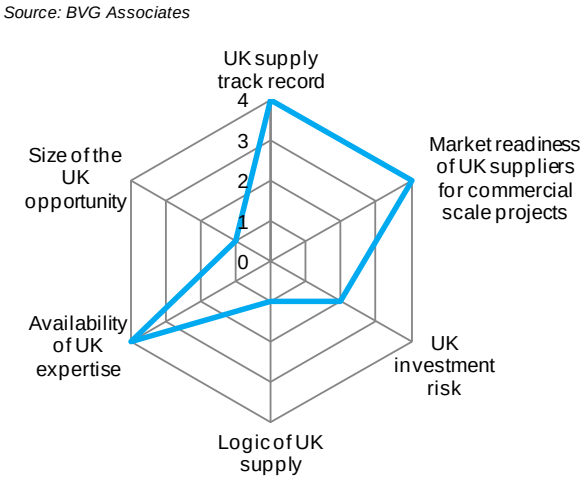

Figure 6.9 Summary of considerations concerning turbine installation.

Table 6.7 Summary of conclusions on subsea cable installation and turbine installation.

Criterion	Subsea cable installation	Turbine installation
UK proven expertise (supplied greater than 200MW equivalent)	Manufacture: There is little economic capacity for large vessel construction in western Europe and none in the UK Operation: DeepOcean, Prysmian Powerlink Services (Global Marine Energy), Reef Subsea, Technip Offshore Wind	Manufacture: None Operation: MPI Offshore, Seajacks
Additional future UK expertise	Operation: Bechtel, Subsea7	Operation: Bechtel, Subsea7, Technip
UK supply track record	A small number of vessels have been made in the UK and some vessel modification has been undertaken in the UK The UK has world-class expertise in cable installation equipment The UK has competitive operators	The UK has competitive operators in the offshore wind turbine installation market There is little economic capacity for large vessel construction in Western Europe
Market readiness of UK suppliers for commercial scale projects	UK contractors have a proven expertise to deliver large projects Cable installers have developed plans for new vessels which are pending an investment decision	UK contractors have a proven expertise to deliver large projects UK vessel operators have made large investments in new capacity New UK entrants could be potential EPC contractors that currently lack their own installation fleet
UK investment risk	Cable installers have been hesitant to invest in new equipment specifically for offshore wind	The investment risk in installation vessels is lowered by their use in other sectors
Logic of UK supply	Vessel operators typically provide services globally Local suppliers can form long-term relationships with their customers that can help to optimise project logistics	Vessel operators typically provide services globally Local suppliers can form long-term relationships with their customers that can help to optimise project logistics
Availability of UK expertise	The UK expertise in offshore wind cable-laying is based on historical strengths in offshore telecoms and oil and gas industries	The oil and gas industry is the origin of UK expertise in turbine installation
Size of the UK opportunity	About half the value of an installation contract is the charter or depreciation cost of the vessel	About half the value of an installation contract is the charter or depreciation cost of the vessel

7. Operation, maintenance and service

OMS is considered in two sections:

- Operation, maintenance and minor service, which includes:
  - Operational costs relating to the day-to-day control of the wind farm, including minor spares and consumables
  - Maintenance activities that are undertaken using the wind farm's normal staff and equipment
  - Condition monitoring, and
  - Costs of rental of the operations base, port facility, mother ship and crew transfer vessels.
- Major service, which includes:
  - The cost of repair or replacement of major components that cannot be undertaken using a workboat, and
  - The cost of using any additional vessels required to repair the fault.

The breakdown of OMS costs is shown in Figure 7.1. The figures include the maintenance of transmission assets but not the payments made to the offshore transmission owner (OFTO) as the cost of building the transmission assets is included in balance of plant costs (see Section 5). The OMS other costs include major items such as the grid use of system charges, rent to The Crown Estate and insurance. The grid use of system charges vary significantly between projects based mainly on the wind farm's proximity to areas of high electricity demand. The costs presented here are representative.

The following sections primarily focus on specialist external services and equipment used during OMS. Excluding taxes, transmission use of system charges and spares, these include:

- Vessel manufacture
- Vessel operation and maintenance, including fuel, and
- External OMS services such as health and safety equipment and services, and survey, inspection, cleaning and repair services.

Almost all operational offshore wind turbines are either in warranty or under a long-term service agreement (LTSA) by the wind turbine manufacturer, though the transfer to full control of the asset owner has occurred at some early UK projects. UK asset managers are starting to consider the issues raised by increasing numbers of onshore turbines coming out of warranty by developing OMS strategies. The three main options are:

- Continue to purchase from the turbine manufacturer
- Move to using a third party service provider, or
- Establish in-house maintenance expertise.

A number of utilities use in-house expertise from their other power generation support functions for maintaining onshore wind turbines, using specialist third-party service providers (such as blade and gearbox specialists) where necessary. It is anticipated that offshore, more asset managers will continue to purchase offshore maintenance from the turbine manufacturer given the additional level of risk associated with the technology.

Source: BVG Associates

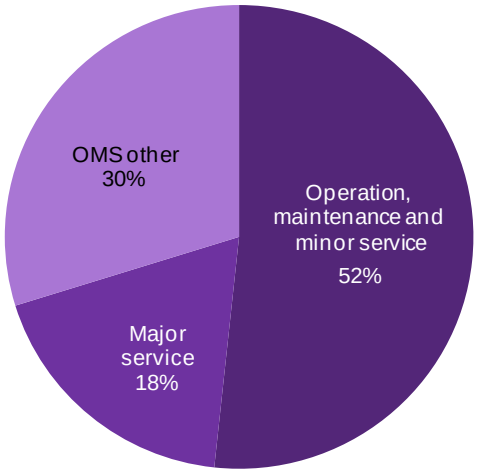

Figure 7.1 Breakdown of operation, maintenance and service costs.

7.1. Operation, maintenance and minor service

The operations base houses crew areas and spare parts as well as the transport vessels. If implementing a strategy using shore-based personnel transfer vessels, typically, wind farm operators will look to use the nearest port to the wind farm that meets its specification in order to minimise travelling time and make the best use of weather windows. Future wind farms that are further from shore are expected to require new vessel designs.

There are three main types of maintenance vessel:

- Personnel transfer vessels
- Offshore support vessels, and
- Mother ships.

Personnel transfer vessels are used to undertake daily visits carrying up to 12 technicians at a time as well as basic spares and equipment. The size of the vessels varies between 14m and 24m. The upper limit is because in the UK vessels 24m and above are classified as cargo ships and require additional certification. Vessels less than 24m in length are usually classified by the Marine Coastguard Agency as Category II, which limits their operating to range to 60nm (111 km) from base.

Offshore support vessels are likely to be semi-permanently stationed offshore and therefore are able to respond to issues more quickly. They will be floating vessels equipped with dynamic positioning (DP) that are typically designed to be have advanced personnel access systems, cranes, workshops, a helideck and accommodation for about 50 people. Siemens Wind and SSE Renewables are currently using an offshore support vessel at Greater Gabbard, which is approximately 65km from its operations base at Lowestoft.

Mother ships are variants of offshore support vessels but are typically larger, with accommodation for about 100 people and have the ability to launch and recover two or more "daughter" personnel transfer vessels. To date, UK projects have relied on shore-based operations but this is likely to change for projects built further offshore.

Both offshore support vessels and mother ships will be able to transfer technicians onto a turbine in much more challenging sea conditions than a personnel transfer vessel. 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 their use is proven at sea. With most operational offshore wind farms relatively close to shore, the scale of the market for offshore support vessels and mother ships is still unclear. Hotel vessels, often converted ferries, have been used to accommodate technicians during installation and major refurbishment but they are unlikely to be used extensively during operation.

Most of the maintenance vessels are owned and operated by specialist companies, although some wind farm owners have bought their own vessels.

UK supply track record (4)

The UK has manufactured personnel transfer vessels for a significant proportion of UK offshore wind farms. Personnel transfer vessels for UK wind farms have been built at a number of shipyards in UK, the rest of Europe and Asia. UK manufacturers of aluminium and composite vessels such as Alicat (and its subsidiary South Boats IOW), Alnmaritec and CTruk have been competitive in the UK market.

Most personnel transfer vessels for UK projects are operated by UK-based companies. A number of companies have been set up to own and operate personnel transfer vessels for asset owners. Although many were formed in response to local demand, companies now typically operate vessels for several wind farms across Europe.

There are UK designs for offshore support vessels and mother ships. Houlder, OSD-IMT and SeaEnergy have developed concepts and detailed designs for offshore support vessels and mother ships. Such vessels have not been used for offshore wind farms yet, although Siemens Wind Power recently agreed a long-term charter for two support vessels built by the Norwegian boat-builder Havyard which are due to enter service in early 2015.

Market readiness of UK suppliers for commercial scale projects (3)

Investments have been made which will enable UK manufacturers of personnel transfer vessels to supply Round 3 wind farms. Before its acquisition by Alicat, South Boats IOW moved to new premises and was awarded a DECC grant to develop a modular design of a personnel transfer vessel.

There is an increased focus on the supply of higher specification vessels by UK manufacturers in response to the demand for vessels that can operate further from shore. Feedback was that the asset owners are taking an increasing role in the specification of vessels.

UK operators of personnel transfer vessels already provide services to commercial scale offshore wind farms. All owners of Round 2 wind farms over 300MW have contracts with UK vessel operators.

There are no third party providers of offshore turbine maintenance services. Such service providers are frequently used for onshore turbines but for offshore wind farms there is a high proportion of turbines under warranty and plans by providers are at an early stage.

UK investment risk (4)

Further investments in new vessel manufacturing operations can be made incrementally at existing boatyards. While this typically means that investment is low risk, feedback was that a challenge for boat builders was that they were paid on delivery and could suffer from cash flow shortages, especially in fulfilling larger orders.

UK vessel operators have shown the appetite to make significant additions to their fleets. The lead time for a new personnel crew transfer vessel is about six months. Operators can therefore invest in new fleet capacity in time to meet demand for a given project. Feedback from industry is that there is a potential oversupply of vessels which increases the risk new investments. For wind farms further offshore, uncertainty over the OMS strategies chosen by operators is likely to deter investment without a firm order.

Most OMS services do not require significant capital investment. Excluding vessel and access system procurement, most expenditure is on Labour and although recruitment and training of suitable individuals in an expanding market is inevitably difficult, this can be achieved in time to fulfil orders. For third party turbine maintenance service providers, the scale of offshore wind projects means that such companies cannot invest incrementally to meet a demand.

Logic of UK supply (4)

Customers value a close relationship during the design and manufacturing processes. More than 10 boat builders in Europe and Asia have built personnel transfer vessels for UK offshore wind operators. Although cost is inevitably a factor, the specification of the vessel and its capability to deliver technicians to the turbines fit for work are important. The need for the close involvement of the end user in vessel design favours local suppliers.

Personal transfer vessel operators can operate vessels across Europe. Although some operators were set up to meet the demand from local wind farms, in a number of cases these have expanded and now supply several geographically diverse wind farms.

External OMS service providers do not need to be based close to the wind farm maintenance base. UK wind farm operators tend to use UK providers as these services can be secured at the required quality and price. Apart from turbine maintenance, external OMS services are generally needed intermittently and so a close proximity to the operations base is unnecessary. As the industry grows, clusters are likely to emerge as service providers look to develop a closer relationship with their customers.

Availability of UK expertise (4)

The UK has had a long-term demand for robust, lightweight vessels for the emergency services and leisure markets. This has enabled the UK to sustain a competitive composite and aluminium boat-building industry.

The oil and gas industry has developed a wide range of solutions for safe access to offshore structures. Inspection and repair activity is high within the North Sea sector with a high number of skilled and experienced technicians. It has also developed sophisticated logistics models which can be applied to the specific challenge of offshore wind farms.

There are synergies between the maintenance of rail fleets and wind farms. Rail operators have introduced fleet monitoring and logistics tools that could be applied to offshore wind farms.

Table 7.1 Synergies of parallel sectors with operation, maintenance and minor service and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Medium	CTruk
Nuclear	Low	None
Oil and gas	High	Hughes Sub Surface Engineering, Pharos Marine, Red7 Marine
Rail	Medium	None

Size of the UK opportunity (4)

Most services are delivered locally and supplied from within the home market. Figure 7.2 shows that large proportions of the expenditure on Labour, Materials and Other is potential UK expenditure, with an overall figure of about 85%.

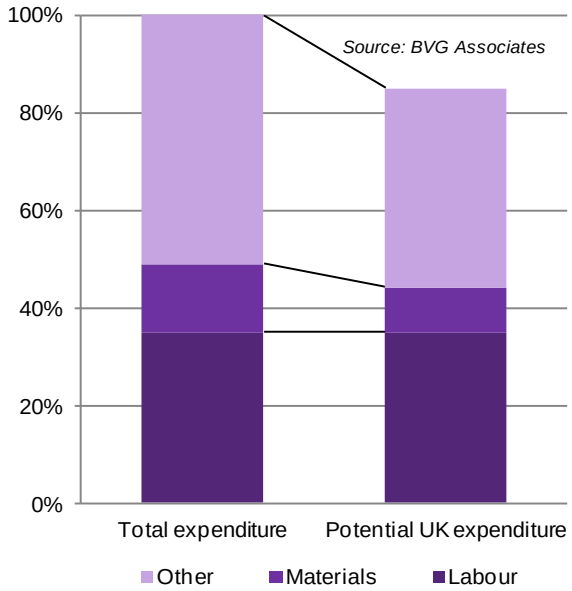

Figure 7.2 Breakdown of total operation, maintenance and minor service expenditure and potential UK expenditure.

Operation, maintenance and minor service forms about 52% of OMS costs and 20% of wind farm lifetime costs. With a potential UK expenditure of 85%, it creates a UK opportunity of 17%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
20%	85%	17%

Summary

Source: BVG Associates

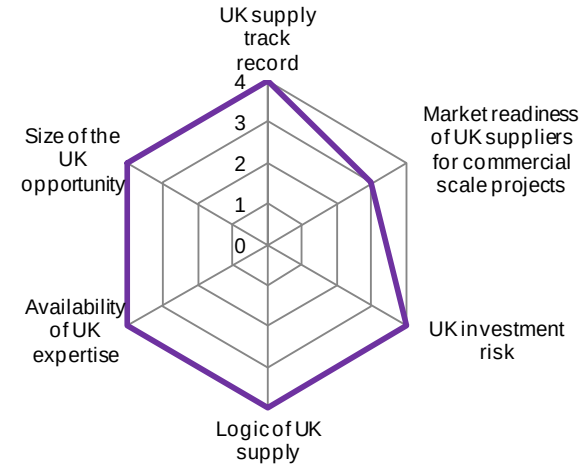

Figure 7.3 Summary of considerations concerning operation, maintenance and minor service.

7.2. Major service

Large vessels are needed to undertake the removal and replacement of major components, such as turbine blades or gearboxes, during operation. This may occur following a failure or as part of a replacement programme for components nearing the end of their lives.

As for installation, the current practice for replacing large up-tower components that cannot be lowered to the tower base using on-turbine cranes is to use a jack-up vessel, either the same or similar to the vessel used previously for installation. These vessels are needed to keep the hook movement to acceptable levels at the tower top. For installation, the demand is now for larger, self-propelled vessels with bigger cranes (see Section 6.4) so these are typically over-specified for large component replacement, with larger cranes and deck area than is needed. This has created a demand for dedicated OMS jack-up vessels, which may be met either by older installation vessels, converted to maximise their efficiency for unplanned service, or new purpose built vessels.

The UK supply of replacement turbine components is directly tied to UK manufacture of the original product discussed in the Section 4 and so is not discussed further in this section.

UK supply track record (3)

The UK has highly competitive operators with fleets likely to be increasingly involved in large component replacement. With the growth in the size of offshore wind turbines, it is likely that second generation offshore wind jack-ups, such as *MPI Resolution*, will be too small for the installation of the next generation of turbines but will be well suited for OMS.

There is little economic capacity for large vessel construction in the UK. Except for the construction of military vessels where political motivations and security concerns favour UK shipyards, the UK is unlikely to secure contracts for large vessel construction against global competition. UK shipyards may be competitive for vessel modification, however, and shipyards such as A&P, Cammell Laird and Harland and Wolff routinely undertake this kind of work for other offshore sectors. Cammell Laird undertook the extension of the cable-laying vessel *Nexans Skagerrak* in 2010, for example.

Market readiness of UK suppliers for commercial scale projects (3)

UK operators have already invested to meet the needs of the offshore wind industry. Much of this investment in new capacity is in larger turbine installation vessels but this has been sufficient to create new capacity for OMS services. UK operators therefore have the scale and vessels required to support commercial scale projects.

UK investment risk (3)

The market for specialist large component replacement vessels is at an early stage of development. The demand for vessels for large component replacement will increase and, unlike installation, there is a long term market. It is less clear that bespoke investments in new build vessels will be competitive compared with former or existing installation vessels.

An industry that is successful in addressing reliability issues will require fewer large component replacements. The development of next generation turbines has a strong focus on reliability. The degree to which this is successful will have a significant impact on large component vessel demand.

Vessel conversion is potentially a low cost and low risk investment. A converted vessel may be able available at lower charter rates which will be attractive to the industry provided that it is fit for purpose.

Logic of UK supply (3)

Large vessel operators could form part of local OMS clusters. Local vessel availability makes logistics sense. Vessels used for large component replacement will typically be chartered for a few months each year and it is therefore unlikely that operating from a site close to an individual wind farm will be attractive. As wind farms become larger and clusters form, there will be sufficient activity to sustain locally operated vessels, including through arrangements between owners of adjacent assets.

Availability of UK expertise (3)

There is a relevant offshore oil and gas expertise that can be applied to offshore wind. Feedback from industry was that while the skills from the oil and gas industry were recognised, there was concern that the differences were

not fully appreciated. The principal differences are that offshore wind activities involve multiple operations undertaken over a wide area.

Table 7.2 Synergies of parallel sectors with major service and the applied expertise of UK companies.

Sector	Synergy	Examples of applied UK expertise
Aerospace	Low	None
Automotive	Low	None
Composites	Low	None
Nuclear	Low	None
Oil and gas	High	MPI Offshore, Seajacks
Rail	Low	None

Size of the UK opportunity (3)

For new-build vessels dedicated to the service of turbines in UK waters, much of the cost is in the construction of the vessel. In these cases, as for turbine installation, the potential UK expenditure is likely to approach 60% (see Figure 7.4). In the future if vessels are modified in the UK or where the capital investment has been paid off, the potential UK expenditure could be higher.

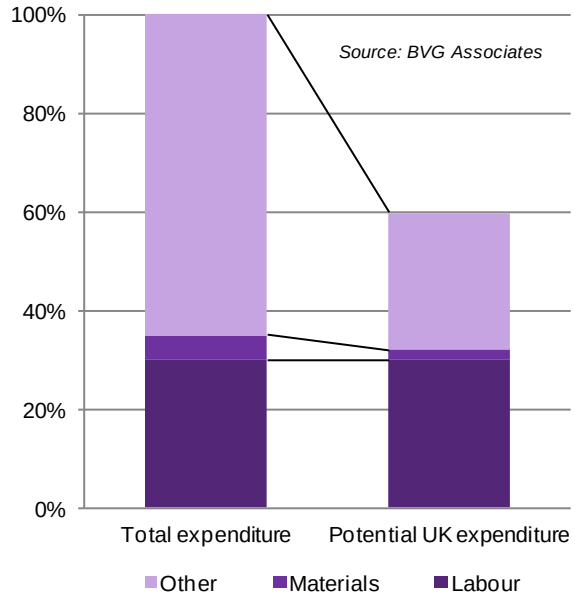

Figure 7.4 Breakdown of total unplanned service expenditure (excluding cost of components) and potential UK expenditure.

Unplanned service costs about 18% of OMS costs and 7% of wind farm lifetime costs. With a potential UK expenditure of 60%, it creates a UK opportunity of 4.2%.

Percentage of lifetime cost	Potential UK expenditure	Size of the UK opportunity
7%	60%	4.2%

Summary

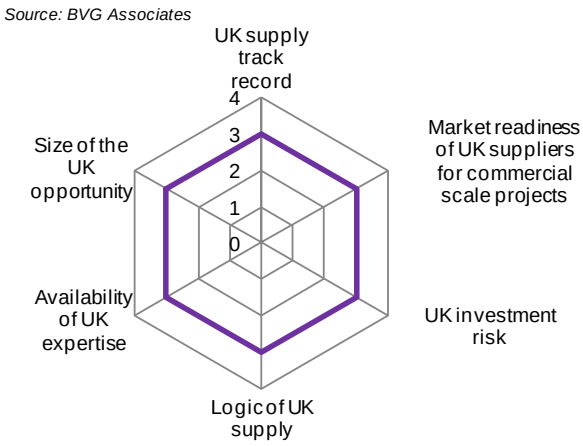

Figure 7.5 Summary of considerations concerning major service.

Table 7.3 Summary of conclusions on operation and unplanned service.

Criterion	Operation and planned maintenance	Unplanned service
UK proven expertise (supplied greater than 200MW equivalent)	Manufacture: Alicat/South Boats, Alnmaritec, CTruk Operation: Numerous suppliers operating locally and nationally	Manufacture: There is little economic capacity for large vessel construction in western Europe and none in the UK Operation: MPI Offshore, Seajacks
Additional future UK expertise	Coastal Marine Boat Builders, Mustang Marine, Turbine Transfers	Operation: Bechtel, Fugro, Gardline, Subsea7, Technip
UK supply track record	The UK has manufactured personnel transfer vessels for a significant proportion of UK offshore wind farms Most personnel transfer vessels for UK projects are operated by UK-based companies There are UK designs for offshore support vessels and mother ships	The UK has highly competitive operators with fleets likely to be increasingly involved in large component replacement There is little economic capacity for large vessel construction in the UK
Market readiness of UK suppliers for commercial scale projects	Investments have been made which will enable UK manufacturers of personnel transfer vessels to supply Round 3 wind farms UK operators of personnel transfer vessels already provide services to commercial scale wind farms There are no third party providers of offshore turbine maintenance services	UK operators have already invested to meet the needs of the offshore wind industry
UK investment risk	Further investments in new vessel manufacturing operations can be made incrementally at existing boatyards UK vessel operators have shown the appetite to make significant additions to their fleets Most OMS services do not require significant capital investment	The market for specialist large component replacement vessels is at an early stage of development An industry that is successful in addressing reliability issues will require fewer large component replacements Vessel conversion is potentially a low cost and low risk investment
Logic of UK supply	Customers value a close relationship during the design and manufacturing processes Personal transfer vessel operators can operate vessels across Europe External OMS service providers do not need to be based close to the wind farm maintenance base	Large vessel operators could form part of local OMS clusters
Availability of UK expertise	The UK has a long-term demand for robust, lightweight vessels for the emergency services and leisure markets The oil and gas industry has developed a wide range of solutions for safe access to offshore structures There are synergies between the maintenance of rail fleets and wind farms	There is a relevant offshore oil and gas expertise that can be applied to offshore wind
Size of the UK opportunity	Most services are delivered locally and supplied from within the home market	For new-build vessels dedicated to the service of turbines in UK waters, much of the cost is in the construction of the vessel

8. Support services

A number of services are relevant to two or more areas of the supply chain, or are independent of the wind farm development, installation and operating phases. These can be categorised under the following headings:

- Research, development and demonstration (RD&D), including full-scale test facilities
- Training
- Enabling activities, including by public bodies and trade associations
- Supply of health and safety services equipment, and
- Supply of tooling, consumables and materials.

The section will focus on large component test facilities as we believe that there are few issues in the other areas that are not covered elsewhere in this report. In general, UK suppliers have been active in these other areas particularly in training and health and safety.

8.1. Full-scale test facilities

This section considers the provision of facilities for offshore wind farm components with a focus on turbine and large component test facilities.

A site for wind turbine demonstration in an environment representative of a commercial offshore wind farm may be:

- A dedicated test site, either onshore or offshore, and consisting two or more turbine models; or
- Part of a commercial offshore wind farm, either as a first phase or as an extension, and likely to use the same supplier of turbine as the commercial phase.

In both cases, public grant funding may need to supplement private investment in order to make the demonstration viable.

For component test facilities, some funding is provided by government either directly through funding the construction of test facilities or by part funding RD&D projects using those facilities, up to relevant state aid limits. The rest of the cost is borne by the supplier and reflected in product cost.

UK supply track record

The UK has operating sites for offshore wind turbine demonstration. In 2013, Siemens Wind installed three of its 6MW offshore turbines in the UK. The first two were at Gunfleet Sands III wind farm with 120m rotors with the third at Hunterston with the new 154m rotor. Also in 2013, Samsung Heavy Industries installed its 7MW prototype at a near-shore site in Methil. In 2005, two Senvion (Repower) 5Ms were installed at the Beatrice Demonstrator wind farm, which provided an opportunity to deploy a new offshore turbine using a novel installation technique. Before this, in 2000, two Vestas V66-2MW turbines were installed at a near-shore site at Blyth, the UK's first offshore wind project.

The UK is establishing a track record for component testing in offshore wind. Narec's Fujin drive train test rig is rated up to 15MW and will be used for the first time for accelerated life testing of SHI's drive train. GE Power Conversion supplied much of the hardware for the drive train test facility at Narec as well as Vestas's 20MW in-house facility in Denmark. Narec also has a blade test facility which is capable of testing wind turbine blades up to 100m in length. Vestas has set up its global blade RD&D centre on the Isle of Wight, reflecting the long-established composites skills in the area, and also has a similar scale blade test facility there.

UK has test tanks and facilities for lightning tests facilities and high voltage systems.

Market readiness of UK suppliers for commercial scale projects

There are well developed plans for offshore wind demonstration sites. Turbine test sites under development in the UK are summarised in Table 8.1

In June 2013, The Crown Estate announced a leasing round to accelerate testing of emerging offshore wind technologies, including the use of floating foundations. The initiative aims to support the progress being made in lowering the levelised cost of energy (LCOE) and to encourage investment. Demonstration projects may be variations to existing commercial projects or new sites. The initiative aims not only to facilitate test new turbines and/or foundations but also new components, installation and OMS methods. Variations to commercial projects are seen as being less expensive than developing dedicated test sites although there may be less flexibility over products that can be tested.

UK support for demonstrating new turbines is available. Support includes the £35 million Prototyping for Offshore Wind Energy Renewables Scotland (POWERS) fund to target inward investment for offshore wind turbine manufacturers, and the £15 million Scottish Innovative Foundation Technologies Fund (SIFT). DECC has provided grants to manufacturers of large components, including to Artemis (now owned by MHI), David Brown Wind UK, GE Power Conversion and Vestas Technology.

The industry and DECC-funded Carbon Trust Offshore Wind Accelerator (OWA) includes nine offshore wind developers. Projects are focused on commercialising innovations in new turbine foundation designs for 30-60m water depths, access systems, designing for wake effects and optimising yields, developing better electrical systems and improving cable installation.

The Energy Technologies Institute is a public-private partnership between energy and engineering companies and the Government. It has supported several offshore wind technology projects, which have typically been further from commercial application than those funded by the OWA.

Table 8.1 UK offshore wind demonstration sites under development.

Site	Number of turbines (maximum total capacity)	Type	Developer	Status
Blyth Offshore Wind Demonstration site	15 (100MW)	Offshore	Narec	Consent awarded
European Offshore Wind Deployment Centre	11 (100MW)	Offshore	Aberdeen Offshore Wind (75% Vattenfall and 25% Aberdeen Renewable Energy Group)	Exclusivity agreement Consent awarded for offshore works
Fife Energy Park (Methil)	1 (SHI 7MW)	Near shore	SHI	Constructed 2013
ForthWind (Methil)	2 (12MW)	Offshore	2-B Energy	Exclusivity agreement
Hunterston	3 (Siemens SWT-6.0-154, MHI 7MW SeaAngel and one other)	Onshore	SSE/ Scottish Enterprise	Siemens turbine constructed 2013
Wave Hub	1 (6MW)	Offshore (floating)	Wave hub	Planning application submitted

UK investment risk

The business case for test sites that are developed by the private sector is not strong. In isolation, test sites cannot offer the same rates of return as commercial scale projects. With pressure on developers' capital expenditure and manpower and the uncertainty about timing of future commercial projects, a number of developers have delayed or rejected opportunities for investment in such sites.

Vattenfall's decision to seek new partners in the European Offshore Wind Deployment Centre (EOWDC) indicates that it wished to share the risk and investment.

Confidence in the timing of the future market is a concern. Investors in offshore technology demonstration need confidence in the timing of the future market to ensure that relevant technology is tested.

There is enhanced price support for offshore test and demonstration sites available in Scotland. The Scottish Government is introducing new Renewable Obligation Certificate (ROC) bands to support offshore test and demonstration sites deploying innovative turbines or floating turbines (2.5 ROCs and 3.5 ROCs respectively) provided they are accredited for ROCs by March 2017.

Logic of UK supply

As the leading market, the UK is an obvious place for offshore demonstration. UK test sites are most likely to represent the conditions experienced by commercial wind farms. UK also has areas of strong onshore and offshore wind resource, helpful in accelerating demonstration, including formal type certification tests.

Availability of UK expertise

The skills needed for offshore wind test facilities are new to the UK. It is important that the investment in new sites and test rigs draws on the best available expertise from more established centres of wind technology development.

Size of the UK opportunity

The cost of test facilities is low compared to the market size, but the learning obtained has a high value. Technical innovation is mainly driven by the need to reduce the LCOE. The investment in RD&D is small compared to the potential savings from the reduced LCOE and thus price support needed in the medium to long term.

World leading open access facilities can attract manufacturing investment. RD&D facilities encourage a greater presence of engineering teams which can be a step towards manufacturing investment in the UK, potentially leading to further supply chain opportunities.

Table 8.2 Summary of conclusions on full-scale test facilities.

Criterion	Full-scale test facilities
UK proven expertise (supplied greater than 200MW equivalent)	Test sites: Beatrice Demonstrator, Blyth Offshore Wind Farm, Gunfleet Sands III Component test facilities: Narec (dynamic drive train test rig to 10MW turbines, blade test rig to 100m blades), Vestas (blade test rig to 100m blades, blade bearing test rig)
Additional future UK expertise	Test sites: European Offshore Wind Deployment Centre, FORTHWind, Hunterston, Methil, Narec (100MW demonstration wind farm offshore), Wave Hub (one floating turbine)
UK supply track record	The UK has operating sites for offshore wind turbine demonstration The UK is establishing a track record for component testing in offshore wind
Market readiness of UK suppliers for commercial scale projects	There are well developed plans for offshore wind demonstration sites UK support for demonstrating new turbines is available
Investment risk	The business case for private sector developed test sites is not strong Confidence in the timing of the future market is a concern There is enhanced price support for offshore test and demonstration sites available in Scotland
Logic of UK supply	As the leading market, the UK is an obvious place for offshore demonstration
Availability of UK expertise	The skills needed for offshore wind test facilities are new to the UK
Size of the UK opportunity	The cost of test facilities is low compared to the market size, but the learning obtained has a high value World leading open access facilities can attract manufacturing investment

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