BVGassociates now in Scotland

Offshore wind pathways for Scotland

A report by BVG Associates

October 2012

BVG Associates

BVG Associates is a technical consultancy with expertise in wind and marine energy technologies. The team probably has the best independent knowledge of the supply chain and market for wind turbines in the UK. BVG Associates has over 130 career years experience in the wind and marine energy industries, many of these being “hands on” with wind turbine or marine device manufacturers in leading engineering, purchasing and production departments. BVG Associates has consistently delivered to customers in many areas of the onshore and offshore wind energy sectors, including:

- Market leaders and new entrants in wind turbine supply and UK and EU wind farm development
- Market leaders and new entrants in wind farm component design and supply
- New and established players within the wind industry of all sizes, in the UK and on most continents
- Department of Energy and Climate Change (DECC), RenewableUK, The Crown Estate, the Energy Technologies Institute, the Carbon Trust, Scottish Enterprise, Highlands and Islands Enterprise, Fife Council and other similar enabling bodies
- Developers, corporate and private landowners, wind farm owners, and
- Investors and technology innovators.

BVG Associates has produced a number of influential public reports for public and private sector clients. Many of these are available for download from our website (www.bvgassociates.co.uk).

BVG Associates in Scotland

BVG Associates has opened an office in Scotland which reflects our confidence in and commitment to the growth of the wind and marine renewable industries in Scotland. This new presence enables us to improve our service to clients in Scotland and those seeking to engage with the industry in Scotland.

The office is located in Burntisland, Fife and the team at the Scottish office have strong skills in offshore wind turbine technology, R&D, supply chain development and marine renewable technology. Our commitment is to be located in the midst of the sector as it establishes. Current clients in Scotland include wind turbine manufacturers and their supply chain, ports, developers, enablers and wave and tidal device manufacturers.

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Cover image courtesy of REpower

Introduction

By the end of 2013, UK offshore wind generating capacity will be over 3.5GW[1], by some distance the highest of any country in the world. The industry has successfully proved that offshore wind farms can be built quickly and at scale.

Due to the offshore wind industry's significant achievements, reducing the cost of energy in moving up to industrial scale has become a key topic. While market support at current levels is viewed as justified in the short term, cost of energy needs to reduce significantly in the medium term in order that offshore wind stays as the large-scale renewable energy generation technology of choice for Northern Europe. Electricity from offshore wind farms will continue to cost more than from onshore projects as the increased energy production cannot compensate for the increased balance of plant, installation and operational costs offshore, but the gap between the two will decrease over time with learning and the benefits of scale. Last year, a target cost of £100/MWh for projects commencing in or close to 2020 emerged, about 40% lower than for projects commencing today.

In the UK, this increased focus on cost led to two initiatives. The first, the Offshore Wind Task Force, brought together key industry figures under the auspices of the UK Department of Energy and Climate Change (DECC) to recommend what actions were needed to achieve this cost of energy reduction. The second, the Offshore Wind Cost Reduction Pathways Study led by The Crown Estate, generated a comprehensive, transparent evidence base, built through significant industry engagement, to show what reduction industry considered was achievable and under what conditions. It modelled offshore wind costs across the supply chain by drawing on three parallel workstreams of finance, supply chain and technology.

BVG Associates delivered the technology workstream and contributed to the supply chain workstream.[2]

Figure 1 The Port of Leith is emerging as a key offshore wind manufacturing site.

This report highlights the main areas of cost of energy reduction anticipated through technology innovation and considers how the increased focus on cost reduction creates opportunities for Scotland.

Scotland has many strengths. Although many of these are not unique and it will face strong competition from other parts of Europe and beyond, it has shown strong political leadership and demonstrated a proactive approach through the work of Scottish Government, Scottish Enterprise (SE), Highlands and Islands Enterprise (HIE), Scottish Development International and others. This focussed activity has, for example, led to the emergence of the Port of Leith as a potentially significant manufacturing location for offshore wind and the successful entry to the industry of a number of Scottish suppliers, transferring excellence from other sectors.

By aligning its investment with the key opportunities for cost of energy reduction and utilising its significant existing skills base, Scotland can enhance the competitive position of its businesses and establish a vibrant new manufacturing and service sector to complement those of steel fabrication, aviation, electronics and oil and gas.

Areas of cost reduction

A crucial element of the Offshore Wind Cost Reduction Pathways Study was that it considered the cost of energy, which is a function not only of the capital expenditure (CAPEX) and operational expenditure (OPEX) but also the lifetime energy production. The levelised cost of energy (LCOE) was defined for the technology works steam as the income per MWh required (from whatever sources, in end 2011 terms) to give the project owner about a 10% return on investment over the life of the project.

[1] Offshore wind deployment chapter in State of the Industry Report Onshore and Offshore Wind: A Progress Update BVG Associates on behalf of Renewable UK, October 2011, available online at http://www.bvgassociates.co.uk/Publications/BVGAssociatespublications.aspx, accessed October 2012

[2] Pathways to Cost Reduction in Offshore Wind: Technology workstream, BVG Associates on behalf of The Crown Estate, June 2012, available online at http://www.bvgassociates.co.uk/Publications/BVGAssociatespublications.aspx, accessed October 2012

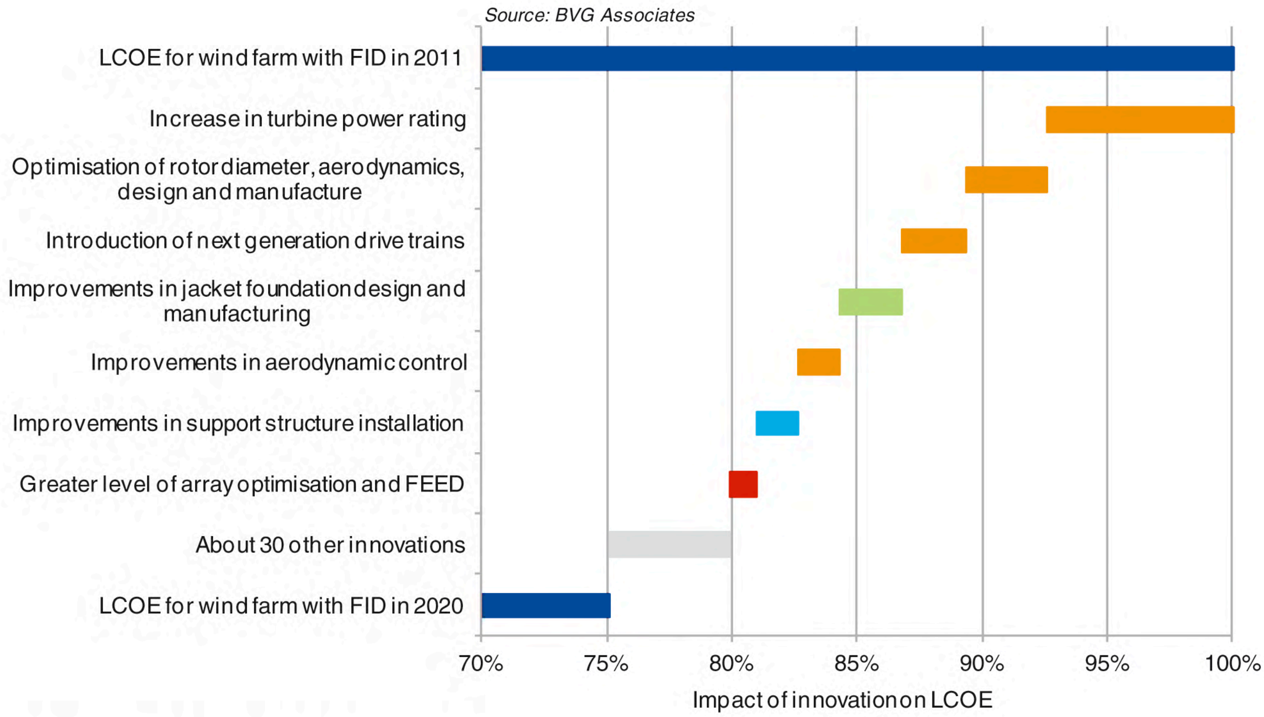

Figure 2 Anticipated impact of technology innovations for a wind farm using 6MW turbines with financial investment decision (FID) in 2020, compared with a wind farm with 4MW turbines with FID in 2011.

The headline finding of the combined study was that with the right conditions and in a technology-focussed scenario with about 18GW capacity installed up to the end of 2020, the LCOE could indeed be reduced by about 40%, made up of about 25% from the impact from technology innovations and about 15% made from changes in the way of doing business and levels of competition.

The key transition described in the study is from a typical wind farm with final investment decision (FID) in 2011, which uses turbines with a rated power of about 4MW, to the use of next generation turbines rated at about 6MW, with much larger rotors, likely to be typical for a project with FID in 2020 and constructed between 2022 and 2024.

At the heart of that study is a cost model in which elements of baseline wind farms are impacted by a range of technology innovations. These wind farms are defined in terms of the turbine rated power (4MW, 6MW and 8MW), site conditions (three at 40km from construction port at 25m, 35m and 45m water depth, and one at 125km from construction port at a 35m water depth, each with different wind conditions), and four points in time at which the projects reach FID (2011 (the baseline), 2014, 2017 and 2020). The analysis also considers four pathways that the industry could take, relating to size of UK market and amount of focus on technology.

Through detailed discussions with companies from across the supply chain using interviews and workshops, about 60 distinct technology innovations were identified as having the greatest quantifiable impact on the cost of energy through changing the design of hardware, software or process.

Turbine innovations

Turbine power rating

Figure 2 shows that over 80% of the total anticipated technology impact is achieved through seven key areas of innovation, of which the largest is the increase in turbine size from 4MW to 6MW. By virtue of having fewer turbines for a given wind farm rated power, there are significant savings in the cost of foundations, installation, and operation, maintenance and service (OMS).

Public sector support can accelerate the route to market for these turbines by making available onshore and offshore test sites that will contribute to the verification of this new offshore technology. Scotland can play a pivotal role here because it has the highest wind resource in the EU, a key requirement for excellent test sites making it especially attractive for turbine manufacturers. There is an onshore test site at Hunterston under construction and others in development, including the near-shore site at Methil and an offshore site at the European Offshore Wind Deployment Centre (EOWDC) near to Aberdeen. Other locations are being explored to meet the urgent need for greater capacity.

With funding support such as that provided for prototypes by the POWERS fund, and potential investments by venture funds, Scotland is well-placed to help bring these cost-saving turbines to market as early as possible and give Scottish companies first experience with them. Swift action is needed, however, in order to meet the development timelines of projects for deployment in 2017-18.

Image courtesy of REpower

Figure 3 The Scottish offshore Beatrice Demonstrator was the first in the world to use large 5MW turbines and deep water jacket foundation technology.

Rotor diameter, aerodynamics, design and manufacture

Optimisation of rotor design and manufacturing process is anticipated to have an impact on LCOE of 4% for projects with FID in 2020, compared to 2011. The primary benefits are gained from optimising the rotor diameter, giving a significant increase in energy production with a smaller increase in wind farm CAPEX. Other significant benefits can be gained through optimising aerofoil performance, blade structural design and improving design processes through improved analysis tools and better characterisation of 2D and 3D aerodynamic coefficients.

There is scope for improvements in blade manufacturing processes to optimise material use, minimise tooling costs and ensure repeatability and quality. While the opportunities for Scottish blade manufacture and design are limited at present, there is some potential for inward investment leading to blade manufacturing in the region, due to the high logistics cost of transporting such large and delicate structures. Most of the blade design and aerodynamic work is not typically associated with manufacturing sites and is usually carried out at blade manufacturers' internal R&D centres, most of which are based on the Continent. Opportunities to impact LCOE do exist for development and supply of novel composite materials, specialist design processes and manufacturing optimisation. These areas may specifically provide opportunities for technology transfer from the Scottish aerospace sector.

Next generation drive trains

Aside from an increase in the turbine power rating, other innovations within the turbine nacelle are anticipated to reduce the LCOE by more than 3%. The major benefit here comes from the introduction of next-generation drive trains, including hydraulic, direct-drive and mid-speed generator solutions, which primarily are anticipated to reduce OPEX costs through greater reliability.

Two Scottish technology companies are at the forefront of efforts to develop innovative drive trains. Artemis Intelligent Power has developed a digital displacement hydraulic transmission system. The company's acquisition by Mitsubishi Heavy Industries has led to its technology being used in the 7MW Sea Angel turbine currently under development with significant UK public funding. Mitsubishi's UK design office is in Glasgow.

Edinburgh-based NGenTec has received public funding to develop an innovative permanent magnet generator for offshore wind turbines.

Image courtesy of NGenTec

Figure 4 NGenTec's 1MW generator demonstrator.

Samsung Heavy Industries has also signed a multimillion pound deal with Scottish-owned David Brown Gear Systems to supply and design gearbox systems for Samsung's next generation offshore wind turbine.

A challenge for turbine manufacturers will be in demonstrating greater reliability of their next generation turbines to customers with experience of drive-train operational issues to date. A step change in verification testing and increased openness are seen as critical to achieving this. Scotland has existing capability within the Scottish Energy Laboratory (SEL) and the establishment of the Offshore Renewable Energy Catapult in Glasgow has the potential to enhance this further. In particular, a Catapult, Narec, is currently constructing a world-class 10MW drive-train test facility in Blyth.

Aerodynamic control

Further developments in active pitch control, inflow wind measurement and active and passive airflow control on blades are accumulatively anticipated to contribute to a further 2% reduction in LCOE.

The aerodynamic control system design teams at MLS Intelligent Control Dynamics, Strathclyde University and GL Garrad Hassan, all in Glasgow, lead the way in independent research into advanced aerodynamic control. Also, Glasgow based Sgurr Energy are working with partners Galion to promote and develop the use of LiDAR. This technology is fast gaining acceptance for inflow measurement for array optimisation, and for turbine control.

A number of the innovations in this area have grown from the aerospace and defence sectors. There is still significant developments needed both in hardware and software development in order to support the next generations of turbines and there is opportunity for further transfer from these sectors in Scotland or elsewhere.

Foundation design and manufacturing

The most common deeper water, larger turbine (greater than 30m depth, 6MW turbine) foundation technology is expected to be the four-legged steel jacket, although other steel designs (such as tripods and tripiles) have also been used. New designs have also been proposed, such as braced monopiles, jackets with three or six legs, jackets with a twisted structure and concrete gravity base structures.

The most significant area of innovation in the production of foundations is expected to be the introduction of lean, serial manufacturing processes and tooling that will reduce labour costs and increase production volumes from a given facility. Through Burntisland Fabrications (BiFab), Scotland is already at the forefront of supply of jacket foundations. It built the first offshore wind turbine jacket for the Beatrice demonstrator project in 2007 and has subsequently completed projects for the German Alpha Ventus project and the UK Ormonde project in the Irish Sea. Looking ahead to the needs of future projects, BiFab has developed a new jacket design, is increasing the footprint of its Methil Energy Park facility and is investing in new equipment that will enable it to produce up to 130 units a year. Importantly, this development was made possible by the provision of R&D grants and the involvement of Scottish utility SSE Renewables which bought a share in the company and agreed to a long-term purchase agreement.

Image courtesy of Ben Barden

Figure 5 Foundations manufactured by BiFab await deployment for the Ormonde Offshore Wind Farm.

Foundation production offers a clear opportunity for Scotland. Over the last 50 years, it has produced some of the largest steel and concrete marine structures in the world for North Sea offshore platforms and it still has a number of suitable port sites with deep water access and heavy lift quayside facilities such as Kishorn, Methil, Nigg and Ardesier. The development of EOWDC is seen by prospective foundation suppliers as a crucial opportunity to demonstrate. Furthermore, many of the projects in the Scottish Territorial Waters development round have water depths of more than 40m with challenging sea bed conditions and this is likely to stimulate demand for innovative designs.

A further example of innovation is the introduction of concrete gravity base foundations, installed as part of a float-out-and-sink strategy in which turbine and foundation are assembled together at the quayside before being transported as a single item to site for installation. Key port requirements for concrete foundation fabrication are large areas of land with direct access to deep water quayside. With Kishorn and Ardisier, Scotland has two suitable sites available which could be developed to serve the sector. Beyond this, floating foundations may play a role in reducing the cost of installation but these are not expected to reach significant deployment in the market before 2020.

Support structure and cable installation

Innovations are anticipated that also lower the cost of foundation installation. Benefits will come from the introduction of installation vessels that can operate in a wider range of conditions and bespoke fleets of vessels for jacket foundation installation. The foundation installation vessel fleet will be made up a of a range of vessels, each optimised for their role and including the introduction of large, floating (as opposed to jack-up) heavy lift vessels designed specifically for offshore wind.

Cable installation also provides opportunities. Scotland should exploit its excellence in subsea operations looking to companies to assist in new cable installation processes, particularly around cable termination. Aberdeenshire-based ROVOP has made a significant entry to the market winning contracts to supply European wind farms with remotely operated vehicles (ROVs) to assist in the cable installation process. Technip has based its offshore wind business in Aberdeen and, having acquired the assets of Subocean in 2012, is well positioned to make an impact on the cable installation market.

Overall, the anticipated reduction in the LCOE for projects with FID in 2020 due to innovations in wind farm installation is about 4%.

Array optimisation and FEED

While wind farm development represents a small fraction of lifetime costs, an important finding in the study was that the impact of investments in engineering and site characterisation can lead to reductions in the LCOE of about 2%. The principal innovations relate to greater levels of analysis and optimisation during the front-end engineering design studies (FEED). Cost reductions can be realised by working more closely with design partners and investing in design optimisation effort at an early stage. SSE Renewables has pioneered the collaboration route in offshore wind, building partnerships in key areas of the supply chain such as turbines (Siemens Wind Power), foundations (BiFab), installation (Subsea 7) and wind farm electrical systems (Siemens Transmission and Distribution).

Introduction of multivariable array layout optimisation can play an important role, especially for sites with varying conditions and will also help to automate aspects of the wind farm design procedure. This will require development of software model solutions and Scottish academic institutions such as Strathclyde University and the Scottish partners in the SUPERGEN Wind consortia could play a key role in developing these. Scottish-based geophysical, geotechnical surveyors and consultancies undertaking FEED studies have a lot to contribute, using learning from other marine industries such as oil and gas to optimise processes and component design, such as cable design and installation, at an earlier stage to reduce the width of engineering envelopes and design conservatism.

Electrical connection

A significant amount of new offshore infrastructure will be needed to connect offshore wind farms to the grid, including offshore transformer and high voltage DC converter platforms supported on foundations in deep water. Companies that currently innovate in this space in Scotland could have a key role in shaping offshore transmission in the future.

The development of the proposed SuperGrid offshore DC transmission network will drive the need for testing of a new range of electrical components. Organisations such as the umbrella group of SEL could take advantage of the growth and potential funding opportunities that this will offer.

Innovations in array cable technologies are anticipated to reduce the LCOE by approximately 0.5%. Most significant is the introduction of higher voltage array cables, likely up to 66kV, which reduce capital costs and electrical losses with larger turbines.

Operation, maintenance and service

The cost of unreliability is much greater offshore than onshore, with the loss of generation during down time in bad weather (often associated with high wind speeds and hence good energy production) and the cost of the vessel needed to exchange the component often of greater significance than the cost of the failed component itself.

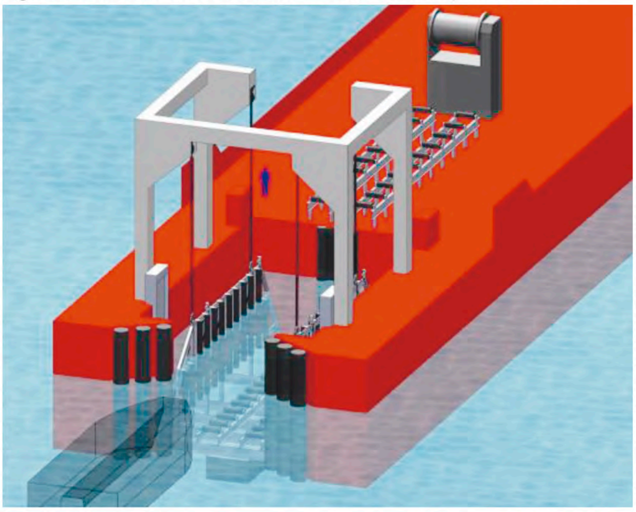

Image courtesy of Divex

Figure 6 The Divex vessel launch and recovery concept.

Investment in turbine reliability will in time lead to cost reductions, as will the introduction of more sophisticated holistic, condition-based maintenance strategies, which offer the prospect of reduced downtime and frequency of unexpected, large component retrofits.

A further important innovation will be improvements in the transfer of personnel from vessel to turbine. Adapting principles from the diving industry, Aberdeen-based Divex has won Carbon Trust Offshore Wind Accelerator funding to develop its launch and recovery system that uses a semi-submersible cradle that can be lowered from the stern of the mother ship to launch and retrieve daughter craft.

Condition monitoring of wind farm components to allow early diagnosis of faults will have an increasing role in managing OPEX. The Centre for Advance Condition Monitoring based at Strathclyde University is developing innovative technologies to improve the availability of offshore wind farms and reduce the need for expensive reactive, offshore maintenance. The centre is supported by industrial partners Sgurr Energy and David Brown.

SE and HIE have also shown leadership in supporting R&D work in condition monitoring. Wood Group and others have been building experience of wind turbine OMS onshore that will be of direct relevance offshore, especially as today's model of wind turbine manufacturer dominance in the warranty period softens.

Reductions in OMS costs are largest further from shore due to the greater opportunity for innovation presented when moving into more severe conditions.

Further ahead

There is further scope for technology innovation leading to cost reductions likely to impact beyond 2020. Among these are new turbine concepts, such as two-bladed rotors, generally regarded as well suited to offshore conditions, and floating foundation solutions, enabling economic access to deep water sites close to shore with high wind speeds that are common around the Scottish coast. At a wind farm level, centralised grid control and moving complexity from each turbine to the substation offers the prospect of further savings, along with changes to the wind farm design life. At a system level, it is anticipated that there will be significant further progress in terms of high voltage direct current (HVDC) networks for transmission, with added benefits when combined with DC power take off at the turbine level. The unused potential at FID in 2020 of innovations modelled in the project, coupled with this further range of innovations not modelled, suggests that there are significant further cost reduction opportunities when looking to 2030 and beyond, giving creative Scottish businesses a long-term opportunity to make a difference.

Critical in delivering successful investment in innovation is the industry's confidence in a growing and sustainable market, targeted support and clarity about where Scottish company capability and industry need overlap with the biggest opportunities for reducing cost of energy.

Making a difference

During our engagement with industry to establish the opportunities for cost reduction through technology innovation, it was clear that offshore wind businesses recognised the need for cost reduction and were active in exploring opportunities. With support, Scottish companies with ideas for new products and services can realise these opportunities. Key areas for companies to focus on are given in Table 1, with a traffic light indicator of the scale of the opportunity in Scotland based on the potential for cost reduction and the technical strengths of the Scottish supply chain.

The definitions for the traffic light colours are:

- (Green) Good opportunities for Scottish companies to contribute to cost reduction through innovation.
- (Amber) Limited opportunities for Scottish companies to contribute to cost reduction through innovation.
- (Red) Minimal opportunities for Scottish companies to contribute to cost reduction through innovation

Table 1 Focus areas for cost reduction in Scotland.

Opportunity	Innovation area
A	Turbine power rating
A	Rotor diameter, aerodynamics, design and manufacture
A	Next generation drive trains
A	Aerodynamic control
G	Foundation design and manufacturing
G	Support structure and cable installation
G	Array optimisation and FEED
A	Electrical connection
G	Operation, maintenance and service
G	R&D, testing and demonstration

As the Scottish government has appreciated, to do this, Scotland needs to identify the strengths of its infrastructure, such as R&D and test facilities and port infrastructure, and promote technology transfer from parallel sectors, focussing on the key opportunities for cost reduction. With further proactive support and focus on the right areas, there is a strong future for Scottish businesses in accessing the economic benefits from exceptional wind resources of the Scottish coast and further afield. Scottish businesses can also benefit from investments elsewhere in the UK such as through DECC funding and the Regional Growth Fund.

BVG Associates is excited to share in that journey by providing market-leading technical and supply chain support to those focussed on success in one of the most dynamic and exciting industries we have today.