BVGassociates

Approaches to cost-reduction in offshore wind

A report for the Committee on Climate Change

June 2015

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 more than 150 years of experience in the wind industry, many of these being "hands on" with wind turbine manufacturers, leading RD&D, purchasing and production departments. BVG Associates has consistently delivered to customers in many areas of the wind energy sector, including:

- Market leaders and new entrants in wind turbine supply and UK and European 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, and
- The Department of Energy and Climate Change (DECC), RenewableUK, The Crown Estate, the Energy Technologies Institute, the Carbon Trust, Scottish Enterprise and other similar enabling bodies.

The views expressed in this report are those of BVG Associates. The content of this report does not necessarily reflect the views of the Committee on Climate Change.

Front cover image courtesy of DONG Energy

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Glossary

Term	Definition
Allocation round	Part of the UK's CfD process (see CfD below) in which developers of most renewable and low carbon technologies (excluding nuclear, CCS (see CCS below) and tidal lagoon, which negotiate CfDs on a project-basis) apply for support. These rounds are expected to be held annually. The UK Government divides the LCF (see LCF below) budget into pots (see CfD pot below) and auctions are held if there is an over-subscription for a pot.
Balance of plant (CAPEX)	Foundation (including seabed connection and secondary steel work to provide personnel and equipment access), array cables and array cable support. This element includes warranty costs but excludes the offshore substation, export cables and onshore transmission assets.
Capacity Factor	Ratio of annual energy production to annual energy production if all turbines generated continuously at rated power.
CAPEX	Capital expenditure (see "Balance of plant", "Installation", "Project" and "Turbine" for specific element definitions).
CCS	Carbon capture and storage.
CfD	Contract for difference. A support mechanism for renewable and low carbon generation in the UK, in which a generator is paid (or pays back) the difference between a "Strike Price" (see below) and a measure of the average market price for electricity for electricity generated electricity for 15 years. The CfD regime replaces the RO regime (see RO below). The budgets for CfDs are released in "CfD pots" (see below) in "Allocation rounds" (see above). The earliest offshore wind projects supported by CfDs will be installed from 2017.
CfD pot	The budget for CfD allocation rounds (see above) is split into pots. Pot 1 is for established technologies, including onshore wind and large-scale solar photovoltaic. Pot 2 is for less established technologies, including offshore wind.
Cost of energy	The revenue required (from whatever source) to make a rate of return on investment equal to the WACC (see WACC below) over the life of the wind farm. See Section 2 for detailed description.
Cost of capital	The weighted average lifetime cost of capital in real, pre-tax terms, taking into account the cost of debt and equity and the ratio between debt and equity.
DECC	The UK Government Department for Energy and Climate Change.
Driver	A government policy affecting the offshore wind market.
EMR	Electricity Market Reform. The process started by the UK Government in 2011 to change the way it supports the development of new renewable, low carbon and fossil fuel generation. This includes the replacement of the RO regime (see RO below) with the CfD regime (see CfD above).
Energy production	Net energy production averaged over the wind farm life at the offshore metering point at entry to the offshore substation.
FID	Final investment decision, defined here as the point of a project life cycle at which all consents, agreements and contracts required to commence project construction have been signed (or are at or near execution form) and there is a firm commitment by equity holders and debt funders to provide funding to cover the majority of construction costs.

FIDER	The UK Government's Final Investment Decision Enabling for Renewables regime, an interim precursor to the enduring CfD regime.
Finance (opportunity)	Changes in the approach to the provision of capital and insurance, such as policy and regulatory measures to reduce systemic risk, changes in capital structures, reductions in the margin charged by debt providers and reductions in project specific risks.
GW	Gigawatt.
Installation (CAPEX)	Transportation of components from the port nearest to the component supplier, plus all installation and commissioning activities for turbine, foundation, turbine and array cables. This element includes contingency and insurance during construction but excludes the installation of the offshore substation, export cables and onshore transmission assets.
LCF	Levy Control Framework. The UK Government's system for funding a number of electricity market interventions, including the RO and CfD regimes (see above and below). The Government levies funding from electricity suppliers up to an agreed annual cap. Suppliers then recoup this cost from their customers, UK energy users.
LCOE	Levelised cost of energy. See "cost of energy".
MW	Megawatt.
MWh	Megawatt-hour.
OFTO regime	Offshore Transmission Owner regime. The UK regime under which the transmission infrastructure of an offshore wind farm (including the onshore and offshore substations and export cables) is owned, operated and (in some cases) built by a separate party to the owner of the main wind farm infrastructure.
OPEX	Operational expenditure (see "Transmission" and "Wind Farm" for specific element definitions).
Project (CAPEX)	The wind farm design, consenting, contracting and developer's project management activities through to the works completion date (WCD).
R&D	Research and development.
RO	Renewables Obligation. A support mechanism for renewable energy generation in the UK. The RO regime will be phased out in 2017 and replaced with the CfD regime (see above).
Supply chain (opportunity)	Small, evolutionary changes in the design of hardware, software or process, especially including interfaces between organisations, in the broadest sense.
Strike Price	The price per MWh (see above) that a generator receives for a project with a live CfD (see above). If the average market price for electricity in the Great Britain (GB) market is less than the Strike Price, the UK Government will pay the difference from the LCF (see above). If the average market price is more than the Strike Price, the generator will pay back the difference. The Strike Price for a given project is defined by the result of a given allocation round.
Support cost	The additional cost of offshore wind deployment compared with the equivalent cost of the lowest cost alternative. For this study, we use the cost of generation by combined cycle gas turbines (CCGT) with carbon price uplift. For more detail, see Appendix D.
Technology (opportunity)	Substantive changes in the design of hardware, software or process. The definition is wide and innovation may be evolutionary or a breakthrough. Innovation may also be a collection of advances with

	the same objective or relate to the development of new technology standards.
Transmission (OPEX)	All offshore transmission owner (OFTO) charges and generation transmission use of system (G-TNUoS) charges.
Turbine (CAPEX)	The rotor, nacelle, tower and auxiliary systems, including equipment that may be located in the tower. This element includes delivery to the nearest port to the supplier and warranty and commissioning costs.
TWh	Terawatt-hour.
UK energy user	Private and commercial customers of UK electricity suppliers who contribute to the LCF fund (see above) through their energy bills.
WACC	See "Cost of capital", above.
Wind farm (OPEX)	Operational expenditure covers all costs from when the developer commissions the first turbine, including operational costs relating to the day-to-day control of the wind farm, condition monitoring, and planned preventative maintenance, health and safety inspections. This includes reactive service responding to unplanned systems failure in the turbine or balance of plant, insurance during operation and land rent.

Executive summary

Given the right market and policy support, the offshore wind industry is likely to be an important player in a decarbonising European energy market in the 2020s.

This does not need dramatic shifts in policy or radical breakthroughs in technology. Countries across Europe are already deploying offshore wind on an industrial scale and much of the technology and expertise needed to achieve major cost of energy reduction is already in place.

This report builds an evidence base for the drivers of cost reduction, combining a detailed bottom-up engineering analysis of the opportunities for cost reduction, using latest industry insights.

This evidence suggests that the visibility of a sustainable European market with an annual average deployment rate of 3GW to 4GW (comprising 1.5GW in the UK) is the most important single driver of cost of energy reduction. At this rate of deployment, providing good visibility decreases the cost of support for UK energy users by 24% (equivalent to a saving of £1.9 billion between 2021 and 2030) compared with current levels of visibility.

There is the potential to achieve even greater cost of energy reduction. In a European market with an annual average deployment rate of 4GW to 5GW (comprising 2GW in the UK), the UK could see 35% more generation with an increased total cost of support to UK energy users of only 4%. These results reflect a balanced assessment of future developments, however, any assessment of future cost is subject to uncertainty. The scenario analysis in this report explores this in detail.

Other government interventions (such as funding for R&D and measures to reduce financial risk) cannot replace visibility and market size but can help achieve further cost of energy reduction in a healthy market.

Methodology

The objective of this study is to identify the elements of a policy strategy for offshore wind that balances effectiveness in cost of energy reduction in projects with first generation in the 2020s with minimised support cost to UK energy users. This involved:

- Reviewing the opportunities for cost of energy reduction in offshore wind over the next 15 years and preparing an “Upper bound” for cost of energy reduction in the 2020s
- Assessing the position of the UK market in a European and global context to show the relative importance of UK Government policy decisions for future cost of energy reduction in offshore wind
- Defining the policy drivers that will affect the cost of offshore wind energy in the 2020s and quantifying the impact of each driver in the “Upper bound” scenario
- Quantifying the impact of each driver in a number of scenarios to explore the impact of different approaches that European governments could take to offshore wind in the 2020s, and
- Presenting key lessons for UK Government policy to efficiently enable cost of energy reductions while giving best value to UK energy users.

We have based the results of this study on the findings of a detailed programme of one-to-one engagement with senior staff across the industry. This survey sample covered multiple players at each stage of the supply chain, developers and financiers. It is not exhaustive, however, and specific industry representatives may have views that differ substantially from what we represent here. We have supplemented and tested this industry input with knowledge from previous industry studies and a detailed literature review, including the most recent industry surveys on progress in cost of energy reduction.

Opportunities for cost of energy reduction

There is now strong evidence to suggest that the offshore wind industry is on track to reduce the cost of energy to the UK Government’s target of £100 per MWh for projects with financial investment decisions (FID) in 2020. This includes the results of the first Contract for Difference (CfD) allocation round in early 2015 and the findings of the Offshore Wind Programme Board’s *Cost Reduction Monitoring Framework* study.[1]

It is also clear that there are many opportunities for further significant cost of energy reduction in the 2020s. From a technology perspective, this reduction in the cost of energy for UK projects is based on innovations such as:

- The anticipated development of more reliable turbines, including with rated capacities of 10MW or higher
- The continued development of existing support structure designs and the introduction of novel concepts
- Improvements in HVAC transmission technology and the development of more cost-effective HVDC systems, and
- Optimised lifetime care of wind farm assets, including improved vessel access and condition monitoring systems.

[1] ORE Catapult, Cost Reduction Monitoring Framework: summary report, February 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/ORE+Catapult+report+to+the+OWPB/a8c73f4e-ba84-493c-8562-acc87b0c2d76, last accessed March 2015.

Alongside these innovations, we also expect to see the supply chain grow and mature, giving benefits through increased levels of competition and collaboration and improved management of risk.

Finally, we expect to see reductions in the weighted average cost of capital (WACC) of UK projects as the finance community builds experience in offshore wind and the UK regulatory environment.

Under the most positive market conditions, we estimate the cost of energy for a typical UK project with first generation in 2030 will be £80 per megawatt-hour (MWh) in 2012 terms. This “Upper bound” scenario is a P20 assessment, in which we assume there is only a 20% chance of exceeding this level of cost of energy reduction. We based this estimate on a detailed literature review and extrapolations of cost models created during the preparation of earlier industry reports. These included the *Offshore wind cost reduction pathways study*[2] published by The Crown Estate in 2012 and *Future renewable energy costs: Offshore wind*[3] published by KIC InnoEnergy in 2014. We have based all analysis in this report on a set of typical project characteristics fixed across the period of this study.

To ensure a robust analysis, we allocated the cost of energy reductions in two different ways. First, we allocated it to innovations in different elements of the wind farm. Second, we allocated it to opportunities in technology, supply chain and finance. We validated this assessment through a programme of industry engagement.

The position of the UK offshore wind market

Offshore wind is of strategic importance to the UK. We have the greatest wind resource in Europe and a large seabed area with many relatively shallow areas that are well suited to the deployment of large-scale projects. This gives the opportunity for the UK to establish a competitive advantage in a carbon-constrained world, making it less dependent on overseas energy markets.

The UK has also been an early mover in supporting offshore wind. Our first offshore wind project was installed in 2001 and, since then, it has supported a strong and consistent programme of deployment. The UK is currently the global market leader in offshore wind, with 46% of installed capacity at the end of 2014, and it is expected to retain this leading position for the foreseeable future.

Although much of the supply chain is currently based on the Continent, there is now growing investment in industrial capacity in the UK.

Despite this, it is critical to understand that, although we expect the UK to remain the single largest market in Europe, there is also a rapidly growing market in the rest of Europe. As such, most large industry players treat the European market as a single entity, basing investment decisions in this broader context. Likewise, most view technology in a global market context. As such, it is important that policy drivers are considered in a wider context than just the UK market.

Drivers for cost of energy reduction

In this study, we identified six government policy drivers of the cost of energy reduction in offshore wind. These are summarised in Table 0.1. We consider all industry actions, both at a company level and collaboratively, as responses to one or more of these drivers. In other words, we assume there will be no cost of energy reduction in the 2020s, except in response to these drivers, whether directly or indirectly.

We also considered two further policies; the leasing of lower cost of energy sites; and the strategic planning of electrical transmission infrastructure. These have the potential to affect the cost of energy in the 2020s in the UK but cannot be considered in the same way as the other drivers. The first involves a change in site conditions (compared with our assumed fixed set of site conditions), and both require significant analysis that is outside of the scope of this study to quantify their impact robustly. The cost of energy benefits of both are supplementary to the results presented in this report.

[2] The Crown Estate, *Offshore wind cost reduction pathways: Technology work stream*, May 2012, available online at http://www.thecrownestate.co.uk/media/5643/ei-bvg-owcrp-technology-workstream.pdf, last accessed June 2015.

[3] KIC InnoEnergy, *Future renewable energy costs: offshore wind*, May 2014, available online at http://www.kic-innoenergy.com/wp-content/uploads/2014/09/KIC_IE_OffshoreWind_anticipated_innovations_impact1.pdf, last accessed June 2015.

Table 0.1 Definitions of government policy drivers.

Driver	Definition
Deployment	
1. Market scale, visibility and confidence (Market)	The impact of governments on the interconnected issues of: • Market scale: the amount of capacity to be installed • Visibility: the level of information available about this future pipeline at a market level, and • Confidence: the extent to which industry believes in government statements on market scale and visibility.
2. Confidence in future levels of own supply (Own supply)	The impact of governments on the confidence of any given player in its own pipeline of future activity due to frameworks, relationships and the market.
Innovation	
3. Public funded R&D and skills development (Innovation)	The impact of public funding made available by governments to support technology innovation and skills development.
Other	
4. De-risked investment in projects (De-risking)	The impact of governments on the attractiveness of the industry to investors due to the market structure, contracting structures, industry track record and transparency and Government initiatives.
5. A well-structured supply chain (Supply chain)	The impact of government processes beyond market scale, visibility and confidence that affect both collaboration and competition.
6. A cost-efficient support mechanism (Mechanism)	The impact of rational reductions in government-specified support over time to avoid too high or low profits.
Availability of lower cost of energy sites	The proactive licensing of sites in UK waters that offer lower cost of energy compared with existing sites.
Strategic planning of transmission infrastructure	The planning of transmission infrastructure, including the integration of the grid assets of separate projects and international collaboration.

We undertook a detailed engagement programme with senior staff at developers, turbine and other suppliers and enabling organisations to build evidence about the impact of these policy drivers on cost of energy reduction in the 2020s. We gathered quantitative and qualitative evidence that we combined to give an overall industry view. We show an example in Figure 0.1, presenting the relative impact of each driver on cost of energy, comparing UK offshore wind farms with first generation in 2020 and 2030 in the "Upper bound" scenario.

Source: BVG Associates

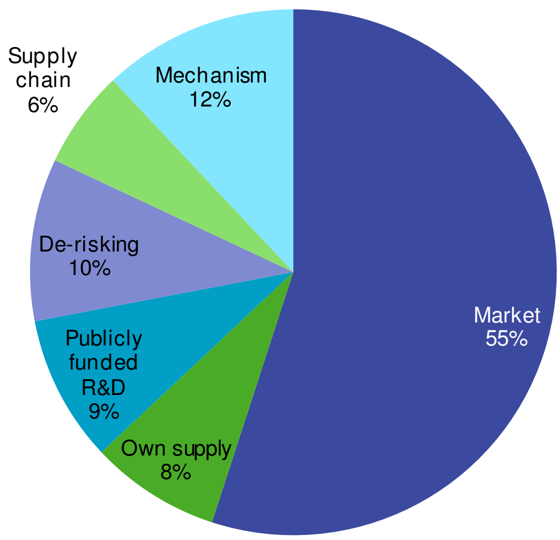

Figure 0.1 Relative impact of policy drivers on cost of energy reduction, comparing UK offshore wind farms with first generation in 2020 and 2030 in the "Upper bound" scenario.

This shows that industry sees the market scale, visibility and confidence driver as dominant, accounting for the majority of potential cost of energy reduction.

Our analysis shows that the visibility of future market activity is crucial to reducing the cost of energy. Consultees say this is the most efficient way of ensuring that companies make timely investment decisions about manufacturing capacity, R&D and skills development. This has an impact across the industry as it affects developers, the supply chain and the finance community.

Consultees agree that strong competition is vital for cost of energy reduction and we established the levels of market activity to achieve this for different elements of supply. Sustainable competition in wind turbine supply requires a larger market than any other sub-sector. Consultees say a European market with an average annual deployment of 3GW to 4GW (including 1.5GW in the UK) is needed to support three to four strong players, which is sufficient to gain the majority of the benefit of competition and investment.

Feedback about other drivers was more varied, with consultees from different companies placing more emphasis on different government actions.

There was also general agreement that, while public funding for R&D is a useful complement in supporting a sustainable market in achieving cost of energy reduction, it is not a substitute. For the turbine in particular, the scale of costs involved in developing a new generation of technology and the associated balance of plant and installation hardware is so significant that it needs market volume, rather than solely R&D support, to facilitate.

Policy scenarios

We prepared a number of scenarios of government intervention in which we vary the combination of drivers to reflect different approaches that European governments could take to offshore wind in the 2020s. We then assessed the cost of energy impact of each scenario and drew learning from comparing results.

We have assumed the support cost to UK energy users is the additional cost of offshore wind deployment compared with the equivalent cost of the lowest cost alternative. For this study, we use the anticipated cost of electricity from combined cycle gas turbines (CCGT) with carbon price uplift, based on forecasts by the Committee on Climate Change.

Figure 0.2 shows the results for four key scenarios. The grey line shows our forecast cost of energy for UK projects with first generation in 2015, 2020 and in the "Upper bound" scenario in 2030. The bars showing generation and support cost are for CfD projects with first generation between 2021 and the end of 2030 only. In line with the Department for Energy and Climate Change (DECC) processes, values are in 2012 terms. This analysis does not consider the potential impact of the leasing of lower cost sites or the strategic planning of electrical transmission infrastructure. In reality, there will be a range in cost of energy from projects with first generation at a given point in time, due to varying commercial relationships and site characteristics. For simplicity, we present figures for a typical UK project.

"Strong support" achieves almost 85% of the potential cost of energy benefit available in this period, while "R&D only" achieves only 15% of the potential. Both lines are less steep than the trajectory between 2015 and 2020, which reflects the fact that the rate of introduction of innovations drops and the incremental benefit of each step is less as the industry matures and industrial scale increases.

Figure 0.2 also shows the importance of governments giving clear visibility to industry about its plans for future deployment. With poor levels of visibility, the "Current approach" scenario achieves less than 30% of the potential cost of energy reduction available in the period. This is in contrast to the "Balanced" scenario in which good visibility means industry achieves twice as much cost of energy reduction with the same level of deployment and marginally more generation.

Figure 0.3 shows the breakdown of where the cost of energy reduction is achieved, split by driver, element and opportunity, using the example of the "Strong support" scenario. This shows that

- The market scale, confidence and visibility driver accounts for the majority of the impact
- The greatest reductions are due to innovations in turbine supply and the cost of capital, and
- Cost reduction is spread relatively evenly between opportunities in technology, supply chain and finance.

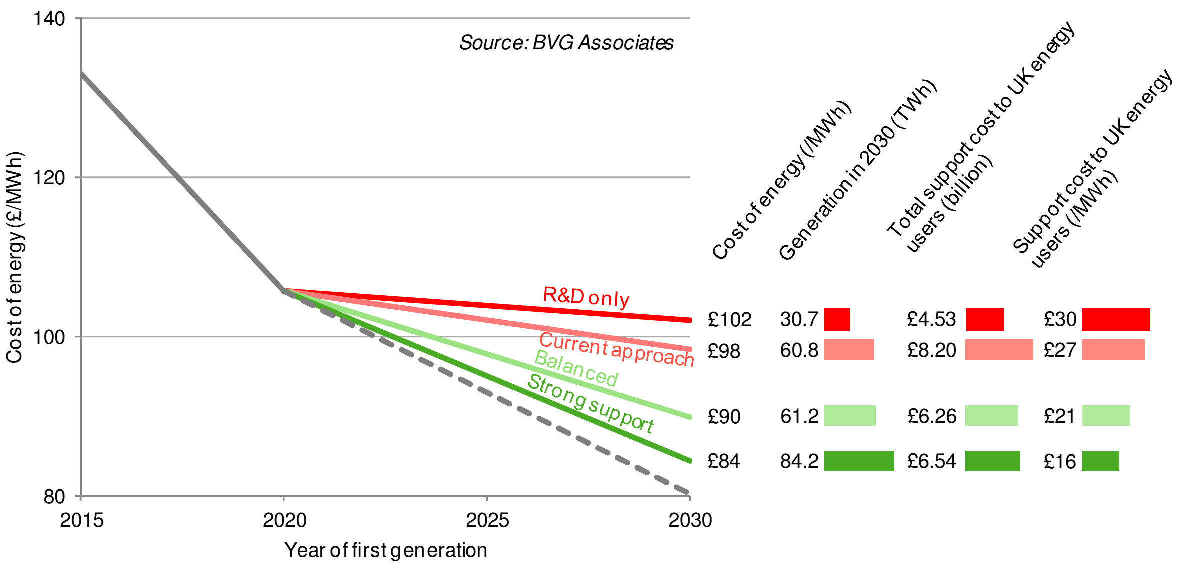

Figure 0.2 Summary of scenario analysis. Dashed grey line represents "Upper bound" scenario. All generation and support costs are for offshore wind projects built under the CfD regime between 2021 and the end of 2030. Values are in 2012 terms.

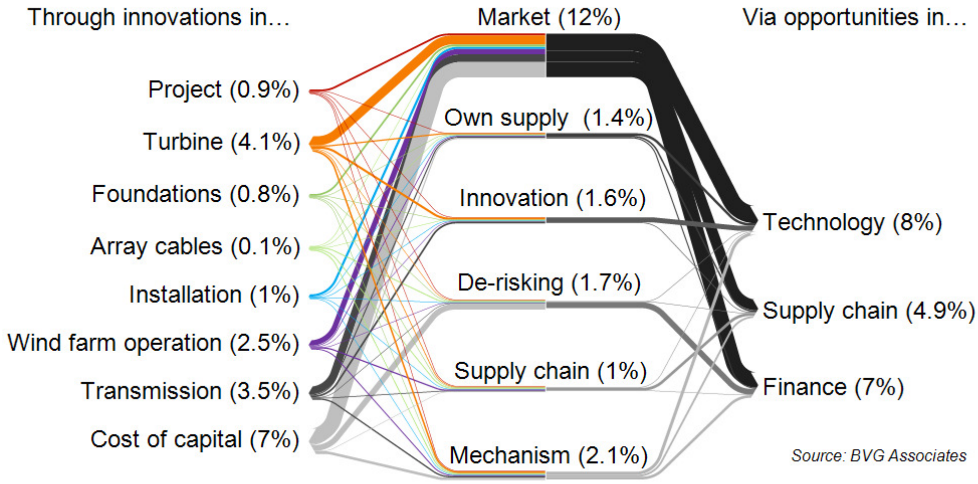

Figure 0.3 Impact of government interventions in the "Strong support" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020. For an explanation of how to read this figure, see Section 4.5.2.

Strategic lessons for UK Government policy

Based on our analysis, we set out key lessons for UK Government policy to efficiently enable cost of energy reductions in offshore wind in the 2020s, while giving best value to UK energy users.

1. Give clear visibility of market plans

The message from industry is clear: market scale without visibility means the offshore wind industry cannot deliver nearly as much cost of energy reduction or industrialisation.

Actions

- *Clearly state the annual Pot 2 budget for CfD future allocation rounds with a rolling five-year horizon*
- *Provide long-term market information to support industry plans for growth, and*
- *Create a robust framework and logic for renewable energy deployment.*

Benefits of providing visibility, comparing the "Balanced" scenario with "Current approach":

- **24% decrease in cost of support for UK energy users, plus marginally more energy delivered (£1.9 billion saving between 2021 and 2030)**
- **More industrial activity moves to the UK, and**
- **All energy sectors benefit from visibility.**

2. Establish a sustainable market and gain pan-European consensus for more

The UK is the global leader in offshore wind. It has a pool of experienced developers, a proven regulatory regime and a growing supply chain.

There is a major opportunity for the country to build on this track record to get increasingly low cost, renewable energy and hence establish a competitive advantage in a carbon-constrained world, becoming less dependent on overseas energy markets. It also has the opportunity to build a strong supply chain that can export services, skills and products around the world.

To do this however, the UK needs to commit to supporting a sustainable market size.

Actions

- *Give clear support for a central scenario of an annual average UK deployment rate of 1.5GW (giving approximately 25GW of installed capacity in UK by the end of 2030), and*
- *Proactively engage with other European countries to support strong offshore wind deployment programmes, with the option to support an average annual UK deployment rate of 2GW (giving approximately 30GW of installed capacity in the UK by the end of 2030).*

Further benefits of providing a larger market as part of a strong European market:

- **35% more generation in "Strong support" compared with "Balanced" scenario at only 4% higher cost of support to UK energy users**
- **UK achieves significantly more benefit from industrialisation, and**
- **Increased competitive advantage for the UK in a carbon-constrained world.**

3. Refine the CfD regime

Industry is generally supportive of the UK's CfD regime and now expects regulatory stability following the uncertainty of Electricity Market Reform. Within this CfD regime, however, there are still opportunities to reduce the cost of energy by reducing risk and improving confidence.

Actions

- *Investigate ways to reduce the impact of CfD allocation risk for developers*
- *Review the timing of the CfD milestone delivery date*
- *Ensure the assumptions underpinning the CfD process are fit for purpose*
- *Compare clearing prices in CfD auctions with elsewhere in Europe to ensure that the UK is obtaining value for money for energy users*
- *Provide clear and timely advice about how the regime will evolve in the future, including how to take the benefit of large-scale Round 3 zonal approaches which offer further cost of energy reduction opportunities, and*
- *Support the harmonisation of support mechanisms across key national markets.*

4. Maximise the benefit of public R&D funding

Public funding for R&D has an important role to play in reducing the cost of offshore wind energy and moving economic benefit but it is not a substitute for deployment.

Actions

- *Quantify the anticipated impact of funding to date on future cost of energy reduction, and*
- *Investigate the potential impact of increased, targeted R&D funding.*

5. Help reduce the cost of capital

Supporting and providing visibility of a sustainable market as described above will have a significant impact on the cost of capital during the 2020s. In addition, the UK Government has already taken positive steps to address a number of key market risks, which has helped to reduce the cost of capital.

It can do more, however, particularly when given the anticipated increased use of project finance and UK suppliers.

Actions

- *Provide Treasury-backed infrastructure guarantees for offshore wind developments and export credit for UK suppliers.*

6. Use Supply Chain Plans to drive positive behaviour

Industry is generally wary of supply chain interventions but the UK Government should use its influence over the industry through DECC's Supply Chain Plans to encourage and support best practice.

Actions

- *Develop the use of Supply Chain Plans as a tool for steering positive market behaviour.*

Further benefits of interventions 3 to 6 above:

- **Aggregate a 6% reduction in cost of energy (equivalent to £1.4 billion saving between 2021 and 2030), and**
- **Increased UK benefit from technology and supply chain development.**

1. Introduction

The Committee on Climate Change has commissioned this report to identify and provide an evidence base for the most efficient UK Government policies to drive long-term cost of energy reduction in offshore wind and give best value to UK energy users.

Given the right conditions, offshore wind can follow a cost reduction trajectory to compete in volume in a carbon-constrained European energy mix within the next 15 years. The policies of European governments are critical in providing these conditions. It is therefore important that the impact of different policy drivers is well understood.

The structure of this report is as follows:

- Section 2 summarises the opportunities for cost of energy reduction in offshore wind over the next 15 years and discusses the trends in cost of energy to date and the anticipated trend in the rest of this decade. We also present an “Upper bound” of cost of energy reduction in the 2020s that we use in assessing the potential impact of the different drivers discussed in Section 4.
- Section 3 sets out the position of the UK market in a European and global context. We do this to show the UK’s key role and hence the relative importance of UK Government policy decisions for future cost of energy reductions in offshore wind in the UK and beyond.
- Section 4 defines the key drivers that will affect the cost of offshore wind energy between 2020 and the end of 2030. It incorporates the industry evidence base and quantifies the impact of each driver, showing how it supports cost of energy reduction.
- Section 5 explores scenarios in which we vary the impact of the drivers to reflect different approaches that European governments could take to offshore wind in the 2020s. We then compare and contrast the results of these scenarios to identify threats and opportunities.
- Section 6 considers the output of Sections 4 and 5 and presents key lessons for government policy to efficiently enable cost of energy reductions while giving give best value to UK energy users.

To make the report as accessible as possible, we have only included short summaries of the report methodology and assumptions in the main body of the report. We have set these out in detail in the appendices at the end of the report, along with further results.

2. Cost of energy reduction

The offshore wind industry is a young, European-focused sector building on a global wind industry that had a turnover of more than £50 billion and generated almost 3% of the world's electricity demand in 2014.

It also builds on the progress made with onshore wind turbine technology with more than 360GW operating globally.[4] The offshore application, however, offers significant new opportunities for cost of energy reduction, as well as a number of different challenges.

This section starts by summarising the opportunities for cost of energy reduction in offshore wind over the next 15 years. It then discusses the trends in cost of energy to date and the anticipated trend in the rest of this decade. It then presents an upper bound of cost of energy reduction in the 2020s that we use in assessing the potential impact of the different drivers discussed in Section 4.

In this report, we refer to "cost of energy", by which we mean the levelised cost of energy or LCOE. LCOE is defined as the revenue required (from whatever source) to make a rate of return on investment equal to the weighted average cost of capital (WACC) over the life of the wind farm (tax, inflation and the like are not modelled). In other words:

$$LCOE = \frac{\sum_{i=-m}^{n} \left((C_i + O_i + D_i) / (1+W)^i\right)}{\sum_{i=-m}^{n} \left(E_i / (1+W)^i\right)}$$

Where:

LCOE	Levelised cost of energy in £MWh
C_i	Capital expenditure in £ in year i
O_i	Operational expenditure in £ in year i
D_i	Decommissioning expenditure in £ in year i
E_t	Energy production in MWh in year i
W	WACC in % (real)
n	Operating lifetime of wind farm (baseline 20 years)
m	Years before start of operation when expenditure first incurred
i	i year of lifetime (-m, ..., 1, 2, …n)

[4] Global Wind Energy Council, *Global wind statistics 2014*, 2015, available online at http://www.gwec.net/wp-content/uploads/2015/02/GWEC_GlobalWindStats2014_FINAL_10.2.2015.pdf, last accessed June 2015.

2.1. Specific opportunities for cost of energy reduction

We highlight some of the key opportunities for cost of energy reduction in offshore wind below. There are hundreds of discrete, independent opportunities for cost of energy reduction with many different implementation paths. Indeed, a challenge in assessing opportunities is to rationalise between:

- Top-down cost of energy reductions based on past trends and shared industry expectation, and
- Forecasts of much larger savings available that come from a rational, bottom-up combination of these individual opportunities, even taking into account realistic times to market and market shares of new technologies, supply chain practices and methods of financing.

This wealth of technology, supply chain and finance innovations gives strong confidence that, given the right environment, the offshore wind industry will continue to deliver significant savings, even if some opportunities do not materialise. All the innovations discussed below have the potential to play a significant role in reducing the cost of energy during the period up to the end of 2030.

Figure 1 shows the contribution of all the key work packages (elements) to the cost of energy of a project with first generation in 2020, derived from the analysis summarised in Appendix A. This illustrates the relative importance of each element to cost of energy. We provide definitions of these elements in the Glossary.

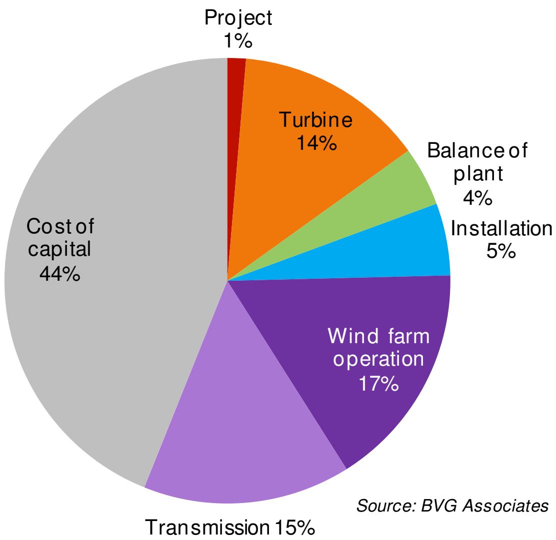

Figure 1 Breakdown of cost of energy for a typical UK project with first generation in 2020.

Larger, more reliable wind turbines

The most significant opportunity for cost of energy reduction in the next 15 years is through the commercialisation of another generation of larger wind turbines. These will have larger diameter rotors and higher-rated energy conversion equipment mounted in the nacelle (at the top of the tower) and in the tower itself. As discussed in detail in previous analyses, their introduction significantly decreases the cost per megawatt of foundations, installation and operation, maintenance and service.[5] Accessing winds higher in the atmosphere and improving reliability also drives up energy production, which further decreases the cost of energy. These innovations combine technology development with a significant amount of investment in manufacturing capability throughout the supply chain to allow for the efficient manufacture and installation of larger components.

A detailed description of wind farm elements is provided in *A guide to an offshore wind farm* published by The Crown Estate in 2010.[6]

Improved design, manufacturing and installation of foundations for large turbines

Turbine foundations, supporting the turbine rotor, nacelle and tower from the seabed, also offer significant opportunities for cost reduction. These opportunities include:

- Further extending the use of tubular steel monopile foundations, used in the vast majority of projects installed to date, through improved design methodologies and tooling
- Industrialising the manufacture and installation of cross-braced steel jacket foundations, used for larger turbines in deeper waters, including holistic optimisation of “whole structure” designs, and
- Further developing concrete and hybrid gravity-base designs, including onshore installation of turbines for so-called “float-out-and-sink” installation, to minimise offshore work and the use of floating cranes.

Improved electrical transmission arrangements

Again, there is a range of opportunities that will reduce the cost of energy, including:

- Increasing the alternating current (AC) voltage (and possibly reducing the AC frequency) of array cables between turbines and export cables to shore
- Simplifying and optimising the physical layout of transmission components to reduce the need for specific substation infrastructure
- Developing more cost effective and flexible direct current (DC) electrical architectures, and
- Sharing transmission arrangements between wind farms located close together and with transnational interconnects.

Optimised lifetime care

Both unplanned service activities in response to hardware faults and planned routine maintenance are significantly more expensive for offshore wind than for onshore wind, giving significant opportunity for optimisation. Crew access to turbines is limited to below 50% of the time for long periods on some sites.

Robust processes, proactive condition-based methods, a fix-first-time approach and improved crew transport and access will all reduce costs and increase energy production by minimising downtime.

The other key opportunity in lifetime care is to increase energy output directly. Industry is working on solutions relating to the management of aerodynamic wakes from turbines and optimising power output of different turbines under different operating conditions based on turbine load measurements and site wind conditions.

[5] The Crown Estate, *Offshore wind cost reduction pathways: Technology work stream*, May 2012, available online at http://www.thecrownestate.co.uk/media/5643/ei-bvg-owcrp-technology-workstream.pdf, last accessed June 2015.

[6] The Crown Estate, *A guide to an offshore wind farm*, 2010, available on line at http://www.thecrownestate.co.uk/media/5408/ei-a-guide-to-an-offshore-wind-farm.pdf, last accessed June 2015.

Early-stage project optimisation

Although the cost of project development is not a significant contribution to the cost of energy, activities at this phase of implementation can have a significant effect on lifetime cost of energy. Industry has a range of opportunities, including:

- Improving the layout of turbines across the wind farm site, using models now starting to be validated through operating experience, reducing both capital cost and increasing energy output
- Improving certainty of wind resource though the use of lower-cost, flexible measurement solutions (including floating LiDAR) to reduce risk and cost of capital, and
- Maximising the efficiency of design through the availability of more detailed seabed and metocean survey data.

Decreased cost of financing projects

Continental project-financed projects have managed to secure low-cost debt through improved risk management and packaging of construction contracts. The UK has had a market designed around utility balance-sheet construction financing, which is now in short supply. As the industry moves to a world of project finance and more sophisticated refinancing, lower merchant risk and a track record will also enable a lowering of financing costs for UK projects.

Maturing of the supply chain

Many of the savings discussed above depend on both technology innovation and investment in the supply chain to realise the benefit. In an environment with insufficient competition, unilateral investment by one player to reduce cost typically results in increased margins for that player. In a more confident, competitive market, a maturing supply chain drives companies to pass on these savings to energy users.

Other important elements of maturity that we anticipate will help drive cost of energy reduction are:

- Improved vertical collaboration and sharing of experience in project teams, facilitated by more effective contracting methods
- Improved horizontal collaboration and information sharing between industry players across projects, and
- Joint industry projects on standards and standardisation to reduce unnecessary differences between projects

2.2. Reported trends in cost of energy to date and to 2020

This section frames the discussion of future cost of energy reduction in the historical context of the trends in cost of energy to date.

Until 2015, there was no formal public reporting of the cost of energy in offshore wind. Indeed, developers have typically been reluctant to release information about any of the constituent elements of cost of energy, namely capital expenditure (CAPEX), operational expenditure (OPEX), energy production and cost of capital. Some developers have stated a headline CAPEX for their projects at different stages of completion, but have not typically clearly described the scope of work included in their figures.

There has been enough evidence, however, to indicate a trend between 2005 and today of CAPEX rising significantly and then levelling off.

This increase in CAPEX has been due mainly to:

- The increased water depth and distance to shore in which projects have been constructed
- Improved industry understanding about the real costs of working at the scale required in offshore conditions
- Evolving dynamics in the supply chain and its interaction with market mechanisms, and
- Changes in the Sterling to Euro exchange rate.

In terms of the cost of energy, these increases in CAPEX have been partially offset by increases in energy production from sites further from shore and, for some projects, lower costs of capital.

In February 2015, the UK's Offshore Wind Programme Board published the results of two studies it commissioned.

The first study provided quantitative evidence of changes in the cost of energy for projects with first generation nominally between 2010 and 2016.[7] The data collection and reporting process involved wind farm developers populating a standard-form spreadsheet to derive a cost of energy from profiles of CAPEX, OPEX, energy production and cost of capital. Only the resulting cost of energy was communicated to the study delivery team and these were carefully aggregated to avoid any chance that results for individual projects could be back-calculated. The projects included in each data point were stated and, from this, it is possible to derive the evolution in site conditions and technology used over the period. In most cases, there can be a high degree of confidence in CAPEX, but whole lifetime levels of OPEX, energy production and cost of capital remain quite uncertain at the early stage of each project considered.

[7] Deloitte, *Cost Reduction Monitoring Framework: Quantitative assessment report*, February 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/CRMF+Quantitative+Assessment+report/41afada6-1459-4ac1-8dee-29ca77168dc4, last accessed June 2015.

The second study provided qualitative evidence of progress against the Technology Acceleration pathway.[8] This is considered the most realistic option presented in the *Offshore Wind cost reduction pathways study* published by The Crown Estate in 2012.[9] This second study concluded that, on balance, industry was still on course to deliver a headline cost of energy of £100/MWh for projects (in 2012 terms) with FID in 2020 (first generation in 2022 or 2023).

It is relevant to note that this qualitative study concluded that progress in cost of energy reduction is not uniform across all wind farm elements. The confidence that industry is "on track" comes from an earlier than anticipated uptake of 6MW and 8MW turbines, with a significant impact on the cost of energy. Progress in other areas of the supply chain, such as foundation supply, is slower than expected because of lower market scale and visibility than modelled in this pathway in 2012.

It concluded that industry cannot sustain the current progress in cost of energy reduction unless there is an increase in investment in the supply chain, most likely facilitated by increased visibility of a larger market.

The results of these two recent studies are discussed in a summary report published by the Offshore Renewable Energy Catapult and summarised in Figure 2.[10]

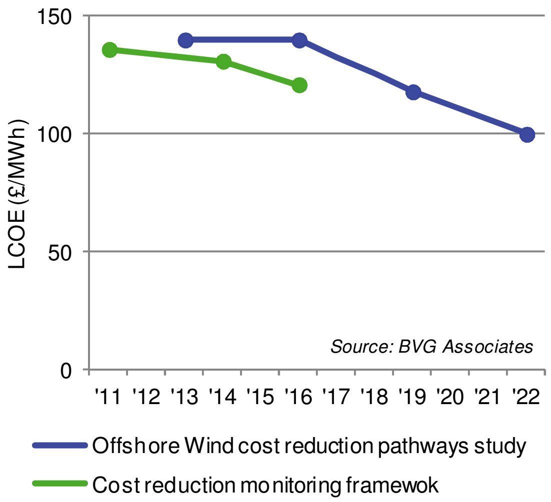

Figure 2 Cost of energy for UK projects with first generation between 2010 and 2023. Derived from ORE Catapult Cost Reduction Monitoring Framework: summary report. Values in 2012 terms.

2.3. Cost of energy for projects with first generation in 2015, 2020 and upper bound for reductions to 2030

For projects with first generation in 2015 and 2020, we used in-house models to calculate the cost of energy for a typical UK site. We tuned these models through a detailed literature review of other published studies, including those presented in Section 2.2, and validated results during our consultation with industry. We based all analysis in this report on a set of typical project characteristics, fixed through time, such as water depth and distance from shore. These assumptions are set out in Appendix A.

We recognise that the portfolio of projects at any point in time will have a range of such characteristics and that costs also depend on contracting within a dynamic supply chain. This means that, in reality, there will always be a range in the cost of energy. To provide visibility of the effect of government drivers, in this study, we have reduced this to a single, headline, typical cost of energy that we anticipate will reflect auction price.

In Section 4, we describe the impact of each driver against an "Upper bound" baseline scenario of cost of energy reduction from 2020 to 2030, which we treat as an upper bound, achievable only if all drivers have their full impact.

We set out the detailed methodology and underlying assumptions used to prepare this scenario in Appendix A. It is a P20 scenario in which we assume there is only a 20% chance of exceeding this level of cost of energy reduction. Again, we validated the cost of energy trend in

[8] DNV GL, *Cost Reduction Monitoring Framework: Qualitative assessment report*, February 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/CRMF+Qualitative+Summary+report/dc37fb9c-e41e-429c-862e-747f8db091c0, last accessed June 2015.

[9] The Crown Estate, *Offshore wind cost reduction pathways study*, May 2012, available online at http://www.thecrownestate.co.uk/media/5493/ei-offshore-wind-cost-reduction-pathways-study.pdf, last accessed June 2015.

[10] ORE Catapult, *Cost Reduction Monitoring Framework: summary report*, February 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/ORE+Catapult+report+to+the+OWPB/a8c73f4e-ba84-493c-8562-acc87b0c2d76, last accessed June 2015.

this scenario with industry consultees as part of our engagement programme.

Inputs to the analysis of drivers are summarised in two figures:

Figure 3 shows a cost of energy for projects with first generation in 2015 and 2020 and the "Upper bound" scenario for first generation in 2030, with the reductions in cost of energy split by element. This breakdown reflects the cost of energy reduction due to innovations in each element. The actual benefit may be due to savings in other elements but we link this back to the underlying source. For example, a bar labelled "Turbine" signifies a reduction in the cost of energy due to innovations in turbines, such as the development of more reliable turbines. The benefit of this innovation may come in lower long-term operation, maintenance and service (OMS) costs, but we still attribute the benefit to the turbine as the source of the improvement.

Figure 4 shows the same cost of energy results, but with the reductions broken down instead by opportunity, whether due to progress in technology within the supply chain or in financing projects.

We have included definitions of the elements and opportunities in the Glossary.

As these figures show, we expect the rate of reduction in the cost of energy to slow down in the 2020s as the industry achieves broadly similar levels of reduction over 10 years as it did in the five years between 2015 and 2020. This reflects the fact that, as the industry matures and industrial scale increases, the rate of introduction of new technology drops and the incremental benefit of each step lessens.

Despite this, we still expect progress in technology innovation to remain the largest opportunity for cost reduction during the period, with an ongoing focus on the turbine (although we also expect innovations in foundations and transmission and installation to be significant).

We expect ongoing reductions in the cost of capital available to developers to have the single greatest impact on the cost of energy of future projects.

Innovations in the supply chain will also provide important savings, as the industry matures.

Our analysis in Sections 4 and 5 assumes that policy interventions (drivers) implemented from now on will only affect the cost of energy in the 2020s. This means that we have fixed the cost of energy trajectory presented between 2015 and 2020 in this study. The level of cost of energy reduction achieved during the 2020s depends on the action of the different drivers. The maximum (upper bound) reduction achievable is that shown here. The actual reductions in the scenarios set out in Section 5 range between 15% and 85% of the £26/MWh shown in Figure 3 and Figure 4.

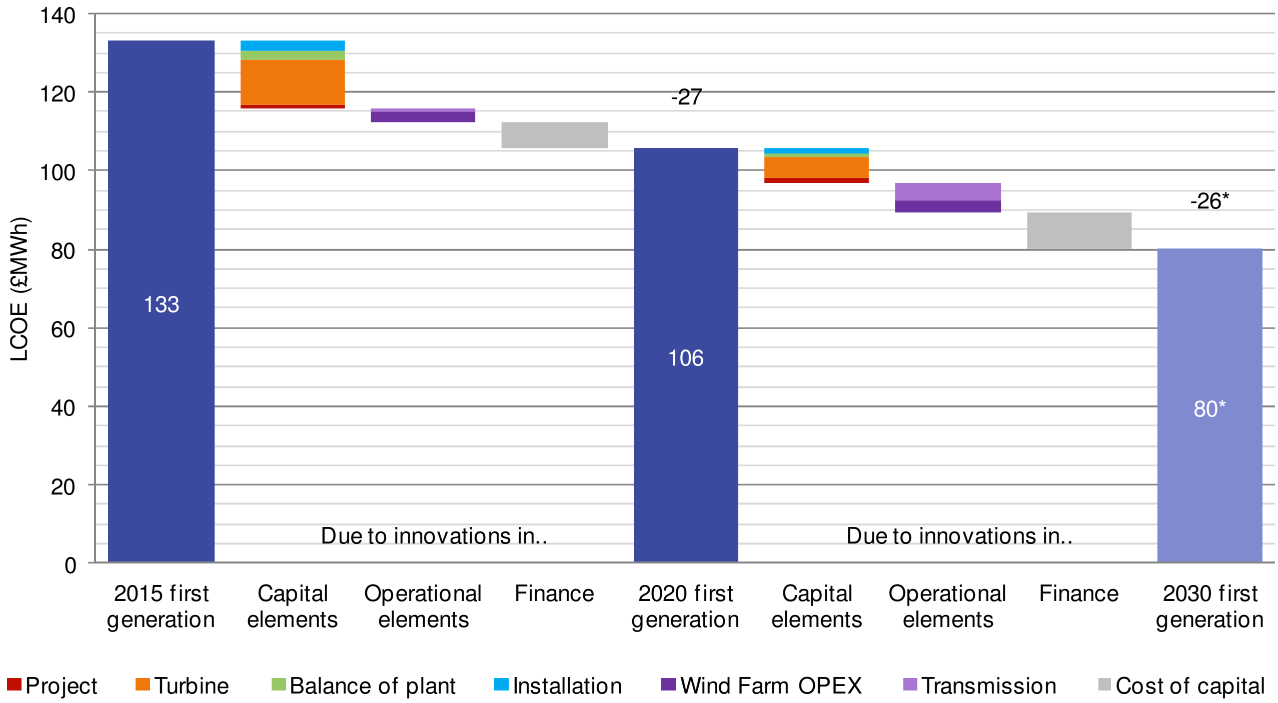

Figure 3 Forecast cost of energy for UK projects with first generation in 2015, 2020 and 2030 in the "Upper bound" scenario, split by impact of innovations in elements. *Only the "Upper bound" of reductions is shown – the actual cost of energy for projects operating in 2030 depends on the policy scenario, ref. Section 5. Values in 2012 terms.

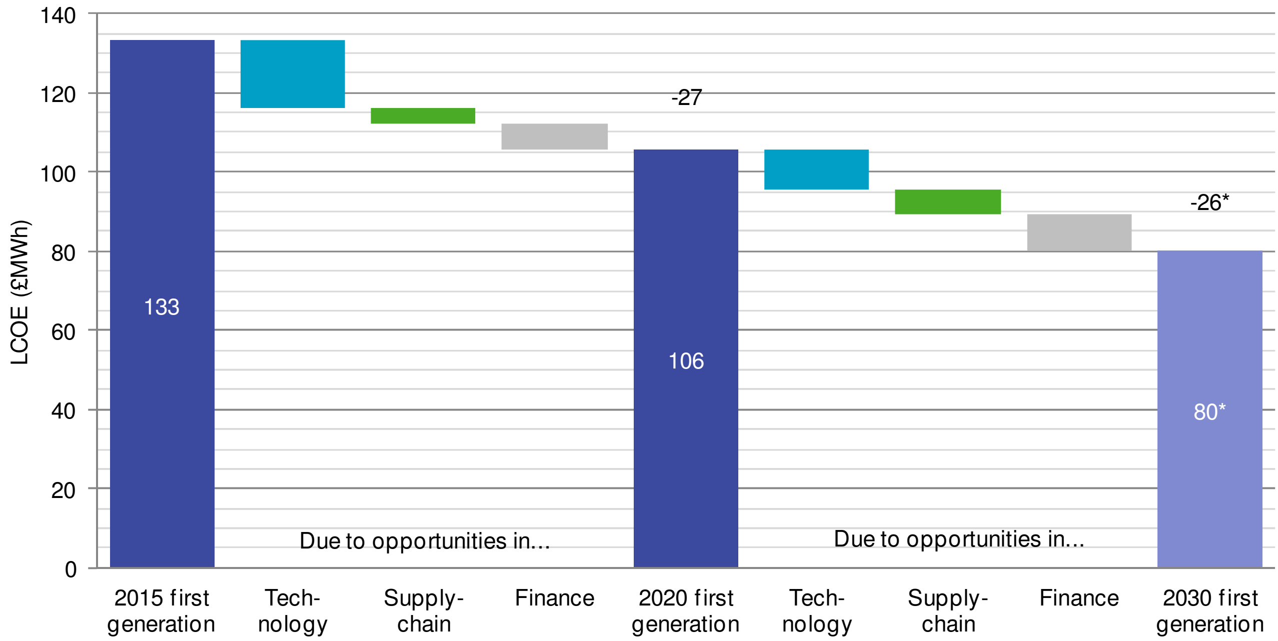

Figure 4 Forecast cost of energy for UK projects with first generation in 2015, 2020 and 2030 in the "Upper bound" scenario, split by opportunity. *Only the "Upper bound" of reductions is shown – the actual cost of energy for projects operating in 2030 depends on the policy scenario, ref. Section 5. Values in 2012 terms.

3. Role of the UK offshore wind market in a European and global context

Like most large, technology-driven industries, the offshore wind industry transcends national boundaries. This section sets out the position of the UK market in a European and global context. We do this to show the UK's key role and highlight the relative importance of UK Government policy decisions for future cost of energy reduction in offshore wind in the UK and beyond.

3.1. The UK has the leading offshore wind market

The UK is currently the global market leader in offshore wind with more than double the amount of installed capacity than any other country. There is already more than 4.5GW of capacity installed in the UK and the Government has set an ambition to support at least 10GW by 2020. We are currently on track to marginally exceed this ambition.

The UK also has the greatest wind resource in Europe with large areas of seabed suitable for offshore wind deployment. We present the UK's market share of installed capacity of offshore wind at the end of 2014 in Figure 5.

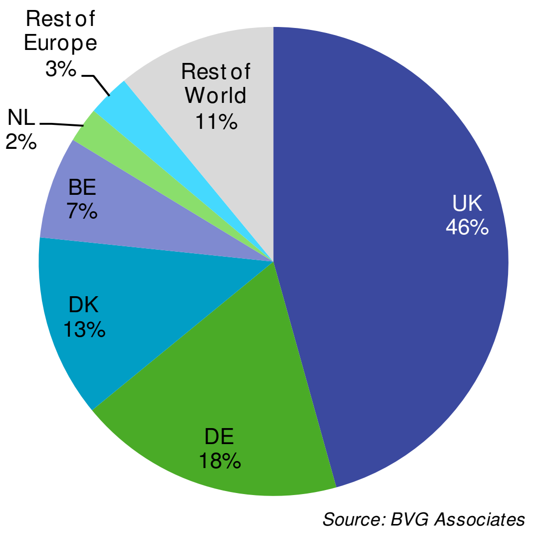

Figure 5 Global market share of installed capacity of offshore wind by MW at the end of 2014 (total capacity 10.1GW).

The UK installed its first demonstrator project in 2001 and there have been commercial projects installed each year since 2003. More than 100 turbines have started operating in each of the last five years. Combined, this record of delivery means the UK has built up a proven and tested regulatory framework for supporting offshore wind. It also means the UK workforce has built up strong experience and knowledge about developing, consenting, installing and operating large-scale commercial projects.

Ernst and Young consistently ranks the UK as the most attractive country for offshore wind in its *Renewable Energy Country Attractiveness Index*.[11] It bases its assessment of a range of economic, political, industrial and technical drivers to reflect the attractiveness of a particular country's investment environment.

We anticipate the UK will hold its market-leading position well into the 2020s. We present its anticipated market share of installed capacity of offshore wind at the end of 2020 in Figure 6.

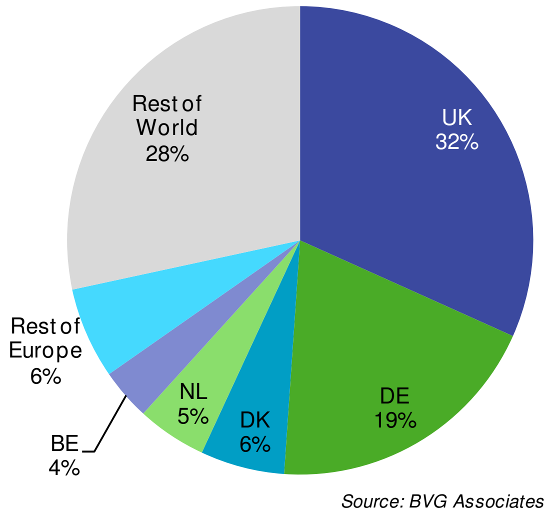

Figure 6 Anticipated global market share of installed capacity by MW at the end of 2020 (total capacity 34.5GW).

Having seen relatively low levels of UK content in projects in the past, there are increasing levels of inward investment in manufacturing capacity, such as the Green Port Hull facility into which Siemens Wind Power and Associated British Ports are investing £340 million.

3.2. The UK position in the European market

Although we expect the UK to remain the single largest market in Europe for the foreseeable future, there is also a rapidly growing market in the rest of Europe and most large

[11] Ernst and Young, *Renewable Energy Country Attractiveness Index*, http://www.ey.com/GL/en/Industries/Power---Utilities/Renewable-Energy-Country-Attractiveness-Index, last accessed June 2015.

industry players treat the European market as a single entity, basing investment decisions in this broader context.

Other countries, including France, Germany and the Netherlands, all have multi-gigawatt deployment programmes in place.

Some countries, like Belgium and Denmark, have long track records of supporting commercial projects but these markets are much smaller than the UK and tend to have intermittent levels of deployment. This affects the ability of developers to build up local skills and experience.

Germany is planning a larger programme than any other European country except the UK, but it is still a relative newcomer to the market. It installed its first commercial project in 2011 and only started operation of more than 100 turbines in a year for the first time in 2014. This means the German regulatory framework is less proven and trusted than the UK's, with greater risk of delays and inefficiencies.

This is also the case for France, which has had a number of project licensing rounds but not seen any offshore deployment yet. The Netherlands restructured its offshore programme last year, taking learning from other markets.

3.3. The global market

This study does not explicitly consider the non-European (rest of world) market but we recognise that it is likely to become an important new opportunity for companies in the 2020s and a growing consideration in investment decisions for global players, such as turbine suppliers. Consideration of global demand is particularly relevant for investment in R&D and product development, whereas investment in skills and manufacturing capacity may be based on regional, or even national, demand.

Currently, outside Europe, only China is also installing offshore wind capacity at scale. We expect this to change in the 2020s, as countries such as Japan, Korea and the USA establish markets.

These countries will be planning to build up their own local capacity but will still rely on the experience and knowledge of the mature European supply chain in the short- to medium-term as they grow. At first, this demand is likely to be less certain and more intermittent than European demand, but will become an important consideration in supporting investment in new manufacturing capacity, R&D and skills development.

4. Evidence on the drivers of cost of energy reduction

4.1. Introduction

In this section, we define and explore the key government policy drivers that will affect the cost of offshore wind energy between 2020 and the end of 2030. The purpose is to present an evidenced case for which drivers will have the most impact on the cost of energy, enabling Government to focus policy on reducing the cost of energy most efficiently for energy users.

4.1.1 Policy drivers

Offshore wind is on a cost reduction trajectory to compete in volume in a carbon-constrained European energy mix within the next 15 years. If the industry can achieve this ambition, offshore wind will become an increasingly important part of the European energy mix, contributing to decarbonisation and affordability goals. Until then, however, the policies of European governments remain critical to the industry's development.

In this study, we define such policies as "drivers". These are summarised in Table 1. We also discuss two other policy drivers: the leasing of lower cost sites and strategic planning of electrical transmission infrastructure. These have the potential to impact the cost of energy by 2030, but we do not consider them in detail.

We consider all industry actions, both at a company level and collaboratively, as responses to one or more of these drivers. In other words, we assume there will be no cost of energy reduction in the 2020s, except in response to these drivers, whether directly or indirectly.

There is uncertainty regarding the impact of drivers on the cost of energy, and the way in which these drivers interact in practice is complex. For example, board level decision-making reflects Government policy but other parts of the business, potentially unrelated to offshore wind, may also have an impact. In this context, one goal of this study is to draw out key characteristics of different cost-reduction strategies that are robust across different scenarios.

Table 1 Definitions of government policy drivers.

Driver	Definition
Deployment	
1. Market scale, visibility and confidence (Market)	The impact of governments on the interconnected issues of: • Market scale: the amount of capacity to be installed • Visibility: the level of information available about this future pipeline at a market level, and • Confidence: the extent to which industry believes in government statements on market scale and visibility.
2. Confidence in future levels of own supply (Own supply)	The impact of governments on the confidence of any given player in its own pipeline of future activity due to frameworks, relationships and the market.
Innovation	
3. Public funded R&D and skills development (Innovation)	The impact of public funding made available by governments to support technology innovation and skills development.
Other	
4. De-risked investment in projects (De-risking)	The impact of governments on the attractiveness of the industry to investors due to the market structure, contracting structures, industry track record and transparency and Government initiatives.
5. A well-structured supply chain (Supply chain)	The impact of government processes beyond market scale, visibility and confidence that affect both collaboration and competition.
6. A cost-efficient support mechanism (Mechanism)	The impact of rational reductions in government-specified support over time to avoid too high or low profits.
Availability of lower cost of energy sites	The proactive licensing of sites in UK waters that offer lower cost of energy compared with existing sites.
Strategic planning of transmission infrastructure	The planning of transmission infrastructure, including the integration of the grid assets of separate projects and international collaboration.

4.1.2 Presentation of results

To illustrate the findings of our consultation, we have produced Sankey plots for each driver to show how industry expects each one to affect future cost of energy. See Figure 7 for an example.

In these centre of these Sankey plots, we show the potential impact of each driver in the "Upper bound" market scenario described in Section 2.

To the left, we break down this overall impact by innovations in each of the seven key elements (for definitions of these elements, see Glossary).

It is important to note that this breakdown reflects the cost of energy reduction due to innovations in each element. The actual benefit may be due to savings in the cost of other elements but we still link this back to the underlying source, as this gives visibility about where government actions need to be focussed for maximum effect. To the right, we break down the overall impact by opportunity, split by technology, supply chain and finance. These follow the definitions that we developed in The Crown Estate's *Offshore Wind Cost Reduction Pathways Study* and the Glossary. This helps to give further visibility about the source of reductions and hence how they can be achieved.

We have set out how we have quantified and verified the data for these figures in Appendix B.

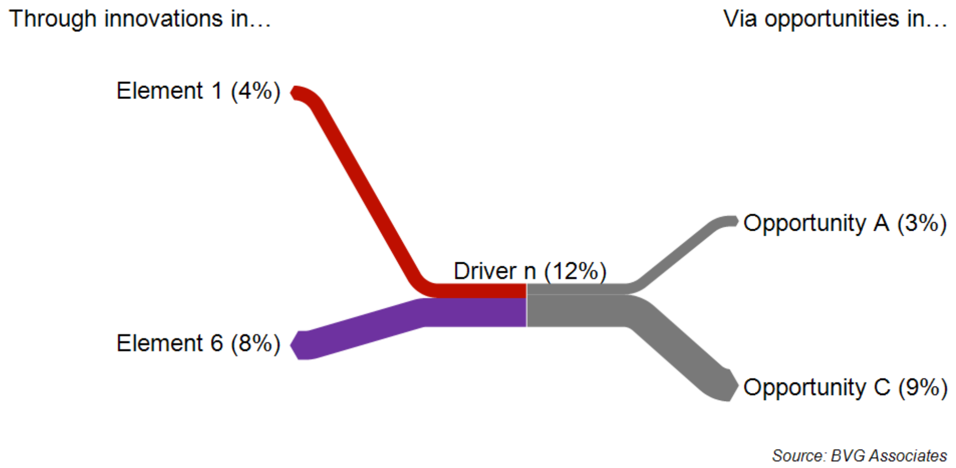

Figure 7 Example of figure presenting impact of a driver.

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4.2. Deployment

This set of drivers explores the influence that governments have in facilitating cost of energy reduction through the level of deployment they support and the way in which they give visibility and confidence to industry.

4.2.1 Market scale, visibility and confidence

Industry says…

Governments providing confidence in visible sustainable future market scale is the dominant driver of cost of energy reduction.

Turbine suppliers have the greatest need for market volume to invest, at a minimum of approximately 1GW per year per player, but their investment facilitates the largest cost of energy reductions.

There needs to be average annual European deployment of 3GW to 4GW to drive a reasonable level of competition and investment across the supply chain and generate interest from the finance community that will drive down the cost of energy.

Visibility and confidence of future market are as important as market scale. To be effective in facilitating investment, this needs to consists of:

- **Visibility five years ahead of future allocation round budgets, and**
- **Legislative frameworks and logic for investment in low carbon generating capacity up to 15 years ahead, coupled with political consensus that offshore wind should play a significant role if it delivers to expectation.**

Scope

Market scale

The most direct influence that governments have on offshore wind is the market scale they facilitate through support mechanisms. Governments base their decisions about market size on factors including decarbonisation targets, cost to electricity users, security of supply and local jobs and economic benefit.

Feedback from almost all major players in the industry is that companies base most of their main investment decisions on a European-wide consideration of market scale, rather than the markets of individual countries. The main exception is the finance community, which invests on a project-by-project basis and looks more closely at the risks associated with different national markets. By the nature of the activity, much of the investment by wind farm developers is in specific wind farm projects, hence in given national markets.

Visibility

Levels of market visibility depend on how governments decide to communicate their intent to the industry and the structure of the market mechanisms in place.

Visibility of the European market size is critical to timely industry decision-making and is a common thread in industry feedback in this study. All consultees recognise that the European market is composed of a number of discrete national markets and, as such, whole market visibility is the aggregate of visibility of national markets.

Confidence

The confidence of industry in market scale is based on the perceived sustainability and logic of government plans, their track record of consistent support in the past and the likelihood of future shifts in political support.

Again, industry typically bases its confidence on a European-wide aggregate of discrete national markets.

Potential impact

Industry advises that this driver accounts for approximately 55% of the cost of energy savings available in the “Upper bound” market scenario, or a reduction of approximately £14 per MWh (or 13.4% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver has a greater impact on the cost of energy than all the other drivers put together through stimulating investment in new technology and supply across the supply chain and in attracting lower cost finance.

Figure 8 shows that, during the decade, the greatest reductions will come from driving innovations in the cost of capital, turbines, transmission and wind farm operations. The greatest opportunities are in technology and finance. The distribution of reductions is in line with that for the “Upper bound” scenario described in Section 2.

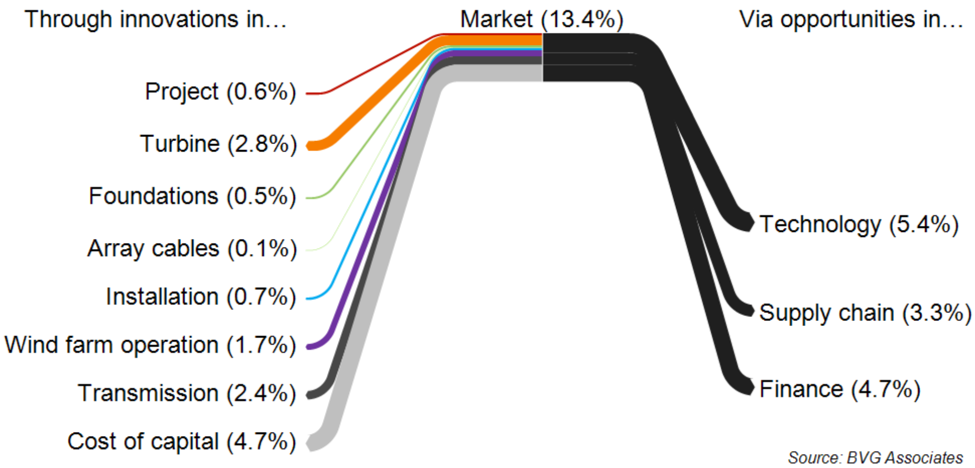


Figure 8 Impact of government intervention in market scale, visibility and confidence in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

Turbine suppliers are only likely to invest in new turbine platforms if they expect to consistently supply at least 1GW a year

There is strong feedback from all relevant consultees that the development of next-generation turbines (with rated capacities of 10MW or more) is a crucial ingredient in cost of energy reduction in the 2020s. In a positive market, we expect these new platforms to account for up to 60% of the anticipated cost of energy reduction related to turbines between projects with first generation in 2020 and 2030.

Appendix E sets out the typical stages involved in the development and commercialisation of an offshore wind turbine. This shows it can take up to eight years from initiation to the start of full-scale commercial deployment of a new platform with typical costs ranging from £300 to £750 million. This excludes investment by the supply chain to series-manufacture components, which may be of similar scale to these costs.

To make a credible business case to start this kind of programme, consultees say turbine suppliers need reasonable confidence that they can capture an ongoing pipeline of at least 1GW of activity per year once the new platform is commercially available. Consultees say this level of pipeline is the minimum requirement and turbine suppliers will still need to build in higher margins on sales than for onshore wind turbines to be commercially viable, given smaller volumes and higher lifetime risks.

Consultees from turbine suppliers say they do not expect this pipeline to be their own committed orders but, instead, consider the long-term European market scale and their prospect of securing a sufficient market share. One consultee says the best available proxy for long-term market size is anticipated market size in the next five years, assuming stable political support over the same period. A number of consultees say that some turbine suppliers have already slowed or paused work on the early stages of next generation platforms as they await visibility of this level of market scale.

If there is a sustained lack of visibility, consultees say there is a risk that some turbine suppliers may exit from the market. Key global industrial players like Alstom, Areva, Mitsubishi and Siemens are all active in a wide range of energy markets, with internal competition for limited funding for new product development. Consultees say the offshore wind divisions of these companies need to make compelling cases to unlock the necessary investment and company boards may opt to cut their losses if there are more promising opportunities in parallel sectors.

For example, Siemens pulled out of the nuclear and solar markets in 2011 and 2012 when they made the judgement that these markets were less attractive than others in which they operated. In offshore wind, other multi-national corporations like GE and Samsung have already decided to pull back from the market after making substantial investments in product development (although GE may now return following its acquisition of Alstom).

The 1GW per year volume relates to sustainable levels of both manufacturing and logistics activity, based on the production of between two to four turbines per week and the delivery of two typical 500MW (0.5GW) commercial scale projects per year.

In addition, most turbine suppliers have at least two sources of supply for key components to encourage competitive tension and manage the risk of failure to provide quality supply. This reduces the rate of supply for some suppliers to one large component per weekly manufacturing cycle, which consultees see as a threshold for efficient supply of components used only in offshore wind.

Consultees say that companies can address the issue of low volume, variable demand by using flexible approaches to production, such as temporary work forces, but this is more expensive and requires a greater focus on quality control because of the lack of retained knowledge and experience.

Cost of energy reduction can still occur with existing turbine platforms but there is less long-term potential and greater risk

Without the expectation of a sustainable 1GW per year pipeline, most consultees agree that turbine suppliers with existing 6MW to 8MW turbines will focus on getting cost out of these products through more learning and efficiencies in the supply chain. They may also introduce turbine variants (where most components are unchanged), such as the Siemens 7MW variant of its SWT-6.0-154, announced in March 2015.

These consultees say that, without new turbine platform development, cost of energy reduction is likely to stall in the second half of the 2020s. This is because cost of energy reduction becomes more difficult as companies have already achieved the easiest gains. This would mean the industry in 2030 would have exhausted the potential of its existing technology and may have lost the corporate experience of the long-term technology development cycle.

Competition between at least three players is critical to cost of energy reduction

The offshore wind industry to date has not yet seen high levels of competition in many key areas of supply. This is different to the onshore wind industry, which has a long track record of cost of energy reduction driven by competing players.

All consultees agree that providing sufficient market size, visibility and confidence is the most effective route to sustainable competition.

Most consultees are strongly in favour of good levels of competition in offshore wind. These consultees highlight that competition not only puts pressure on companies to squeeze margins but also:

- Encourages ongoing technology development
- Keeps companies focused on cost reduction through improving efficiencies throughout supply chain, and
- Drives companies to improve their engagement with customers and share more information.

Consultees also say competition is beneficial at a number of different tiers of the industry:

- Within developers, competition for leases for sites and contracts under support mechanisms drives a cost reduction agenda through their supply chains. This competition is at a European level, but also at a national level, due to the long development times for projects within specific geographical locations.
- Within the first-tier suppliers (including turbine suppliers and EPC package suppliers), that are all working at a European level and have substantial investment requirements.
- At lower tiers of the supply chain, where there may be a narrower geographical basis and more local competition.
- Within investors, competition to provide debt or buy equity drives down the cost of capital. Investors of the size required generally operate across multiple continents.

Some consultees say it is possible to deliver the effects of competition while having fewer than three or four players actively competing. The consensus, however, is that such options hold significant risk of inefficiency or abuse so are unsustainable. This consensus is around seeking a “normal” competitive market with minimal intervention to “engineer” competition.

Sustainable competition in wind turbine supply requires a larger market than any other subsector

Consultees with experience of supply chain development say that competition between turbine suppliers is particularly critical for driving long-term cost reduction. They say the greatest marginal benefit will come from the introduction of strong competitors to the current market leader, Siemens. They also feel that the benefits of competition would probably reach a plateau with four or five competing players in the European market. Overall, most consultees agree it is realistic to expect three strong players in the European market and that this would still offer a reasonable level of competition.

One consultee from a turbine supplier notes that this assumption is contingent on a sustainable market size (see below) as there is a risk that too much competition in a smaller market could be excessive and deter companies from investing because they cannot build a sustainable pipeline of activity.

Consultees say there is an optimum point between excessive competition between too many players of insufficient scale and confidence, and insufficient competition between too few, larger players. On balance, consultees from developers advise that three to four players offers the right balance for turbine supply in a size-limited market. We illustrate this balance in Figure 9, based on a European market size of 3.5GW per year. Consultees advise there are similar shaped trends for other elements of the wind farm.

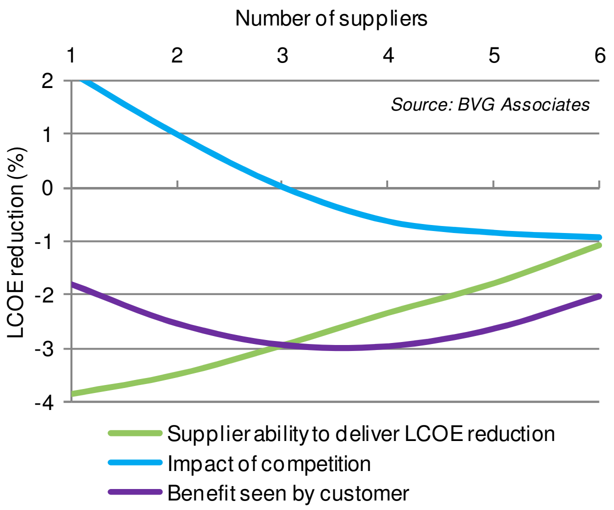


Figure 9 Indicative impact of number of turbine suppliers on the cost of energy in a European market with an annual average deployment rate of 3.5GW.

Consultees say that other areas of supply, such as foundation manufacturing or installation contractors, need lower levels of market activity to stimulate investment in R&D, infrastructure and skills. This means a market that can support three strong turbine suppliers should also support good competition in all other areas. We have set out a summary of indicative minimum market sizes for a sustainable balance between the ability of suppliers to deliver cost of energy reduction and the impact of competition for a range of wind farm elements in Table 2.

Table 2 Comparison of indicative sustainable market size for different elements of the supply chain.

Element	Minimum annual volume per player for efficient cost of energy reduction	Number of players for efficient competition	Minimum market size (annual average deployment rate)	Market level
Project development	0.5GW	4 – 6	2GW - 3GW	Europe / national
Turbine	1GW	3 – 4	3GW - 4GW	Europe / global
Foundation	0.5GW	5 – 6	2.5GW - 3GW	Europe
Cables	0.5GW	4 – 5	2GW - 2.5GW	Europe / global
Installation	0.7GW	4 – 5	3GW - 3.5GW	Europe / global

A sustainable level of deployment across Europe is likely to be 3GW to 4GW per year

To support a competitive landscape with three strong turbine suppliers (with similar levels of competition in other areas), consultees say there needs to be European average annual deployment of between 3GW and 4GW.

Consultees say there is no fundamental requirement for any of this capacity to come from a specific national market, although key markets such as the UK and Germany do have more influence (see below).

Some consultees say that, ultimately, there must be a strong global market to give the necessary competition and investment to achieve margin-levels similar to onshore wind. There is no clear evidence about what this level of global activity needs to be, but some consultees suggest that a global market of 8GW to 10GW with four or five large turbine suppliers with pipelines of 2GW per year is likely to be the plateau for cost reduction, above which further benefits become harder to obtain.

Visibility of, and confidence in, future activity are as important as market scale

An issue raised by most consultees is the legacy of the industry enthusiasm at the launch of the UK's Round 3 offshore wind programme in 2010. The potential size of this programme stimulated strong levels of industry investment but there was no framework and logical demand to deliver this scale of capacity in the timescales discussed at the time. Coupled with similar disappointments in other European markets, this has caused some scepticism about new forecasts of future market activity.

Consultees say this means that companies now place a much stronger emphasis on market visibility (and their confidence in that visibility) when making key investment decisions.

Again, all consultees are realistic that it is not practical to expect governments to give precise market forecasts 15 years ahead but still argue that they could reduce the cost of energy more efficiently if governments gave greater clarity than they currently do. This has particular benefit if this clarity is shaped through government dialogue across the key national markets.

For example, consultees from turbine suppliers say they accept they will need to make investment decisions on new turbine platforms with shorter-term visibility than the development times of their products. They say this is an acceptable risk if there is five years of good visibility of market activity, a long-term logical framework to support ongoing market activity and a reasonable level of political consensus across the European market.

Two consultees say that strong visibility, combined with good levels of competition, would have an additional impact by encouraging turbine suppliers to amortise R&D and infrastructure costs over a longer period. Given confidence in a strong market up to 2030, they advise that such a step could reduce turbine prices by up to a further 20%.

A number of consultees say the most inefficient situation would be the delivery of reasonable market scale but with minimal visibility. This would mean the industry would be likely to meet project demand on a case-by-case basis without making the investment into R&D and manufacturing capacity that this level of activity would sustain. This would mean energy users would support deployment without benefiting from the cost of energy reductions.

Visibility is an important driver for reducing the cost of capital

Consultees in the financial sector agree that visibility is particularly important for reducing the cost of capital.

In part, this is because banks and investors will invest the financial and human resources to understand the sector if they are convinced it is going to become a standard asset class. This will lower risk premiums by improving knowledge and experience of the sector and increasing competition. Feedback suggests that, the larger the market, the faster this will happen.

Some consultees say that strong visibility (combined with market scale) also helps by supporting the development of a sustainable refinancing market. This means that developers can have increased confidence they will be able to access lower cost of finance after construction and build this more aggressively into auction bids.

Long-term commitment from governments to low carbon generation strongly encourages cost of energy reduction

Most consultees say the key to giving industry confidence about long-term levels of activity is legislation-based delivery frameworks that give clear logic for future demand. Governments also need to combine these frameworks with confirmed levels of funding that are sufficient to deliver the proposed levels of deployment.

In the UK, consultees particularly prioritise the need for a 2030 decarbonisation target as a way of confirming long-term demand for low carbon generation. Consultees say it is acceptable that this framework would not give explicit offshore wind targets because companies can make their own judgement about the prospects for offshore wind in the context of a known overall low-carbon generation demand.

Some consultees say that indirect government action to address issues affecting the integration of increasing levels of intermittent generation technology into the grid, such as the development of interconnectors and storage and demand-response technology, are also useful now in demonstrating their long-term commitment.

The UK needs greater short-term visibility to maintain a strong pipeline of projects into the early 2020s

The Round 2 and Round 3 leasing processes for offshore wind sites in UK waters has resulted in a large pipeline of projects all receiving consent in a relatively short period. Consultees say this is a problem because the CfD allocation process is now a serious bottleneck that may cause developers to abandon projects.

As of mid-2015, there is approximately 5.1GW of capacity that is operational or under construction and 5.3GW that is either progressing under the existing Renewables Obligation (RO) regime or has secured Final Investment Decision Enabling for Renewables (FIDER) or CfD support. By the time of the anticipated second CfD allocation round at the end of 2015, more than 11GW of capacity will be eligible to apply, but currently we have little clarity about the size of the budget available.

Consultees say this lack of visibility of allocation round budgets means developers have no insight into when they are likely to secure a CfD.

In the short term, consultees expect this oversupply will push down prices as developers compete to realise the potential of their sunk development costs, which typically range from £50 to £80 million per project. In the medium term, however, consultees say this uncertainty is likely to push some developers to exit the market. Consultees say this is because the carrying costs associated with keeping a project ready for an allocation round are about £5 million per year and it is not possible to hibernate a project under the conditions of the development rights awarded by The Crown Estate and due to the construction windows stated at the time of granting of consents.

Some attrition is acceptable, and indeed necessary for the range of anticipated market size expected in the 2020s and to ensure that only cost competitive projects are constructed. The risk of this situation is that too many developers abandon their projects. This will reduce competition and, in the worst case, mean that there are not enough projects remaining to meet Government ambitions in the 2020s.

Consultees agree the best way to give short-term visibility in the UK is to explicitly state the budget for Pot 2 allocation rounds in the near future. This can involve increasing levels of uncertainty in the longer term but should be precise for at least two years ahead. Most consultees say five years of visibility of Pot 2 allocation round budgets would be optimal as this will give confidence to developers to proceed with investment in consenting new sites and the supply chain confidence to invest, without over-committing government.

We discuss the issues of developer consolidation and improvements to the project development process in Section 4.4.

Industry prioritises political consensus and a stable market framework

Almost all consultees say that offshore wind companies place a strong emphasis on political risk when making decisions about future investment. This is because politicians currently have the power to shut down or restrict national market growth by changing or withdrawing support mechanisms. The announcement to close the RO a year early for onshore wind projects provides a relevant recent example.

As such, consultees say it is important there is a reasonable level of cross-party political consensus underpinning any framework for delivery. As well as general support for offshore wind, this consensus also needs to include an agreement not to radically adjust the current market mechanisms.

This issue is relevant to all countries but most consultee feedback provided in this study was about UK issues. These issues include the mixed messaging about energy policy by the Government, strong negative views from some politicians about onshore wind, mixed levels of political support for the 2050 decarbonisation target and examples of political intervention such as the changing approach to the carbon floor price.

Communicating long-term visibility for offshore wind as clearly as possible is an efficient way to reduce cost of energy

Consultees agree that offshore wind-specific aspirations from governments give added confidence to the industry. Despite this, consultees gave mixed feedback about how governments should present these aspirations.

A number of consultees say governments could increase confidence by providing an annually revised set of holistic aspirations for installed capacity for 10 and 15 years ahead. The Government would do this for a range of energy technologies and include its associated assumptions about the cost of energy, carbon intensity and other related issues. Consultees say this would improve industry understanding of government thinking while preserving the market approach. They also say it is acceptable that the forecast energy mix would evolve over time as different technologies progress and the market changes. This means there will be greater certainty in the forecast in the near-term and less certainty further into the future.

Consultees see ranges of anticipated deployment as useful, but want them to be much narrower than the wide range of scenarios the UK Government has published in the past.

Some suggest that governments could give minimum aspirations to reflect a conservative baseline of activity that they are confident of supporting. This approach would offer an upside for each technology, subject to progress compared with other technologies.

Others consultees are concerned that a conservative minimum aspiration would depress the market compared to a more open approach. These consultees say it is enough to see clear short-term trends that companies can then extrapolate out into the future.

Other consultees are sceptical about the benefits of Government forecasts, having been unimpressed by previous efforts, particularly on future costs of energy of a range of technologies. Instead, these consultees say it is better for the main Tier 1 companies to communicate their own forecasts of activity, based on the wider legislative framework and their own knowledge of the potential for cost of energy reduction. These consultees say this would be a more effective way of communicating future expectations to the rest of the supply chain, which might otherwise misinterpret government forecasts, for example ramping up capacity before it is needed.

There is agreement about the benefits of a "commit and review" approach

There is agreement amongst consultees about the benefits of the "commit and review" policy proposed by the Green Alliance.[12] This involves governments committing to a level of market growth, while retaining the option to reduce this commitment if the industry does not meet cost of energy reduction criteria by a certain date.

Consultees say industry has proved it can respond positively to government challenges on cost of energy, given the expectation of market scale. Some consultees also say this approach needs an annual rolling horizon, rather than occasional larger steps or it risks simply pushing the current cliff edge of market uncertainty into the future. Industry recognises that this involves one government committing future governments to spending plans.

The UK and Germany are the engines of the European offshore wind market

All consultees agree that most of the industry considers the market at a European level when making investment decisions. They also note that the influence of the UK and Germany is strongest because these are the two largest markets.

Consultees say markets like the Netherlands, Belgium and Denmark are less influential because they are smaller and more likely to have intermittent installation. Similarly, consultees consider the French market to be less important than the UK and German markets because of its strong focus on domestic supply and concerns about the proposed timescales for delivery and unproven (and likely unsustainably expensive) support mechanism.

Of the two key markets, consultees say the UK has the most to gain from a mature offshore wind market because of its far larger wind resource and greater need for more low carbon generation capacity.

The influence of the UK means that consultees say there is a relatively high risk that the Continental market could stagnate if the UK decides to pull back significantly from the market.

Even if the Continental market did prove sustainable with low UK participation, consultees say the cost of energy for UK projects would probably remain comparatively high. This is because of the higher logistic costs of a Continental supply chain and the fact that companies might impose a premium on UK projects to reduce the cost burden on energy users in their home markets.

[12] Green Alliance, *UK offshore wind in the 2020s*, November 2014, available online at http://www.green-alliance.org.uk/UK_offshore_wind_in_the_2020s.php, last accessed June 2015.

A UK market with an annual average deployment of only 1GW would restrict cost of energy reduction

Consultees say a UK market with annual average deployment of 1GW or less could not sustain reasonable levels of competition between developers. This is because it is unlikely that enough developers could build a sufficient pipeline of activity if only one or two projects secure support each year. Consultees also suggest there would be little incentive for developers to invest in new site development.

Some consultees say the Government could avoid stagnation by focusing the pipeline on a single developer to give it the clarity and scale needed to drive cost reduction within its supply chain (see Section 4.2.2 for more detail).

Consultees from the financial community also say a UK market of this size would not be attractive enough for investors to put in the necessary resources to understand fully the local risks, rules and regulations. This would reduce competition between lenders and mean they would be less likely to reduce their risk premiums for UK projects.

Industry considers a UK market with an annual average deployment of 1.5GW is sustainable

Almost all consultees agree that an annual average deployment of 1.5GW in the UK offers a reasonable minimum market scale to enable a sustained cost of energy reductions. This assumes a similarly reasonable market in the rest of Europe with an annual average deployment of 2GW during the 2020s.

Consultees say this level of installation fits with the expected capacity of the Great Britain (GB) electricity network to accommodate intermittent generation capacity and the financial resources available to developers.

Pulling back from an existing strong programme of offshore wind deployment means the UK would miss a major industrial opportunity

There is general frustration amongst consultees that the UK Government is not giving clear support for the development of a long-term sustainable offshore wind market, hence losing a real opportunity.

They say the UK has invested a lot of money in supporting deployment during the formative stages of the industry's development and a slowdown now would jeopardise the skills and experience base developed in the UK so far.

Consultees say the UK's programme of deployment to date has created a momentum and given it a first mover advantage that should stimulate investment that will create jobs and export opportunities. Many consultees are concerned that a decision to slow down installation rates (or even delay giving clarity for too long) would mean it would lose this momentum.

Providing visibility to 2030 should be low risk for the UK Government as there are limited options available under the likely decarbonisation scenario

A number of consultees suggest DECC has an outdated and unhelpful focus on maintaining an entirely impartial market-based approach to the development of the energy sector. This stance means it relies on competition between technologies to drive delivery and is culturally opposed to giving market visibility.

Consultees say this approach affects confidence and restricts cost reduction in all electricity generation sectors because no sector has clarity about the size of their long-term opportunity. Consultees say this situation affects offshore wind more than other technologies because it is the low carbon option that can flex to fill deployment gaps quickly.

Consultees argue that DECC's approach is particularly unhelpful because wider market considerations mean there are currently only a limited number of ways in which the UK demand can be met under an anticipated 100g CO_2/kWh decarbonisation scenario. These include the political consensus to remove unabated coal capacity from the UK energy mix, the effective limits on the amount of intermittent generation in the GB electricity network and the slower-than-anticipated progress of large scale nuclear and carbon capture and storage (CCS) projects.

Combined with practical assessments of the technical development, consenting issues and project pipelines of all technology types, consultees argue the Government probably already has a clear idea of the approximate electricity generation mix in 2030 under a 100g CO_2/kWh decarbonisation scenario. Consultees say this means there is little benefit in DECC maintaining such a hands-off market approach as it is only limiting cost reduction and UK industrial development.

Consultees say it would still be possible for DECC to keep flexibility and the market approach within a framework of communicating its expectations.

The CfD regime needs to be refined and improved

Despite being positive about some aspects of the CfD regime, consultees say there are still a number of important issues for the UK Government to address.

Consultees say there are structural concerns about the long-term availability of funding under the regime and this risks damaging industry confidence in Government plans.

In particular, consultees are concerned about the robustness of the Government assumptions used to calculate budget drawdown for all technologies under existing and previous support mechanisms. This includes assumptions around technology-specific load factors and the accuracy of the modelled reference price. The risk is that inaccurate modelling means DECC spends its budget more quickly than anticipated, driving a future restriction in the pipeline unless the budget is increased.

Consultees also seek greater clarity about the level of funding likely to be allocated to negotiated CfDs (such as CCS and nuclear and tidal lagoons) and Pot 3 (biomass conversion). Some also raise concern that the existing arrangements do not enable large-scale Round 3 zonal approaches. These offer further cost of energy reduction opportunities, taking benefit of strategic investment and synergies across a number of projects constructed over five or more years in the same location.

The UK should support efforts to create a European energy market

Consultees say that as the UK deploys increasing levels of intermittent generation capacity, it needs to shift from an island approach for electricity generation towards participating in an integrated European energy market.

Consultees say this is a critical step toward accessing cheaper and less carbon intensive balancing capacity rather than just using gas-powered plants. This will be necessary if the UK is to continue to work toward its 2050-decarbonisation targets. It will also allow the UK to make the best use of the natural resources it has by exporting energy to the rest of Europe.

Consultees say the Government can build stronger long-term market confidence, and pave the way for further offshore wind market growth beyond 2030, by actively participating in work to support the creation of a European energy market.

4.2.2 Confidence in future levels of own supply

Industry says…

There is agreement that generating confidence in future levels of own supply, rather than the sector as a whole, is a more efficient way to enable internal investment decisions and unlock cost reductions.

Some parts of industry, however, are cautious regarding any Government intervention to give more confidence to some players, such as awarding multi-gigawatt packages of capacity to developers in less frequent auctions.

Governments would need to balance the benefit of giving some players a longer pipeline with maintaining an open and flexible market that can support the establishment of long-term collaborations and new entrants. This may be possible through alternative auction models such as those that remove allocation risk but maintain price competition.

Scope

Distinct from the overall market scale and visibility, this driver covers the confidence of companies in their own pipeline of future activity. For example, there is a significant step between the prospect of a 30% share in a future market of 3GW per year for five years and a firm pipeline of committed orders of 1GW per year for five years.

This confidence is relevant for both developers (with ongoing pipelines of projects to consent and build out) and suppliers (with confirmed or provisional orders for goods or services), but is less relevant for financial investors. Confidence may be due to framework agreements or relationships with other companies in the industry.

Governments can support the development of company pipelines of activity by releasing support for projects in larger packages or by encouraging frameworks through such vehicles as DECC's supply chain plans in the UK.

Potential impact

Industry advises that this driver accounts for approximately 8% of the cost of energy savings available in the "Upper bound" market scenario, or a reduction of approximately £2 per MWh (or 1.9% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver affects the cost of energy by stimulating investment in R&D, supply infrastructure and skills as well as supporting the retention of industry learning and experience.

Figure 10 shows that, during the decade, the greatest reductions will come from driving innovations in turbines and wind farm operations, with reduced impact of innovation in cost of capital compared to the "Upper bound" scenario. This is because confidence in the pipeline has less effect on financial players than on developers and their supply chains. The greatest opportunities are therefore in technology and supply chain.

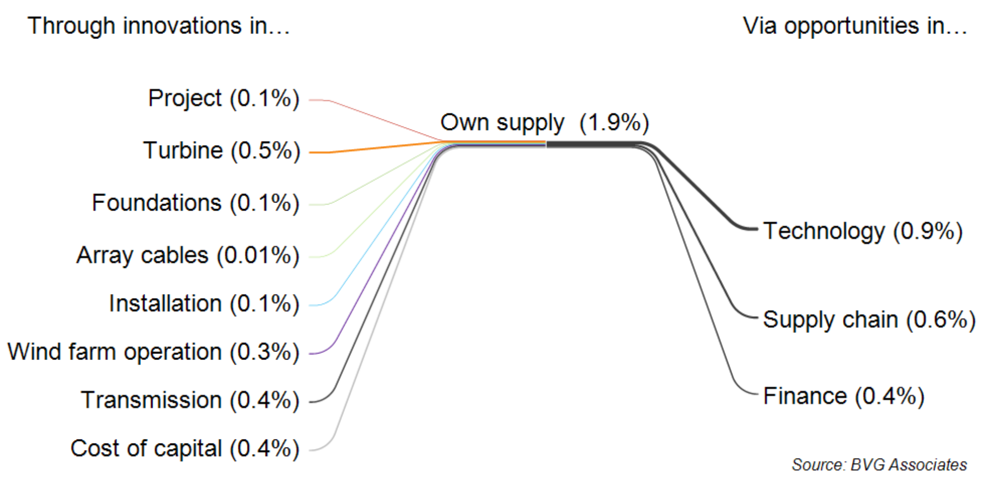


Figure 10 Impact of government intervention to improve confidence in future levels of own supply in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

Awarding pipelines of work avoids the risk that companies hold back from investment

Consultees say that, without a confirmed pipeline of projects, companies are much more likely to focus human and financial resources on short-term opportunities. This means they will aim to get the best price for their current projects and not necessarily invest in facilities, tooling and innovations that offer benefits on subsequent projects.

For a developer, examples of long-term multi-project opportunities highlighted by consultees include standardisation of designs, establishing confidence in reusable technology like floating LIDAR and the demonstration of new technology, such as novel foundation designs and next-generation turbines.

Consultees agree that DONG Energy is currently the only developer in a position to take this longer-term approach in the UK market, having built up a programme of projects that will last until the end of the decade under the existing RO regime and the FIDER process.

For suppliers, a pipeline of activity may unlock investment in new production facilities, equipment or skills development that might not take place if the company only has visibility of one or two projects.

For example, consultees say that the Government managed the FIDER process to give Siemens a large enough pipeline of work to invest in its Green Port Hull facility. This has logistic benefits for serving the UK market but Siemens had previously held back from investing because it did not have enough committed orders.

A pipeline of activity means companies retain learning and build up experience

There is strong industry experience of companies getting measurable improvements in efficiency during project delivery through learning. Consultees say this benefit is likely to be lost if a company has to disperse a team because it cannot assign them to a new project straight away.

Ideally, a company's pipeline will include broadly similar levels of activity in projects that are either starting, in progress or closing out. In these circumstances, companies are able to continually redeploy teams and implement rigorous lessons learnt processes.

Companies can most efficiently implement such an approach when they have a confirmed pipeline of activity. Consultees say this process of building up company knowledge and experience is particularly important in less buoyant markets that cannot stimulate strong investment in new technology, meaning that there is a greater opportunity to make repeat work more efficient.

There is limited enthusiasm about the potential of multi-gigawatt CfD awards to single teams

Despite acknowledging the benefits that a secure pipeline of activity can offer developers and their supply chains, most consultees do not want governments to intervene to create a market with larger chunks than individual project size.

The Government rations funding under the UK's CfD mechanism as it decides the budget for each annual allocation round. There are also no restrictions about the size of offshore wind project that can apply for support. This means that, if the budget in a single CfD allocation round was large enough, it could be awarded to a multi-gigawatt tranche of projects that could give a developer and its supply chain the confidence to invest in long-term opportunities.

Industry advises that it is happy with this arrangement as long as it does not lead to less frequent allocation rounds. Such a change may better suit a strategy of awarding large tranches of capacity but risks damaging developer interest (see also Section 4.2.2).

Some consultees say that governments could move away from having unrestricted auctions with no minimum project size and ring fence some funding for projects over a certain capacity.

For example, the UK Government could decide to auction a CfD for a single project or tranche of projects with a capacity of up to 4GW and allow the developer to build this out over up to five years. Such an auction could be repeated on a regular basis so new contracts continue to be available.

This approach would effectively offer developers a similar scale of pipeline that DONG Energy achieved through the FIDER process but with a competitive auction to determine the price.

A minority of consultees say this approach could stimulate a positive process of aggressive assessments of future cost reduction and greater collaboration between developers and their supply chains.

Most consultees say, however, it would probably entail more risk and may be less successful in long-term cost of energy reduction than yearly auctions that enable players with one or more projects to compete. This is because consultees were not sure there were enough developers able to bid for such large contracts and this would limit the impact of competition. Furthermore, consultees say developers would probably be unable to forecast future cost reduction accurately and therefore use conservative estimates when bidding.

Consultees were also concerned that an auction process that only gave one winner a year would mean some players may not win any capacity for a number of years. This would mean they would face high carrying costs if they decided to continuing bidding for such a large project and would be unable to retain the delivery team needed to it build out. Furthermore, if governments only held auctions every two or three years, developers would only have one or two chances to bid with a project before their five year consenting window elapses.

Overall, consultees recognise the potential benefits in governments facilitating confidence in own pipelines in this way but generally are not comfortable with a move in this direction.

Confidence in own supply has a larger enabling effect on investment decisions in a lower volume European market

As discussed on Section 4.2.1, most consultees say a UK market with an average annual deployment of 1GW or less with poor visibility would not support significant cost of energy reduction.

Some consultees say some cost of energy reduction would still be possible if the Government gives maximum visibility and commitment to only one or two developers. By concentrating the pipeline of activity, these developers (and their supply chains) would still be able to take a long-term approach and invest in innovation, infrastructure and skills.

Most consultees say this benefit is outweighed by the increased risk that the selected developers would not pass on the full cost of energy reductions to energy users because of the lack of competitive pressure.

Even if governments attempt to address this issue through careful planning of the trajectory of the strike price, consultees say this lack of competition would mean they might eventually face a situation in which the selected developer refuses to build projects at the proposed price. In this case, other developers would struggle to step in as their teams and pipelines would have become degraded.

Furthermore, there would be no guarantee that developers or suppliers would be willing to make long-term investment based on this arrangement because of the increased political risk. As discussed in Section 4.2.1, many key players have internal competition for funding and such a constrained market is fundamentally less attractive to them.

4.3. Innovation

4.3.1 Public-funded R&D and skills development

Industry says…

Public funding has an important role in some stages of the process of bringing new technology to market, such as concept development and the full-scale demonstration of new foundations and turbines.

Large-scale R&D programmes, such as the development of a next generation turbine platform, are best delivered by large, commercial players who are already experienced and active in the market and are stimulated through competitive conditions in a sustainable market size with good visibility.

The commercialisation of new technology needs a lot more than just R&D funding. It also needs investment in new delivery capacity throughout the supply chain, practical experience from operating existing wind farms and buy-in from customers.

Scope

Governments can support R&D and skills development activities through public funding. This support may be direct or indirect.

Direct support involves funding to companies or academic institutions to support R&D programmes or collaborative work.

Indirect support involves funding enabling bodies that can facilitate and enhance industry efforts or testing facilities that can be used by industry.

Potential impact

Industry advises this driver accounts for approximately 9% of the cost of energy savings available in the "Upper bound" market scenario, or a reduction of approximately £2 per MWh (or 2.2% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver affects the cost of energy by accelerating technology innovation in all elements.

Figure 11 shows that, during the decade, the greatest reductions will come from innovations in turbines and transmission, with no impact through reduction in cost of capital, due to the increased risks associated with the introduction of new technology. The greatest opportunities therefore are in technology.

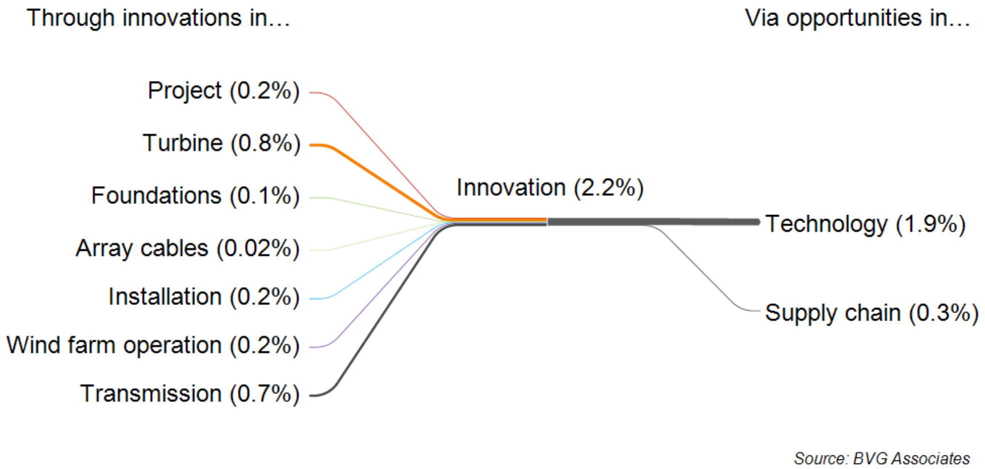


Figure 11 Impact of government intervention in public funded R&D and skills development in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

Public funding is important for some stages of the R&D cycle

Consultees say public funding can be critical for pushing forward the introduction of new offshore wind technology at particular points in the technology development process.

Consultees say the most important example of this is the full-scale demonstration of key project components, particularly offshore demonstration of turbines and foundations. In this case, there is typically a large cost for the owner of the project but much of the benefit of proving the new technology is shared rapidly across the industry. This means there is often insufficient incentive for a private company to be a first mover and government funding can have an important role in accelerating the commercialisation of new technology.

Consultees also say there is an important role for governments in supporting early concept designs when technology is still years away from commercialisation, provided there is a strong focus on end-user needs, facilitated by direct or indirect involvement.

In a buoyant market, public funding can accelerate some industry-led activities

Given suitable confidence in future market scale, consultees say that companies will invest their own funds in developing new technology and skills. In this case, consultees say that public funding can be important for enabling investment in technology that has greater associated risk or has benefits that are more marginal.

Consultees say this process needs to be managed carefully to avoid duplicating existing work or focusing on solutions that do not sufficiently match industry requirements.

Administered effectively, however, consultees say that public funding has a valuable role to play enabling the development of technology that would not otherwise have progressed in a timely fashion. This may be because of the high cost of testing, or because smaller companies with innovative solutions lack the resources to exploit their full potential or because end-users just need to see more evidence of progress before they commit resources to adopting third-party ideas.

Consultees also say that the impact of public funding is greater where there is coordinated action between agencies in different national markets, as this avoids repetition and focuses effort where there is the greatest specialism.

Public funding cannot replace private investment in pushing forward major technology innovation

All consultees agree that private funding by industry is needed for much of the R&D activity required to drive down the cost of energy.

The main reason for this is the level of investment needed to commercialise new technology. For example, as discussed in Section 4.2.1 and Appendix E, the cost of developing a new turbine platform typically ranges from £300 to £750 million. This excludes investment by the supply chain to series-manufacture components, which may be of similar scale to these costs. Consultees say commercial players have much greater financial and knowledgeable personnel resources available than any public body and are able to channel these more effectively when they see a commercial opportunity and can better react to an evolving market picture and learning from operational projects.

Consultees also say governments often need to be seen to spread public funding for R&D across a range of areas. This means even their larger investments can only have a limited effect in particular subsectors.

Consultees also say that governments are often not good at identifying the areas where innovation can have the greatest impact on cost of energy. There is a perception that governments focus public support on initiatives that are more likely to stimulate investment in factories and jobs but that may not have a significant effect on the cost of energy. Indeed, as much of the offshore wind supply chain is located overseas, it is likely to be politically sensitive if the UK Government awards significant R&D funding to companies without securing a direct industrial benefit to the country.

Turbine suppliers and others are also protective of their intellectual property and knowhow and consultees say it is unlikely that any player would consider sharing significant core technical knowledge in the interest of pushing forward a public technology programme.

Investment in R&D is only one element of commercialising a new technology

All of the consultees with experience of product development say R&D is only one of the activities in taking innovations from concept through to full-scale commercial use.

In particular, consultees say there is often significant investment required by the supply chain to adapt their production capacity to supply new components.

For example, the development of a new turbine platform will involve the design of larger blades, towers and structural and drive train nacelle components. In most cases, it is unlikely that existing suppliers will have the capacity to produce these larger components and will need to invest to upgrade their capacity. Such activity is generally not funded as R&D and needs some level of commitment from the turbine supplier about future demand.

New technology development needs to build on the experience of operating existing designs

Consultees say a critical non-financial element of technology development is the corporate practical experience of operating the previous generation of technology.

Consultees say this experience provides critical information in defining how companies can improve technology. They say there is strong evidence from the onshore wind sector of companies pushing turbine designs to their technical limit and maximising cost effectiveness because the engineering teams have built up a detailed knowledge about how components work in the field.

Consultees say there is a limit to how much additional R&D spend can replace this insight.

There needs to be a controlled ramp-up in deployment of new technology to avoid high costs of capital

Consultees say that developers and financial investors are typically cautious about the use of new technology because of the high cost of failure in offshore wind projects. This means the increased cost of capital imposed to cover this risk may outweigh the cost of energy benefits of using an innovation.

Consultees say industry addresses this issue through structured programmes of deployment, with sequential increases in project size. For example, the Siemens SWT-6.0-154 turbine initially underwent a programme of onshore demonstration with two units in Denmark and one in Scotland in 2011, 2012 and 2013 respectively. The first offshore demonstration was a two-turbine project in UK waters in 2013 and the first medium-scale commercial deployment started in 2014 with 35 units on the Westermost Rough project.

Consultees argue this programme of deployment is critical to understanding the practical operating issues of new technology before developers use it on large-scale commercial projects. As there are strict state aid limits on the amount of public funding that governments can award to electricity generation projects (particularly at a commercial scale), consultees say it would be impossible for governments to support such a process to any significant degree.

4.4. Other supporting actions

In this section, we consider other actions that governments can take to support cost of energy reduction that are not related to deployment or innovation support.

4.4.1 De-risked investment in projects

Industry says…

De-risking offshore wind projects through export credit agencies and government infrastructure funds has already had a positive effect on the cost of capital for Continental projects. This has not yet happened in the UK, although plans are well advanced.

Government interventions such as the Electricity Market Reform process, the Green Investment Bank, the Offshore Transmission Owner (OFTO) regime and requirements on the Planning Inspectorate have all de-risked UK projects for project developers and investors.

The UK's system of competitively awarding CfDs after developers have invested heavily in consenting projects has higher risks for developers than Danish and Dutch systems of central development and permitting prior to auction.

Scope

Commercial offshore wind projects are large-scale infrastructure developments that need significant investment; this is routinely now more than £1 billion per project. The cost of capital has a major impact on the cost of energy of projects, as shown in Figure 1.

Governments can help reduce this cost of capital through reforms that reduce the level of risk that developers, equity owners and debt providers face.

While this driver affects all projects, the financial community looks more closely at the risks associated with different national markets than other parts of the supply chain. As such, we have primarily focused on actions that the UK Government can take to reduce the risk associated with UK projects.

Potential impact

Industry advises this driver accounts for approximately 10% of the cost of energy savings available during the 2020s in the "Upper bound" market scenario, or a reduction of approximately £3 per MWh (or 2.4% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver affects the cost of energy almost exclusively by reducing the cost of capital.

Figure 12 shows that, during the decade, almost all the savings are coming directly from innovations relating to the cost of capital, with minor savings elsewhere due to the knock-on benefits of de-risking.

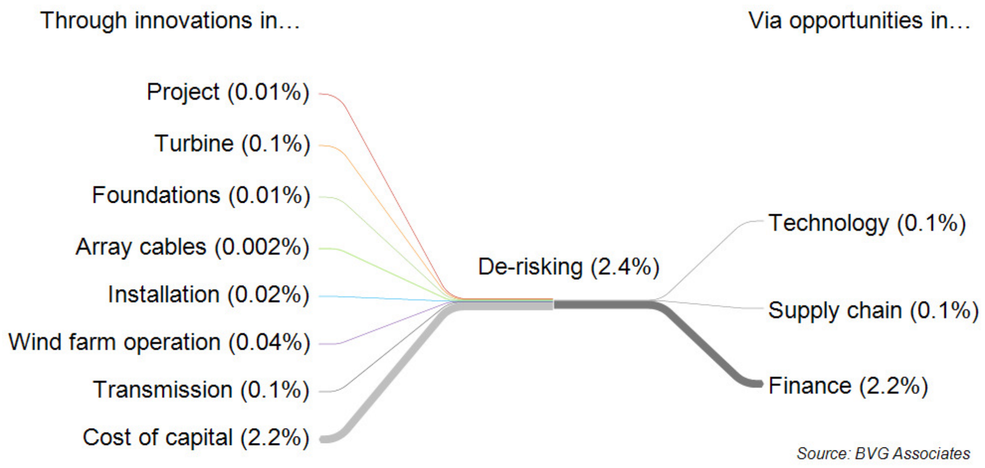


Figure 12 Impact of government intervention to de-risk investment in projects in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

The UK Government has already taken many important actions to de-risk investment

Examples of positive intervention already taken by the UK Government that consultees highlight are:

- The CfD mechanism, which was set up to address risks associated with project revenue
- The Green Investment Bank, which was set up to address concerns about a potential lack of funding
- The OFTO regime, which was set up to address regulator issues about asset ownership and attract investment in transmission infrastructure, and
- The Planning Inspectorate, which was set up to address concerns about the uncertainty and potential length of time for consent determination.

There are still concerns about the complexity of the CfD mechanism compared with support regimes in other countries. This is expected to add some cost to UK projects until developers and investors become more familiar with the process and see a track record of revenue generation. We set out more detailed views about potential reforms to the CfD regime in Section 4.4.3.

UK developers are also making progress towards attracting lower cost project finance

Most developers of operational UK projects have been multinational utilities that have typically used their own balance sheets to finance the construction of offshore wind projects. Some have then gone on to recycle capital after some years of operation. This is in contrast with a number of Continental projects, where developers have been smaller and have tended to use limited equity combined with non-recourse project finance debt more routinely.

Consultees say that, because many utilities have faced severe financial problems in recent years, future market growth in the UK requires developers to become much better at accessing external finance, either pre- or post-construction.

Consultees say that, despite some difficulties on specific projects in the past, developers of UK projects are now making strong progress toward this goal.

In particular, consultees say most utility-developers now recognise the importance of structuring their projects so they are attractive to the financial community. This means the developer should award a maximum of three main contracts, as this reduces complexity and means it is easier to allocate risk clearly. Ideally, some of the main contractors should also take some equity in the project to give investors added reassurance about the delivery of the project.

Further government action could further reduce the cost of capital

Consultees say the Government could do more to support further de-risking of UK projects by following best practice already seen on Continental offshore wind projects and other large-scale infrastructure projects in the UK.

For example, consultees say that the Government should ensure that developers have access to the same kind of Treasury-backed infrastructure guarantees that have already been offered to the Hinkley Point C consortium. This will directly reduce the cost of capital for developers.

The use of export credit agencies to underwrite the liabilities of Continental companies in the supply chain has already been used effectively on Continental projects. The active support of the UK export credit agency would help UK companies to increase competition with Continental suppliers by putting them in a better financial position to take on larger projects.

There is mixed feedback about the likelihood that cost of capital will reduce significantly for UK projects

A minority of consultees are still sceptical about how much the WACC will reduce on UK projects in the future.

In part, these consultees say this is because UK banks are not in a position to offer long-term project finance to offshore wind projects because they are still repairing their balance sheets following the financial crash. These consultees say this may deter investors who prefer to have a lead arranger based in the country of origin and have strong links with regulators and Government.

Other consultees challenge this and say that attracting overseas investment is not likely to be a barrier for developers that have well-structured projects and have spent time engaging with the finance community

Another concern raised by consultees is the impact of rising interest rates. The current historic low interest rate will not continue indefinitely and consultees say there is uncertainty about the relative impact of increased interest rates on offshore wind, compared with other generating technologies.

Industry believes the UK's current CfD award model puts too much risk on developers

Under the former RO regime, a developer could be confident of building out a project once it has secured planning consent. Under the CfD regime, developers also need to secure a CfD in a competitive auction.

Consultees say that this additional allocation risk means the cost of capital is currently extremely high for spend during project development. The impact of this on the overall cost of energy is small because expenditure is relatively low at this stage. Consultees say this risk is likely to deter developers from investing in new sites until the current backlog of projects seeking CfDs has been reduced, either through the provision of contacts or attrition.

Consultees say the Government could address this situation by changing the timing of when it awards CfDs in the development process.

Consultees say other European countries have already used alternative approaches successfully. For example, the Danish model involves auctioning a consented site along with a support contract. In this way, the government takes the development risk and companies have no allocation risk once they have won an auction. Consultees say that the Netherlands has also now adopted a similar system.

4.4.2 A well-structured supply chain

Industry says…

A well-structured supply chain with at least three or four strong players in each area of supply is important for reducing the cost of energy.

There is not strong support for further government intervention in a buoyant market to engineer collaboration and competition in the supply chain.

In a small market, however, proactive actions could ensure that industry is able to maximise cost of energy reduction.

Scope

Governments may seek to intervene in the supply chain if they identify inefficiencies or failures in collaboration or competition.

Governments may impose these interventions through support mechanisms or more general industrial engagement and pressure.

Potential impact

Industry advises this driver accounts for approximately 6% of the cost of energy savings available in the "Upper bound" market scenario, or a reduction of approximately £2 per MWh (or 1.5% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver affects the cost of energy through improved collaboration and competition in the supply chain.

Figure 13 shows that, during the decade, the greatest reductions will come from innovations in wind farm operations, turbines and transmission. These are the areas of highest lifetime spend. The greatest opportunities are in the supply chain.

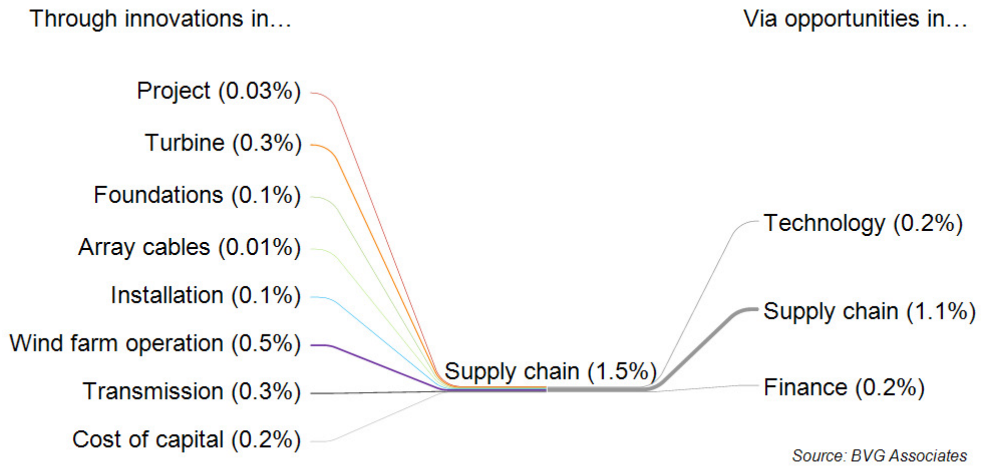


Figure 13 Impact of government intervention to improve supply chain structure in projects in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

Governments can have a role in enabling industry competition and collaboration

Consultees say that governments can use their influence over the market to encourage and support good behaviour by developers and the supply chain.

For example, consultees say the UK Government's Supply Chain Plan is a useful initiative for getting developers to consider how they could use their projects to stimulate new entrants into the market (albeit with a UK-focus) and how to work with other companies to drive down the cost of energy.

Consultees also say that governments (or their agencies) often play an important role in establishing and supporting joint-industry projects (JIPs).

Consultees highlight examples such as the Carbon Trust Offshore Wind Accelerator's Pile Soil Analysis (PISA) and the Offshore Wind Programme Board as examples of publicly-led initiatives that encourage cross-industry collaboration.

There are also benefits from coordinating such activities across national markets to ensure consistency, share best practice and encourage cross-border collaboration, such as through the Seastar Alliance.

There is limited enthusiasm for more direct government interventions on supply chain structure

Most consultees are not keen to see governments become actively involved in changing supply chain structures and do not believe it would have a positive impact on the cost of energy.

The only exception is some interest in ongoing government intervention in the development of port sites that could allow the clustering of manufacturing and installation facilities.

The UK Government may be able to support developer consolidation

A minority of consultees suggest the UK Government could have a role in supporting the consolidation of developers of UK projects.

These consultees say there are currently too many players in the UK market, with approximately 10 companies. This overcrowding is inefficient because it makes it harder for any company to build up a sustainable pipeline of activity or strong track record of delivery, with learning diluted across many players.

These consultees say the current pool should be reduced to around three or four stronger players with the pipeline and human/financial resources to drive cost of energy reduction.

Most other consultees say the market is likely to drive this rationalisation anyway but concede there is a risk that it takes too long, or risks overshooting, with too many companies deciding to pull back.

Some consultees say there are precedents of governments successfully arranging consortia, such as Airbus or in the nuclear sector. Other consultees say these examples are only relevant if the aim is to establish a pan-European player in a global market but, otherwise, governments are more likely to create inefficiency by getting involved.

The CfD process could be more supply chain friendly

A number of consultees say they agree with the recommendation set out in the *Chinn Report* produced for the Offshore Wind Industry Council to increase the length of time between winning a CfD and reaching the Milestone Delivery Date (MDD), which currently requires developers to have spent 10% of project costs within a year.[13]

The Chinn Report said that relaxing this requirement would support first time suppliers into the market by giving them more time to invest in new facilities, equipment and skills development. Consultees agree with this but also suggest there are wider benefits for all parties in terms of reducing the cost of energy.

Consultees say the MDD deadline is so short that there is insufficient time for developers to collaborate with suppliers to reduce costs. Consultees say this is an important opportunity because detailed engineering investigations may be limited before an auction because developers do not want to spend large amounts of money with such high levels of allocation risk.

[13] Matthew Chinn on behalf of the Offshore Wind Industry Council, *The UK Offshore Wind Supply Chain: A Review of Opportunities and Barriers*, November 2014, available online at http://www.thecrownestate.co.uk/media/389763/owic-uk-offshore-wind-supply-chain-review-opportunities-barriers.pdf, last assessed June 2015.

4.4.3 A cost-efficient support mechanism

Industry says…

A government-set feed-in tariff risks the industry pricing to the tariff, while a well-run auction at the right stage in project development offers short-term efficiencies, if competition is sufficient.

Well-managed support mechanisms can facilitate longer-term efficiencies as long as a balanced level of competition is preserved.

Scope

The structure of the mechanisms used to support the development of new offshore wind capacity can play an important role in driving down the cost of energy and maintaining a dynamic market.

If the system does not put enough competitive pressure on developers and the supply chain, then there is a risk of profiteering, with the benefit of investment only partially passed onto energy users.

If there is too much competitive pressure, although there may be short-term benefits, players may decide to leave the sector and the market can become too dependent on a small number of players.

Potential impact

Industry advises this driver accounts for approximately 12% of the cost of energy savings available in the "Upper bound" market scenario, or a reduction of approximately £3 per MWh (or 2.9% of cost of energy) between projects with first generation in 2020 and 2030 (in 2012 terms).

The driver affects the cost of energy through ensuring industry passes through the cost of energy benefits of technology, supply chain and finance innovations to energy users.

Figure 14 shows that, during the decade, the greatest reductions will come from innovations in the provision of capital, turbines and transmission, in line with the "Upper bound" scenario. Likewise, the greatest opportunities are in technology and finance.

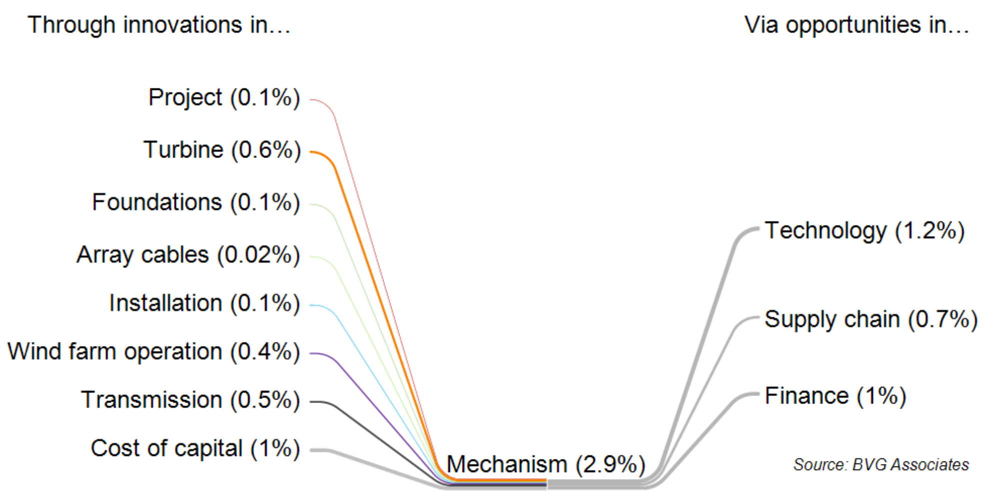


Figure 14 Impact of government intervention to establish a cost-effective support mechanism in the "Upper bound" market scenario for a typical project with first generation in 2030, compared with a project with first generation in 2020.

Key issues

Industry acknowledges that auctions are an important means of cost discovery

Despite some concerns that offshore wind has moved to an auction process in the CfD regime much sooner than expected, consultees agree that it already seems to have achieved strong short-term cost benefits for UK energy users.

Most consultees assume that auctions will continue to be needed in future development rounds so it is in the Government's interest to ensure that competition remains both strong and sustainable.

Many consultees say that there must be losers in an auction process to ensure competition, but that the current levels of competition are not sustainable. A number of consultees suggest that a failure rate of about 30% is sustainable, as most players will back themselves to win, with such odds.

Conversely, if there are not enough participants in future auctions, the Government will need to rely on reducing the headline Strike Price on the right trajectory to achieve cost of energy reduction, which is unlikely to be efficient. This is because, if the trajectory is too steep, it will driver players from the market and decrease the industry's ability to deliver. If the trajectory is too shallow, then opportunities for cost of energy reduction will likely be lost.

Not all consultees believe auctions are a sensible long-term approach to building large-scale infrastructure. Some say this approach does not support the creation of strong, robust developers and note that there are no examples of comparable sectors using a similar approach. These consultees say a more efficient situation would be a small pool of strong developers who are able to negotiate with the government for support for large-scale infrastructure projects, in the same way as nuclear or CCS. The general consensus opposes this view, but accepts it is more likely to be necessary in a smaller market.

Regular access to auctions is important

All consultees from developers say that regular access to auctions is important to sustain a pool of interested developers and suppliers.

For example, developers typically have a five-year consenting window to start building out a project. Consultees say that, if the Government only hold auctions every second year, the decision for an unsuccessful developer to carry over the project until the next time is much more difficult.

There are important unresolved issues for the long-term operation of the CfD regime

The Government currently classifies offshore wind as a "less established" technology under the CfD regime. The Government has said its ultimate aim is have a technology-neutral process in which these technologies compete with established technologies such as onshore wind and large scale solar photovoltaics.

Consultees say there is currently no guidance from DECC about how this transition will be managed or how technology-neutral auctions could work. They say this uncertainty needs to be resolved, or at least more guidance provided, to allow industry to plan for any future changes. Overall, however, few consultees want to accelerate this transition because it will further increase industry insecurity.

European governments should investigate the potential of harmonising support mechanisms

Consultees say that, as the offshore wind market matures, European states should aim to standardise the way in which their different support mechanism operate.

Consultees say this should remove inefficiencies for developers playing in multiple markets and allow for easier sharing of best practice and increased visibility of costs between markets.

Consultees say there is already progress toward this goal as there are similarities between the support mechanisms of some of the key North Sea markets.

The UK's FIDER programme appears expensive, if seen purely as a cost-of-energy-reduction exercise

The UK Government has been criticised for the way in which it ran the FIDER programme, which was an interim process designed to bridge the gap between the closing of the RO regime and the start of the CfD regime.

These criticisms include the fact that it ended up accounting for almost 30% of the uncommitted funding available at the time under the Levy Control Framework 2020 cap. Furthermore, there was no competitive element or auction to the process so the developers of the successful projects received the headline Strike Price set by the Government. This has since been shown to be much higher than the Strike Prices achieved in the 2014 allocation round auction.

Critics say that, if the FIDER process was simply about helping the industry to reduce its cost of energy, there would have been more cost-effective ways of achieving this goal. In particular, they suggest the Government could have directed public funding into supporting the industry to reduce its costs to £100 per MWh through R&D technology innovation programmes. These critics argue that even high levels of R&D funding would be less expensive than the premium paid for the FIDER projects.

Our modelling (supported by consultee feedback) suggests that, if the FIDER projects were built out at Strike Prices equivalent to a cost of energy of £100 per MWh, the Government could have reduced the public spend by approximately £5 billion by 2030.

The FIDER programme had wider benefits than just supporting industry efforts to reduce cost of energy

Despite these criticisms, the FIDER programme has been successful in pushing forward the development of the offshore wind industry in the UK.

For example, delays in the development of the CfD process meant there was a serious risk of a prolonged dip in the annual installation rates in the UK market. This was likely to result in the industry losing knowledge, experience and resources as companies had to reduce workforces or diversify into other sectors to survive. The FIDER process accelerated the deployment of a number of projects to fill this gap.

The FIDER programme was also criticised for focusing on a small number of industry players. Almost two-thirds of the offshore wind capacity was awarded to DONG Energy and more than three-quarters of all FIDER project capacity will use Siemens turbines.

While this has meant the impact of the FIDER programme is relatively narrow, it has accelerated the deployment of 6MW and 8MW turbines as well as large-scale standardisation programmes across DONG Energy's portfolio.

The FIDER programme also encouraged Siemens to proceed with its £310 million Green Port Hull development on the Humber, which involves blade manufacture, nacelle assembly and project installation.

4.4.4 Other government interventions to reduce the cost of energy

The intent of this study was to explore the impact of a complete set of policy drivers on the cost of energy on a single project with a set of typical project characteristics, fixed through time.

We based our analysis on the assumption that all industry actions, both at a company level and collaboratively, are responses to one or more of these government-led drivers. In other words, we assume there will be no cost of energy reduction in the 2020s, except in response to these drivers, whether directly or indirectly.

The two drivers in this section have the potential to impact cost of energy in the 2020s in the UK but cannot be considered in the same way as the other drivers. The first involves a change in site conditions, and both require significant analysis that is outside of the scope of this study to quantify their impact robustly.

The cost of energy benefits of both are supplementary to the “Upper bound” scenario.

Leasing lower cost of energy sites

Almost all UK offshore wind projects to date have been developed through leasing rounds organised by The Crown Estate.

The largest of these, Round 3, was based on *a Strategic Environmental Assessment* published by DECC in 2009.[14] This report assessed the potential to locate offshore wind farms in UK-controlled waters, taking account of a wide range of factors including site conditions, marine life, existing and planning industrial activity and environmental issues.

As deployment continues and some sites are declared unsuitable for development, The Crown Estate will, at some point, need to provide further areas of seabed for lease. This is likely to involve a similar process to before, but with an increased understanding of the impact of site characteristics on future cost of energy and of constraints to project development. This, coupled with strategic decision-making about the use of sites closer to shore, for example, has the opportunity to reduce cost of energy from these future leases.

Overall, consultees agree such a process could enable deployment on new, lower-cost sites by 2030. Today, characteristics of operating sites give rise to around a +/- 15% range in the cost of energy, excluding the impact of technology choices. As such, it is reasonable to assume that, given some political intent, a further 10GW of capacity could be developed at 10% lower cost of energy than the average of the sites to be installed during the 2020s.

Consultees with a view confirm that there is likely a cost of energy reduction though accessing such sites, but they are generally more concerned about the destabilising effect this could have on the UK’s developer market. They say developers have invested significantly in consenting projects and are already concerned about the low chance of receiving a CfD in the near future. The threat that new sites with a lower cost of energy could overtake them in the competition for future CfDs could push them to leave the market.

Strategic planning of transmission infrastructure

In the UK, all projects completed so far have involved developers building the transmission infrastructure exclusively for the use of their particular wind farm, and typically then selling this on to an OFTO asset owner.

In Germany, there has been a more strategic approach with an independent operator building HVDC hub substations. A number of offshore wind farms are then connected to these hubs so the cost is shared over a number of projects.

There has been discussion about whether the UK could reduce project costs by adopting a similar strategic approach, potentially even taking advantage of the development of subsea interconnectors connecting countries with North Sea coasts.

Only a few consultees gave any detailed views about the potential of actions in this area. These consultees agree that, from an engineering perspective, such an approach could offer cost of energy benefits but say the commercial risks would probably prevent any significant progress in the period to 2030.

Consultees say the area of German-controlled seabed in the North Sea is relatively long and narrow, which is conducive to a hub-based strategic approach. In contrast, offshore wind activity in the UK is taking place all around the coastline with no particular cluster. This would be less of an issue if there was a clear, long-term pipeline of activity for which infrastructure could be planned. The CfD auction process means, however, there is no certainty that a particular project will be able to proceed in a definite timeframe. This would significantly increase the risk associated with any anticipatory investment in strategic transmission infrastructure.

[14] DECC, *UK offshore energy strategic environmental assessment*, 2009, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/194328/OES_Environmental_Report.pdf, last accessed June 2015.

4.5. Conclusions from the driver analysis

Figure 15 presents the relative impact of each driver on the cost of energy, comparing UK offshore wind farms with first generation in 2020 and 2030 in the "Upper bound" scenario.

This shows that industry sees market scale, visibility and confidence as the dominant driver, accounting for the majority of potential cost of energy reduction.

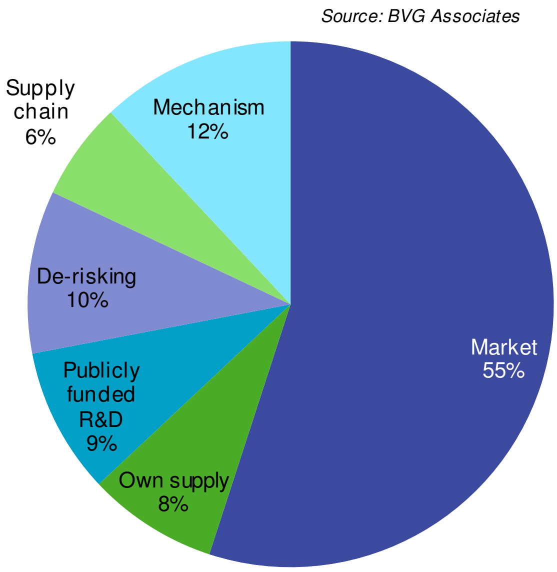


Figure 15 Relative impact of policy drivers on cost of energy reduction, comparing UK offshore wind farms with first generation in 2020 and 2030 in the "Upper bound" scenario.

5. Scenarios of government intervention

5.1. Introduction

In Section 4, we defined the key drivers of cost of energy reduction and explained their relative impact on the "Upper bound" scenario of cost of energy reduction between projects with first generation in 2020 and 2030.

In this section, we describe a number of scenarios of government intervention in which we vary the combination of drivers acting, to reflect different approaches that European governments could take to offshore wind in the 2020s. We then assess the cost of energy effect of each scenario and draw learning from comparing results.

5.1.1 Scenarios

We prepared 10 scenarios to explore different combinations of drivers (excluding the leasing of lower cost sites and strategic planning of electrical transmission infrastructure).

For each scenario, we used the results of Section 4 to model the cost of energy for projects with first generation between 2020 and 2030 (in 2012 terms). We have set out the methodology for identifying and modelling these scenarios in Appendix C.

We intended these scenarios to be as real life as possible, based on the feedback from the industry consultation and our experience of current market behaviour. In most scenarios, we chose to change the influence of more than one driver. A risk of this approach is that it obscures the effect of individual drivers but it also avoids a large number of extreme and unrealistic scenarios.

We have assessed the impact of these scenarios in groups to compare the effects of different approaches to a number of opportunities, as shown in Table 3.

Table 3 Summary of scenarios.

Scenario	Area of investigation
The contribution of visibility and confidence to cost of energy reduction in the UK	
1. Current approach	The impact of the "visibility" and "confidence" elements of Driver 1, Market scale, visibility and confidence
2. Balanced	
The effect of the UK and rest of Europe market size on cost of energy reduction in the UK	
3. Strong support	The impact of the "market scale" element of Driver 1, separating the impact of UK and rest of Europe markets
4. UK slows	
5. Rest of Europe slows	
6. Market stagnation	
The contribution of publicly-funded R&D to cost of energy reduction in the UK	
7. Balanced with enhanced R&D	The impact of Driver 3, publicly-funded R&D, in different market conditions
8. R&D only	
The contribution of other supporting actions to cost of energy reduction in the UK	
9. Improvements to market design	The impact of government intervention through Drivers 2, 4, 5 and 6
10. Supply chain interventions	

5.1.2 Modelling the support cost to UK energy users

For each of the scenarios, we used the modelled cost of energy to calculate the support cost of offshore wind deployment for UK energy users. We have set out the methodology for this in Appendix D.

We have assumed the support cost to UK energy users is the additional cost of offshore wind deployment compared with the equivalent cost of the lowest cost alternative. For this study, we use the cost of electricity from CCGT with carbon price uplift.

The focus of this study is the support cost to UK energy users of new offshore wind projects deployed under the CfD regime with first generation between the start of 2021 and the end of 2030. During this time, however, UK energy users will also be paying for other offshore wind projects deployed under other regimes and under the CfD regime before the end of 2020. As such, we have created a forecast support cost to UK energy users of offshore wind projects deployed under the RO regime, the FIDER process and the CfD regime up to the end of 2020. This support cost forecast is fixed for all scenarios and we have set out the methodology for calculation and a breakdown of the results in Appendix D.

5.1.3 Presentation of results

For each scenario, we provide the forecast average annual level of deployment in the UK and in the rest of Europe and a short qualitative description of the scenario.

We also provide quantitative results:

- Cost of energy and Strike Price for projects with first generation in 2030. The Strike Price is derived from the cost of energy in line with Appendix D
- Total generating capacity (GW) in the UK by the end of 2030
- Annual offshore wind electricity generation (TWh) in UK in 2030
- Total offshore wind electricity generation (TWh) in UK between 2021 and 2030
- Annual support cost to UK energy users of offshore wind in UK in 2030 (£billion)
- Peak annual support cost of offshore wind to UK energy users in the 2020s (£billion)
- Total support cost of offshore wind to UK energy users between 2021 and 2030 (£billion), and
- Average support cost of offshore wind-generated electricity to UK energy users between 2021 to 2030 (£/MWh).

Data about levels of generation and support cost to UK energy users include all offshore wind farms, without considering any decommissioning of early projects, some of which will be more than 25 years old by 2030.

We also separate out the capacity, generation and support cost to UK energy users of offshore wind projects installed under the CfD regime with first generation from 2021 to the end of 2030.

Scenario by scenario, we then qualitatively describe key features of the market and the effects of different drivers on the industry, based on the findings of our engagement programme.

We then compare the impact of different scenarios on the support cost to UK energy users.

For each scenario, in Appendix F we also present figures for the period 2020 to 2030, to show:

- Annual and cumulative deployment rates in UK and the rest of Europe, and
- Annual and cumulative support cost of offshore wind deployment to UK energy users.

We also present Sankey plots for each scenario to break down the overall level of cost of energy reduction between projects with first generation in 2020 and 2030 by innovations in the seven key wind farm elements and by opportunity.

5.2. The contribution of visibility and confidence to cost of energy reduction

This section explores the importance of governments giving clear and timely information about their market support plans to industry. This particularly reflects the visibility and confidence elements of Driver 1, as set out in Section 4.

We have considered two scenarios to investigate this issue, which are summarised in Table 4.

Table 4 Assumptions of analysis of the contribution of visibility and confidence to cost of energy reduction in the UK.

Scenario		Capacity generating in 2030 (average annual installation in 2020s)		Description
		UK	Europe non-UK	
1	Current approach	~25GW (~1.5GW per year)	~36 GW (~2GW per year)	Reflects the current situation, with most governments focusing on delivery up to 2020 and not yet confirming longer-term ambitions or frameworks for delivery. A focus on the need to let market forces drive cost of energy reduction means the UK Government gives minimal quantitative information about its short- and long-term ambitions to the offshore wind industry (and other electricity generation sectors). This approach has the benefit of minimising future government commitments to particular technologies but means each sector has less visibility to enable investment and reduce cost of energy. European governments support levels of deployment sufficient to stimulate sustainable competition in the supply chain. The UK Government also take a hands-off approach to policy interventions via any of the other drivers.
2	Balanced			Governments support the same levels of deployment as above. Governments also give clear and timely information about budgets for support mechanisms and their overall market ambitions. This includes short-term forecasts of anticipated levels of support and robust long-term frameworks that give industry confidence that there will be ongoing demand for renewable generation capacity at least 10 years ahead, as long as it reduces cost of energy in line with expectations. Governments also take a more hands-on approach to intervening and addressing any potential market issues via the other drivers available to them.

Table 5 Results of analysis of the contribution of visibility and confidence to cost of energy reduction in the UK. See Section 5.1.3 for further detail.

	1 Current approach	2 Balanced
Projects with first generation in 2030		
Cost of energy (MWh)	£98.33	£89.96
Strike Price (MWh)	£104.77	£94.69
Total UK fleet in 2030		
Generating capacity (MW)	26.3	26.3
Generation in 2030 (TWh)	104.4	104.8
Generation between 2021 and 2030 (TWh)	737.7	739.0
Annual support cost to UK energy users in 2030 (billion)	£3.3	£2.8
Annual support peak to UK energy users in 2020s (billion)	£4.0	£3.8
Total support cost to UK energy users between 2021 and 2030 (billion)	£36.8	£34.9
Average support cost to UK energy users per MWh	£49.9	£47.2
Of which, 2020s CfD projects		
Generating capacity (MW)	14.8	14.8
Generation in 2030 (TWh)	60.8	61.2
Generation between 2021 and 2030 (TWh)	302.4	303.8
Annual support cost to UK energy users in 2030 (billion)	£1.1	£0.7
Annual support peak to UK energy users in 2020s (billion)	£1.2	£0.8
Total support cost to UK energy users between 2021 and 2030 (billion)	£8.2	£6.3
Average support cost to UK energy users per MWh	£27.1	£20.6

5.2.1 Current approach

Industry will be unlikely to make long-term investments

Despite an average annual deployment rate of 3.5GW across Europe, the lack of visibility in this scenario means no turbine supplier is likely to build enough confidence about its future pipeline to invest in a next-generation turbine platform.

This means the industry will continue to use the existing 6MW and 8MW turbines throughout the 2020s. Turbine suppliers will achieve some cost of energy reduction by developing product variants and there will be improvements in supply chain efficiency across the industry, including in installation and operation, for this size of turbine. Industry will exhaust these improvements by 2030, so opportunities for further cost of energy reduction will be limited.

The lack of visibility also means other companies throughout the supply chain will not invest in new production and installation facilities or new equipment and vessels. This means the industry will not achieve the full benefit of optimised production facilities and logistic costs. Any investment will be likely to be incremental and focused on existing facilities (which are primarily on the Continent) so the economic benefit to the UK will be low.

There will also be little incentive for the supply chain or developers to invest in programmes or technology that have a long term cost of energy benefit. This includes demonstration projects or work to standardise designs and processes across a portfolio of wind farms.

Competition will decrease

Without visibility of future growth, many companies in the supply chain will not see the point of committing resources to a low-margin, politically-dependent sector and will pull out of the market.

As well as losing knowledge and experience, this process will reduce competition so the remaining players will be able to increase their margins rather than pass on any cost of energy improvements to their customers and energy users.

The UK will lose wind farm developers and their experience

The limited visibility of future CfD round budgets means developers will face much higher allocation risk. Without knowing the level of funding available several years ahead, they cannot make an informed judgement about when they are likely to secure a contract.

This uncertainty will increase the cost of capital during the development stage but also has wider, indirect effects. For example, it will be much more difficult for developers to justify keeping experienced engineering and project management teams as their pipeline of activity will not be secure. More generally, this uncertain environment will tend to force developers out of the market, which will reduce competition for public support.

Even for those developers that do secure CfDs, these factors mean developers will focus on getting the best return for their current project, rather than investing in activities that also have an impact on future projects.

The cost of capital will not reduce significantly

Without visibility of the future market, offshore wind does not establish as an accepted asset class and banks and investors will not commit the human and financial resources to understand the risks and opportunities of the market. Without this growth, there will be minimal competition pressure to bring down the cost of capital and the supply of finance may become a bottleneck.

There will be market disconnects in other areas

A part of this approach is for the Government to be hands-off with regard to other drivers. This means it is likely to be slow to implement any measures to address market disconnects, in terms of competition, collaboration, risk and efficiency of support mechanism.

5.2.2 Balanced

There will be good competition and investment throughout the industry

Giving companies strong visibility of future activity across Europe will enable much greater levels of investment than the “Current approach” scenario, even with the same levels of deployment. This will stimulate the growth of enough players in each sub-sector to ensure there will be pressure to keep margins low and keep investing in new facilities, equipment, R&D and skills. The visibility will also encourage industry-led initiatives that will reduce the cost of energy in the future and encourage more long-term supply chain collaboration.

In particular, this combination of market scale and visibility will be enough to support three or four strong turbine suppliers.

With high visibility, the turbine suppliers will have sufficient confidence in the market scale to invest in the development of next generation turbines with a capacity of 10MW and above. This means that developers will be able to start deploying these turbines at a commercial scale well before the end of the 2020s.

Cost of capital will reduce

With clear visibility of strong levels of future deployment and an increasingly level of evidence about the performance of offshore wind projects, the financial community will commit effort to the sector and become increasingly comfortable about investing in offshore wind as an established asset class.

This will reduce risk premiums and increase competition between providers, giving developers access to cheaper finance, hence reducing cost of energy.

The UK will capture long-term industrial benefit

With strong confidence in a sustainable long-term market demand, the supply chain will invest in new facilities in logistically efficient locations (albeit with consideration of political support in different locations).

As the UK's installation rate will be almost twice that of any other country in Europe, it will be an attractive destination for inward investors and local suppliers.

Market disconnects will be addressed

The Government's hands-on approach means it engages with industry to understand potential market barriers, such as risk or a lack of competition, and takes practical actions to address them. It also continues current levels of funding for R&D.

5.2.3 Conclusion

This analysis shows there will be a strong cost benefit for UK energy users if the Government gives greater visibility and confidence to industry, without increasing market size.

As shown in Figure 16, the total support cost to UK energy users will be approximately 24% lower in the "Balanced" scenario than for the same installed capacity in "Current approach".[15] This is equivalent to a £1.9 billion saving over the period and is due to a decrease in cost of energy. For projects with first generation in 2030, this equates to a reduction from £98 to 90/MWh.

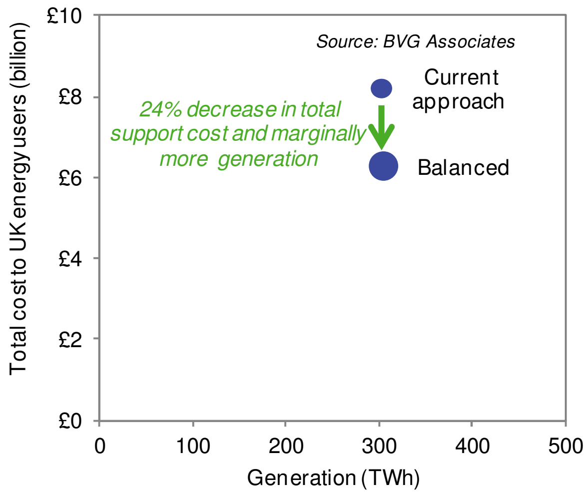


Figure 16 Comparison of results of analysis of the contribution of visibility and confidence to cost of energy reduction in the UK for projects built under the CfD regime in the 2020s. Bubble size reflects cost of energy reduction from 2020 levels for projects with first generation in 2030. Support costs and generation are for the period 2021 to 2030 (inclusive) and are in 2012 terms.

[15] All support costs discussed are in the period 2021 to 2030 (inclusive) for offshore wind projects built under the CfD regime in the 2020s.

5.3. The effect of the UK and rest of Europe market size on cost of energy reduction in the UK

This section explores the relative importance of the UK market to cost of energy reduction within the wider European market. This relates to the market scale elements of Driver 1, as set out in Section 4.

We have considered four scenarios to investigate this issue, which are summarised in Table 6.

Table 6 Assumptions of analysis of the effect of the UK and rest of Europe market size on cost of energy reduction in the UK.

		Capacity generating in 2030 (average annual installation in 2020s)		
		UK	Europe non-UK	Description
3	Strong support	~30GW (~2GW per year)	~41GW (~2.5GW per year)	There are high levels of deployment across Europe as governments aim to maximise electricity decarbonisation and cost of energy reduction, while still avoiding the risk of overstretching electricity networks or the supply chain. Governments give clear short- and long-term visibility and proactively intervene to maximise cost of energy reductions through other drivers, collaborating to address pan-European opportunities.
4	UK slows	~18GW (~0.8GW per year)		The UK slows down levels of deployment in the hope that strong levels of deployment in the rest of Europe continue to drive down the cost of energy for the UK projects that remain. This approach allows the UK to make a judgement later in the 2020s about whether to ramp up deployment, based on the relative progress of offshore wind compared with other technologies. All governments continue to give clear visibility, whether of high or low deployment, but the UK Government adopts a hands-off approach to other policy interventions.
5	Rest of Europe slows	~30GW (~2GW per year)	~30 GW (~1.5GW per year)	The UK has the same levels of deployment as “Strong support” but there is a slow-down in the rest of Europe. Governments continue to give clear visibility, whether of high or low deployment, and the UK Government proactively intervenes through the other drivers.
6	Market stagnation	~18GW (~0.8GW per year)		Low levels of deployment across Europe as all countries pull back from the market. All governments continue to give clear visibility of low deployment but adopt a hands-off approach to any other policy interventions.

Table 7 Results of analysis of the effect of the UK and rest of Europe market size on cost of energy reduction in the UK. See Section 5.1.3 for further detail.

	3 Strong support	4 UK slows	5 Rest of Europe slows	6 Market stagnat-ion
Projects with first generation in 2030				
Cost of energy (MWh)	£84.36	£96.96	£91.62	£100.91
Strike Price (MWh)	£87.88	£103.13	£96.71	£107.84
Total UK fleet in 2030				
Generating capacity (MW)	31.8	19.0	31.8	19.0
Generation in 2030 (TWh)	127.8	74.5	127.4	74.4
Generation between 2021 and 2030 (TWh)	844.0	588.0	842.4	587.7
Annual support cost to UK energy users in 2030 (billion)	£2.6	£2.7	£3.2	£2.8
Annual support peak to UK energy users in 2020s (billion)	£3.9	£3.5	£4.1	£3.6
Total support cost to UK energy users between 2021 and 2030 (billion)	£35.1	£32.5	£37.5	£33.0
Average support cost to UK energy users per MWh	£41.6	£55.3	£44.5	£56.1
Of which, 2020s CfD projects				
Generating capacity (MW)	20.3	7.5	20.3	7.5
Generation in 2030 (TWh)	84.2	30.8	83.7	30.7
Generation between 2021 and 2030 (TWh)	408.7	152.7	407.1	152.4
Annual support cost to UK energy users in 2030 (billion)	£0.5	£0.5	£1.0	£0.6
Annual support peak to UK energy users in 2020s (billion)	£0.9	£0.6	£1.2	£0.7
Total support cost to UK energy users between 2021 and 2030 (billion)	£6.5	£3.9	£8.9	£4.4
Average support cost to UK energy users per MWh	£16.0	£25.7	£21.8	£28.8

5.3.1 Strong support

There will be strong levels of competition throughout the supply chain

This level of deployment (combined with strong visibility) will support stronger levels of competition across all elements of the supply chain than in the "Balanced" scenario.

This will increase competition and industry appetite for investment in developing next generation turbine platforms. This will mean the industry deploys 10MW (or larger) turbines on a commercial scale earlier in the decade than the "Balanced" scenario, developers will establish more of a pipeline approach to project delivery and the finance community will see offshore wind as a substantial opportunity, all leading to significant cost of energy reduction.

Market disconnects will be addressed early

As with the "Balanced" scenario, governments proactively identify and address potential market barriers and continue to provide effective levels of funding for R&D.

In combination with the large market scale, this proactive approach has a strong, positive effect on cost of energy reduction from UK projects.

5.3.2 UK slows

There will still be competition to drive cost of energy reduction

Despite a weaker UK market than the "Strong support" scenario, the overall European market will still have average annual deployment rates similar to the "Balanced" scenario. This market scale, combined with good visibility, will be large enough to support good competition amongst turbine suppliers and the rest of the supply chain.

This means the industry will still be able to achieve most of the competitive and collaborative benefits described above for the "Balanced" scenario.

The UK market will be unattractive to the finance community

The limited pipeline of activity and weaker confidence in the UK market means there will be no incentive for banks and investors to commit financial and human resources to UK projects, with different rules and regulations than other markets.

This means risk premiums for debt will fall more slowly and there will be limited competition between investors so the cost of capital remains higher for UK projects than in the rest of Europe.

UK loses the industrialisation benefit and skills base

The other main impact of a UK slow-down is it will become a less attractive destination for industrial investment. For example, the reduced scale of the UK's deployment programme means it will be the same size as the German market and only moderately larger than some other markets. As much of the supply chain is currently located on the Continent, most companies will decide to upgrade and extend existing facilities rather than invest in specialist facilities with better logistics for the UK market.

This will mean there will be less opportunity to reduce the cost of energy of UK projects through supply chain development and lower logistic costs. It will also restrict the opportunity for the UK Government to support technology innovation proactively through R&D funding and the UK skills base and resulting export potential will not materialise.

Competition between developers on UK projects will suffer

As Government will only be supporting a maximum of two projects a year and has a limited 2030 target, the UK will be unable to support a strong field of developers with domestic teams of engineers and project managers with a good understanding of UK conditions and suppliers.

This may mean that there will not be enough interested players to stimulate competitive auctions in CfD allocation rounds, so the Government may be forced to drive cost of energy improvements by reducing the headline Strike Price, with the risks that it will set the level too high (penalising energy users) or too low (driving industry away).

Given the strong market in the rest of Europe in this scenario, it is more likely that there will still be developer interest in UK projects but these will only be part of a wider portfolio of a Continental-focused developer. This means the UK workforce will miss the opportunity to build the consenting and development knowledge and experience that could be exported to other markets and UK suppliers are much less likely to be involved, as they have no home customers.

There will be market disconnects in other areas

As with the "Current approach" scenario, the Government's hands-off approach to interventions means it is slow to implement any measures that could reduce risk or support supply chain competition and collaboration.

There is a risk that the whole of the European market will fall into stagnation

The UK is the country with the most to gain from a thriving offshore wind industry with competitive cost of energy. This means there is a serious risk that, if the UK decides to slow down its programme of deployment, other governments will do so too. In this case, the market will fall into the "Market stagnation" scenario, below.

Industry will be aware of the risk of this instability and this may deter companies from large-scale investment, even if there is short-term evidence to suggest that Continental markets are still progressing.

There is mixed opinion about the likelihood of other countries following the UK in slowing down or not. Many expect that if other markets continued with sustainable levels of deployment, UK projects would be penalised by Continental players subsidising activity in their home markets by inflating prices in the UK.

5.3.3 Rest of Europe slows

There will still be competition to drive cost of energy reduction

As with the "UK slows" scenario, average annual deployment rates in the European market in this scenario will still be similar to those of the "Balanced" scenario. This means the market will support two to three turbine suppliers and good competition in the rest of the supply chain.

There will be strong UK industrial benefit but high political risk

In this scenario, the UK will support more deployment than the rest of Europe combined. This means the incentive for industry to focus industrial investment in the UK will be even higher than the "Strong support" scenario, giving strong industrial (jobs and economic) benefit to the UK.

The imbalance in markets will however also involve greater political risk for industry, as it will be more dependent on the decisions of one government than in the "Balanced" scenario.

5.3.4 Market stagnation

There will not be sustainable competition in turbine supply

With annual average deployment levels of 2.3GW, the European market will only be large enough to support two turbine suppliers.

This may be enough to stimulate some competitive pressure but there is a much greater risk that little of any cost of energy benefit will be passed onto developers (and hence energy users).

In particular, there is a risk that one of the two suppliers will decide to pull back from the market, curtail investment, or suffer from technical problems, leaving only one dominant player, as we saw late last decade.

There will be variable levels of competition elsewhere in the supply chain

This scale of deployment is similar to anticipated levels of activity at the end of the current decade so will support reasonable competition in some sectors, such as foundation and cable supply.

In other areas, such as installation vessel supply, the level of activity will not be sufficient to drive competition so there will be less investment in equipment and skills development.

There will be limited opportunities for industrialisation anywhere

This level of deployment means it will be unlikely that any new manufacturing capacity will be required in the 2020s, with only limited upgrades to existing facilities.

As the supply chain is currently mainly located on the Continent, this has a bigger impact on the levels of economic benefit in this UK.

There will be market disconnects in other areas

Given stagnating levels of support for offshore wind, it will be unlikely that any European government will be proactively addressing market barriers.

Furthermore, with low levels of growth and strong uncertainty about the future of the industry, any interventions that governments do make are unlikely to stimulate a positive reaction from developers or the supply chain.

5.3.5 Conclusion

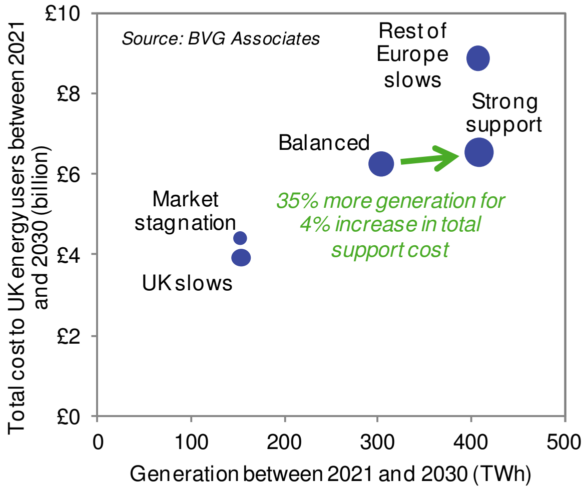
This analysis shows there is the potential to significantly increase the amount of capacity installed from the "Balanced" scenario, with only a marginal increase in support cost to energy users.

As shown in Figure 17, almost 40% more electricity is generated in the "Strong support" scenario compared with the "Balanced" scenario but the rapidly decreasing cost of energy means the total support cost to UK energy users increases by only 4%, or approximately £0.3 billion.[15] This equates to a 22% reduction in support cost per MWh to UK energy users (or £1.4 billion).The cost of energy reduction equates to a change for projects with first generation in 2030 from £90 to £84/MWh.

The "Strong support" scenario could evolve into the "Rest of Europe slows" scenario if the rest of Europe slows deployment rates for whatever reason, with the UK continuing with a strong market. If this was to happen, then the result is that the average support cost for UK energy users per MWh would be only moderately higher than in the "Balanced" scenario.

Under the "UK slows" scenario, the average support cost per MWh to UK energy users is 25% higher than in the "Balanced" scenario. This is because if the UK pulls back from the market, the cost of energy on UK projects will reduce more slowly.

This increase becomes 40% if the rest of Europe slows in response to the UK's decision, as described by the "Market stagnation" scenario. This would likely signal the end of the offshore wind industry, with the cost of energy from UK projects with first generation in 2030 at £101/MWh, which is 20% above the "Strong support" scenario.



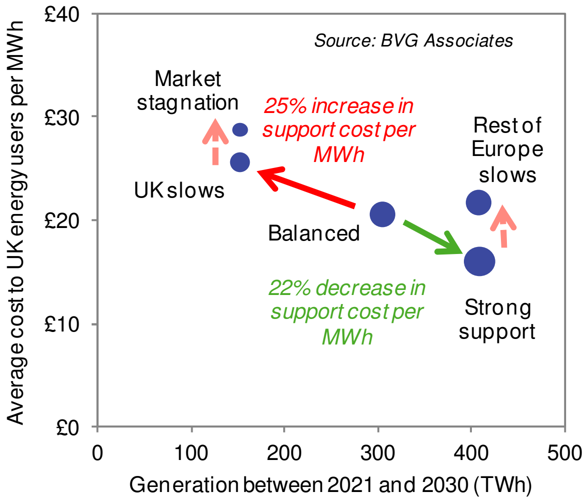


Figure 17 Comparison of results of analysis of effect of the UK and rest of Europe market size on cost of energy reduction in the UK for projects built under the CfD regime in the 2020s. Bubble size reflects cost of energy reduction from 2020 levels for projects with first generation in 2030. Support costs and generation are for the period 2021 to 2030 (inclusive) and are in 2012 terms.

5.4. The contribution of publicly funded R&D to cost of energy reduction in the UK

This section explores the potential for governments to support offshore wind cost reduction through publicly funding R&D rather than large-scale deployment. This relates to the effect of Driver 3, as set out in Section 4.

We have considered two scenarios to investigate this issue, which are summarised in Table 8.

Table 8 Assumptions of analysis of the contribution of publicly funded R&D to cost of energy reduction in the UK.

		Capacity generating in 2030 (average annual installation in 2020s)		Description
		UK	Europe non-UK	
7	Balanced with enhanced R&D	~25GW (~1.5GW per year)	~36 GW (~2GW per year)	There are the same levels of deployment and visibility as “Balanced” but governments also choose to give enhanced levels of public R&D funding to accelerate cost of energy reduction.
8	R&D only (Market stagnation with enhanced R&D)	~18GW (~0.8GW per year)	~30 GW (~1.5GW per year)	There are the same levels of deployment and visibility as “Market stagnation”. Governments decide to reduce levels of deployment but attempt to drive cost of energy reduction by providing higher levels of public R&D funding. We have not modelled a specific amount of funding although we assume: • The level of funding is significantly more than “Balance with enhanced R&D” • The cost is shared across relevant European governments • There is an ambition to develop next-generation turbine platforms with rated capacities of 10MW or more, despite the small market.

Table 9 Results of analysis of the contribution of publicly-funded R&D to cost of energy reduction in the UK, with results from Scenarios 2 and 6 for comparison. See Section 5.1.3 for further detail.

	2 Balanced	7 Balanced with enhanced R&D	6 Market stagnation	8 R&D only
Projects with first generation in 2030				
Cost of energy (MWh)	£89.96	£88.76	£100.91	£102.06
Strike Price (MWh)	£94.69	£92.67	£107.84	£109.22
Total UK fleet in 2030				
Generating capacity (MW)	26.3	26.3	19.0	19.0
Generation in 2030 (TWh)	104.8	104.9	74.4	74.4
Generation between 2021 and 2030 (TWh)	739.0	739.3	587.7	587.6
Annual support cost to UK energy users in 2030 (billion)	£2.8	£2.7	£2.8	£2.8
Annual support peak to UK energy users in 2020s (billion)	£3.8	£3.8	£3.6	£3.6
Total support cost to UK energy users between 2021 and 2030 (billion)	£34.9	£34.5	£33.0	£33.1
Average support cost to UK energy users per MWh	£47.2	£46.6	£56.1	£56.4
Of which, 2020s CfD projects				
Generating capacity (MW)	14.8	14.8	7.5	7.5
Generation in 2030 (TWh)	61.2	61.2	30.7	30.7
Generation between 2021 and 2030 (TWh)	303.8	304.0	152.4	152.3
Annual support cost to UK energy users in 2030 (billion)	£0.7	£0.6	£0.6	£0.7
Annual support peak to UK energy users in 2020s (billion)	£0.8	£0.8	£0.7	£0.7
Total support cost to UK energy users between 2021 and 2030 (billion)	£6.3	£5.9	£4.4	£4.5
Average support cost to UK energy users per MWh	£20.6	£19.3	£28.8	£29.7

5.4.1 Balanced with enhanced R&D

There is likely to be a small net benefit

There is no detailed evidence or consultee feedback available to link specific levels of cost of energy reduction with particular levels of public R&D funding.

In 2014, the UK Government published a summary of the levels of support directed toward offshore wind from all national and devolved public departments and agencies.[1] This stated that, in the four years of the Government's spending review period (April 2011 to March 2015), these bodies had a total budget of approximately £100 million (an average of £25 million per year) to support offshore wind innovation.

Our analysis shows the 1.3% decrease in the cost of energy in this scenario reduces the gross support cost to the energy user by approximately £390 million, compared with the "Balanced" scenario. As such, even a doubling of the existing public R&D budget (hence an increase of £250 million over 10 years) is likely to still generate a net benefit for UK energy users.

Another measure of the benefit of public R&D funding is the amount of private investment that it unlocks. Industry feedback is that the most efficient way to unlock significant R&D investment by large players is through the provision of a visible market, but that there is a role for public support in unlocking investment by smaller players. There is also a role in helping those that close to making investments based on the market to get over the line.

In the analysis, we assume that there are similar levels of R&D funding in the rest of Europe (proportionate to the scale of national markets) and that there would be a similar net benefit for other countries. Industry advises that generally it considers the UK provides more public R&D support than many others. Pan-European funding (previously via FP7 and now Horizon 2020 and other programmes) is also significant.

Success depends on more than just levels of public funding

There will be a range of factors that affect the effectiveness of public funding on cost of energy reduction. These include:

- The structure of funding programmes and the commercial and intellectual property (IP) requirements they impose on applicants
- The expertise and resources gathered in public research bodies and the willingness of industry to engage with public-led initiatives
- The prioritisation of funding allocation to avoid duplication of effort and ensure market relevance, and
- Industry and government measures, such as demonstration programmes, to manage the impact of innovations on the cost of capital.

In addition, strong consultee feedback is that R&D funding is only one element in delivering cost of energy benefit from technology innovation. Significant investment by multiple players in manufacturing, installation and operation infrastructure and tooling is often required to bring new technology to a competitive market. The appetite for investment increases with the size and visibility of the market and, without this, such investment is unlikely, thereby risking "stranding" of new technology without a viable route to deployment at scale.

A strong R&D sector can support industrialisation in the UK

If the UK continues to grow as a global centre for offshore wind innovation, companies will invest financial and human resources to build up local R&D teams and facilities.

In some cases, knowledge will flow back to parent companies overseas so the only benefit to UK energy users will be the lower support costs.

In other cases, this presence of a R&D team will stimulate further investment in UK-based infrastructure, supply capacity and personnel as products are developed and commercialised. Indeed, in other cases, offering products differentiated by technology innovations is a key route for market entry, where offering a "me-too" product to a Continental client is unlikely be sufficient to disrupt its relationships with its existing supply chain.

5.4.2 R&D only

There will be significant risks with publicly-funded turbine development programmes

Some argue that significant public R&D funding could be a substitute for supporting levels of deployment that will facilitate cost of energy reduction. The obvious approach of such a strategy would be to drive the development of new turbine platforms and associated foundation and electrical technology. At current levels of industry maturity, turbine suppliers will be highly unlikely to collaborate on joint-industry R&D projects that require the sharing of core intellectual property. It will therefore be necessary for governments to support two or three suppliers or there will not be the competitive pressure to force companies to pass on cost of energy improvements to customers and energy users.

Such a programme would involve a significant allocation of public funds to private companies, similar to the £1 billion made available by the UK Government for its CCS commercialisation competition, which will support the design, construction and operation of the UK's first commercial-scale CCS projects (although this is focused on the capital expenditure on infrastructure rather than product development).

Such a programme would be politically sensitive as this would involve providing significant sums of money to non-UK companies and there would be little certainty about the results of the scheme. As we assume this funding involves contributions from a number of European countries, it is unlikely the UK could expect any commitments for investment in future manufacturing capacity. Industry feedback is that such activities are rarely successful elsewhere, especially when considering competition between players within Europe.

Overall, this would mean that politicians would need to collaborate across Europe on a programme that will entail significant risk and the results would be long term and difficult to justify to local electorates.

Public R&D funding cannot replace visibility and market scale

Even if governments do make high levels of public funding available, it will not be legal for them to fund the full process of commercialising new turbines.

For example, public money cannot fully fund the investment in new equipment and facilities needed in the supply chains of the turbine suppliers to produce larger components.

These companies will only be willing to make the necessary investment if they can see the long-term commercial opportunity for doing so. Similar investments would be needed, for example, in foundations and installation tooling. If future market scale is dependent on political decisions to "switch on" the market again based on the anticipated results of the R&D activities, then companies will be unlikely to invest their own money in such capacity (even if partially subsidised) because the risk is too great.

Governments also cannot fully fund the ramp up in deployment needed in the commercialisation of new technology, running through onshore test sites, small-scale offshore demonstrators and one or more early commercial projects, as discussed in Appendix E.

Without this programme of deployment to identify and resolve performance and reliability issues, developers and the financial community will not be willing to use the technology on large-scale commercial projects.

All other aspects of the industry will suffer

Although substantial public funding might encourage some turbine suppliers to remain in the market, the low levels of deployment and poor visibility will damage many other areas of the industry.

For example, the poor market conditions will force many companies in the supply chain to diversify into other sectors. This means the offshore wind industry will lose the skills and learning that have been built up through market activity to date.

There will also be much higher levels of risk for developers of offshore wind sites, as they would not know whether the programme of cost reduction will eventually stimulate governments to ramp up support for the industry again.

Overall, this means industry will effectively halt, for a time, progress on all technology, supply chain and finance innovations in all non-turbine sub-sectors. It will also slow down in learning the valuable lessons from regular deployment and operation of increasing portfolios of wind farms. Such experience is valuable both in developing next products and improving efficiency of activities across the supply chain.

A step back compared with "Market stagnation"

These factors mean that any cost of energy reduction coming from the development of new turbine platforms (assuming progress is made) will be outweighed by a lack of progress elsewhere.

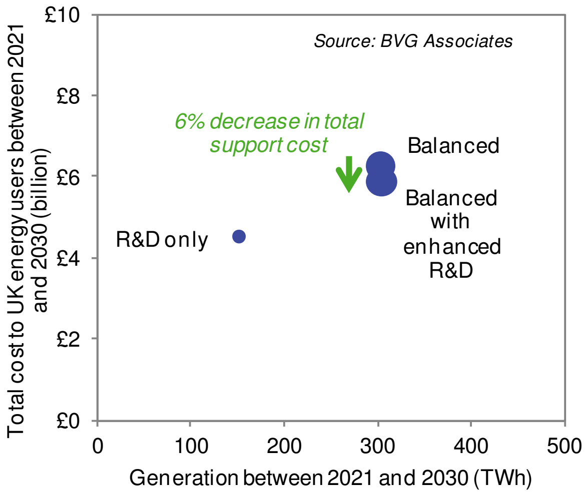
This means that energy users will end up paying even more support costs than the "Market stagnation" scenario, plus the additional costs of the R&D programme.

5.4.3 Conclusion

This analysis shows there is an important role for public R&D funding in reducing the cost of energy, if it is coupled with a sustainable level of deployment.

As shown in Figure 18, the "Balanced with enhanced R&D" scenario sees a reduction of approximately 6% in the total support cost to UK energy users, compared with the "Balanced" scenario.[15] This is equivalent to a £0.4 billion saving.

The "R&D only" scenario shows that an attempt to drive cost of energy reduction through higher levels of R&D, instead of providing a sustainable market, actually increases support cost per MWh to UK energy users by 45% compared with the "Balanced" scenario. This is due to an increase in cost of energy for projects with first generation in 2030, equating to an increase from £90 to £102/MWh.



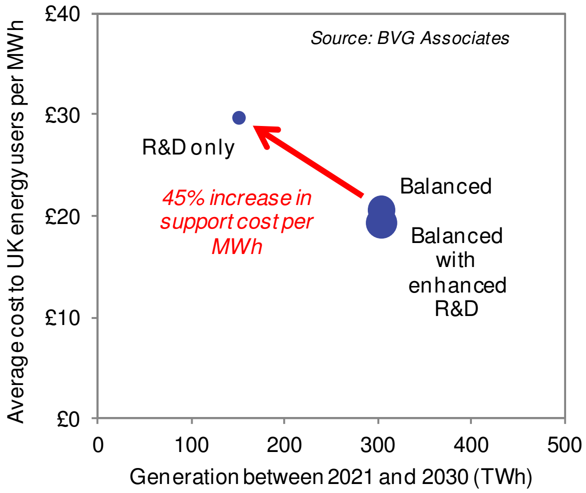


Figure 18 Comparison of results of analysis of the contribution of publicly funded R&D to cost of energy reduction in the UK for projects built under the CfD regime in the 2020s. Bubble size reflects cost of energy reduction from 2020 levels for projects with first generation in 2030. Support costs and generation are for the period 2021 to 2030 (inclusive) and are in 2012 terms.

5.5. The contribution of other supporting actions to cost of energy reduction in the UK

This section explores the potential for the UK Government to support offshore wind cost reduction through other policy approaches. This relates to the effect of Drivers 2, 4, 5 and 6, as set out in Section 4.

We have considered two scenarios to investigate this issue, which are summarised in Table 10.

Table 10 Assumptions of analysis of the contribution of other supporting actions to cost of energy reduction in the UK.

		Capacity generating in 2030 (average annual installation in 2020s)		
		UK	Europe non-UK	Description
8	Improvements to market design	~25GW (~1.5GW per year)	~36 GW (~2GW per year)	Governments adopt the "Balanced" scenario but also decide to intervene proactively to improve the efficiency of support mechanisms and to take other risk-mitigation measures (Drivers 4 and 6, as set out in Section 4).
9	Supply chain interventions			Governments adopt the "Balanced" scenario but decide to intervene proactively to support positive behaviour in the supply chain and support the creation of own pipelines of activities for developers and suppliers (Drivers 5 and 2, as set out in Section 4).

Table 11 Results of analysis of the contribution of other supporting actions to cost of energy reduction in the UK. See Section 5.1.3 for further detail.

	9 Improvements to market design	10 Supply chain interventions
Projects with first generation in 2030		
Cost of energy (MWh)	£87.22	£88.28
Strike Price (MWh)	£91.34	£92.67
Total UK fleet in 2030		
Generating capacity (MW)	26.3	26.3
Generation in 2030 (TWh)	104.9	104.9
Generation between 2021 and 2030 (TWh)	739.3	739.4
Annual support cost to UK energy users in 2030 (billion)	£2.7	£2.7
Annual support peak to UK energy users in 2020s (billion)	£3.8	£3.8
Total support cost to UK energy users between 2021 and 2030 (billion)	£34.2	£34.5
Average support cost to UK energy users per MWh	£46.3	£46.6
Of which, 2020s CfD projects		
Generating capacity (MW)	14.8	14.8
Generation in 2030 (TWh)	61.2	61.3
Generation between 2021 and 2030 (TWh)	304.1	304.1
Annual support cost to UK energy users in 2030 (billion)	£0.5	£0.6
Annual support peak to UK energy users in 2020s (billion)	£0.7	£0.8
Total support cost to UK energy users between 2021 and 2030 (billion)	£5.6	£5.9
Average support cost to UK energy users per MWh	£18.5	£19.3

5.5.1 Improvements to market design

Policy stability is the key priority for industry

Although consultees highlight the need for a number of minor interventions and reforms, a priority is to implement these while preserving as much market stability as possible, following recent upheavals such as the UK's Electricity Market Reform.

With large-scale investment and long-payback periods, companies want governments to give the clear message that they will not radically overhaul existing policies in ways that may increase risks in the timeframes in which the value of these investments would be affected.

The cost of capital will be reduced

The introduction of measures, such as Treasury-backed guarantees, will directly help reduce the cost of capital, which has a significant contribution to the cost of offshore wind projects (as shown in Figure 1).

Such commitments will also send positive messages to the finance community that the Government is prepared to support offshore wind projects in the same way as other large infrastructure projects, such as the Hinkley Point C nuclear power station. This will encourage investors into the industry, leading to increased competition and lower risk premiums.

This study has not considered the potential net cost to the UK Government (and hence UK energy users) of providing such guarantees, taking into account factors including the size of the liability, the risks and the potential socio-economic benefits to the UK of the project, including industrialisation, job creation and increased export potential.

Competitive auctions give UK energy users best value

The Government will need to ensure there is a sustainable pool of projects with committed developers competing for CfDs if it wants energy users to take the full benefit of cost of energy reduction.

5.5.2 Supply chain interventions

Supply chain plans will be effective at encouraging positive industry action

As the controller of future CfD budgets, the UK Government has a strong influence on the behaviour of the industry.

Its policy of requiring CfD applicants to provide supply chain plans is likely to be a good, ongoing tool for prompting developers and the supply chain to work on ways to collaborate and support new entrants.

The success of this policy is dependent, however, on the industry believing that Government has high expectations about industry commitments and that it will robustly monitor and demand progress in delivering these commitments once a project has secured support and act proportionately if this does not occur.

5.5.3 Conclusion

This analysis shows government interventions on risk, supply chain and efficiency of support mechanisms do not have the same level of impact as decisions about market scale, visibility and confidence. They are easier to implement, however, and still reduce the support costs to energy users.

The "Improvements to market design" scenario sees the total support cost to UK energy users reduce by 10% compared with the "Balanced" scenario. [15] This is equivalent to a saving of approximately £0.65 billion.

The "Government-led supply chain interventions" scenario sees the total support cost to UK energy users reduce by 6% compared with the "Balanced" scenario.[15] This is equivalent to a saving of approximately £0.4 billion.

The two scenarios are not mutually exclusive, such that both could be adopted with an overall saving of approximately £1 billion.

5.6. Conclusions from the scenario analysis

Figure 19 shows the results for four key scenarios. The grey line shows our forecast cost of energy for UK projects with first generation in 2015, 2020 and in the "Upper bound" scenario in 2030. The bars showing generation and support cost are for CfD projects with first generation between 2021 and the end of 2030 only. In line with DECC processes, values are in 2012 terms. This analysis does not consider the potential impact the leasing of lower cost sites or the strategic planning of electrical transmission infrastructure.

"Strong support", achieves almost 85% of the potential cost of energy benefit available in this period, while "R&D only" achieves only 15% of the potential. Both lines are less steep than the trajectory between 2015 and 2020, which reflects the fact that the rate of introduction of innovations drops and the incremental benefit of each step is less as the industry matures and industrial scale increases.

Figure 19 also shows the importance of governments giving clear visibility to industry about its plans for future deployment. With poor levels of visibility, the "Current approach" scenario achieves less than 30% of the potential cost of energy reduction available. This is in contrast to the "Balanced" scenario in which good visibility means industry achieves twice as much cost of energy reduction with the same level of deployment and marginally more generation.

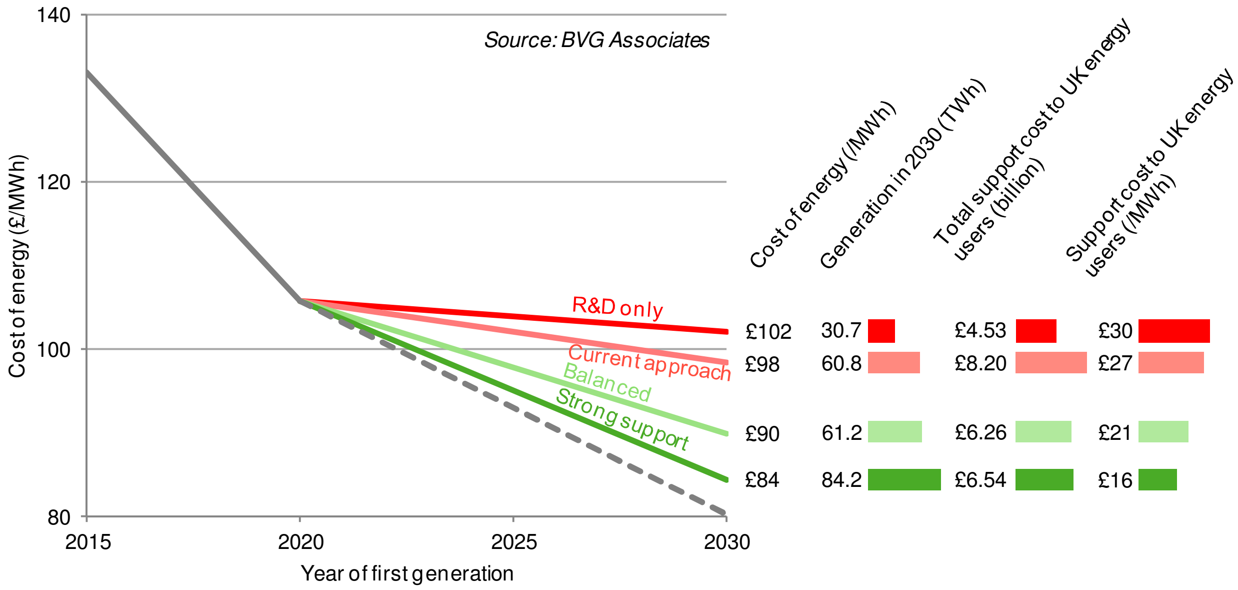


Figure 19 Summary of the scenario analysis. Dashed grey line represents "Upper bound" scenario. All generation and support costs are for offshore wind projects built under the CfD regime between 2021 and the end of 2030. Values in 2012 terms.

6. Strategic lessons for UK Government policy

In this section, we consider the output of Sections 4 and 5 and present key lessons for government policy to efficiently enable cost of energy reductions in offshore wind in the 2020s, while giving give best value to UK energy users.

6.1.1 Give clear visibility of market plans

The message from industry is clear: market scale without visibility means the offshore wind industry cannot deliver nearly as much cost of energy reduction or industrialisation.

Clearly state the intended annual budgets for future allocation rounds with a rolling five-year horizon

Companies cannot plan to invest and reduce cost of energy if they do not know what activity is going to happen in the short term.

The Government should give a clear signal of how much capacity it intends to support by announcing the amount of Pot 2 budget available in future CfD competition rounds. This will give developers confidence that there will ongoing opportunities to secure contracts and allow companies in the supply chain to plan for competing for future growth.

To maximise cost of energy benefit, the Government should provide a rolling five-year horizon of visibility.

Such an approach can still have flexibility, with Government making budgets four to five years ahead conditional on industry progress and the bigger-picture economic position. The more it keeps to its plans, the more confidence industry will build in what it says.

Without rolling horizons, there will be periodic investment crises as industry nears the end of periods of visibility.

Provide long-term market information to support industry plans for growth

Government can give industry much greater confidence by being more open about its assumptions about the future mix of electricity generation in the UK, without removing competition.

In particular, Government should consider publishing annually updated forecasts of the future energy mix in the UK, from five to 15 years ahead. This would include details of the Government's assumptions about the current cost of energy of different technology and their future progress. These forecasts would evolve each year as new information becomes available so that all energy sectors have good visibility of the Government's evolving understanding of their competitive position. As the forecast is far enough ahead, it can be separated from the shorter-term visibility discussed above.

It is relevant to note that a number of consultees that act in multiple electricity sectors advised that each could deliver more effectively based on this type of visibility. A number advised that it is not just the visibility itself that is important (they would trust cost of energy projections by independent experts more than by governments), but the insights into Government thinking that are important.

A 15-year horizon is chosen to be far enough ahead to give industries an understanding of the Government's position out towards where their investment decisions will have impact. For example, Appendix E shows how it takes eight years from initiation to first commercial use of a new wind turbine platform, with a sales life then of a similar period. It is also a short enough time ahead for radical new technologies not to be being installed in commercial projects, thereby simplifying the forecasting.

Create a robust framework and logic for renewable energy deployment

To give credibility to any future shorter-term commitments and longer-term aspirations, the Government needs to commit to a legislation-based decarbonisation target that confirms a long-term need for renewable and low-carbon electricity generation.

This Government needs to back up the framework with a suitable budget in the Levy Control Framework so that industry has confidence that Government can achieve its targets.

Without such logic, an industry that has learnt from the ill-informed optimism of the early years of Round 3 will remain sceptical about true intent. Then, there was an expectation that as much of the new leased pipeline as possible would be constructed before 2020, without due consideration of the cost to energy users, the need for that volume of new energy production and the UK grid's ability to absorb it.

Benefits of providing visibility, comparing the "Balanced" scenario with "Current approach":

- **24% decrease in the cost of support for UK energy users, plus marginally more energy delivered (£1.9 billion saving between 2021 and 2030)**
- **More industrial activity moves to the UK, and**
- **All energy sectors benefit from visibility.**

6.1.2 Establish a sustainable market and gain pan-European consensus for more

The UK is the global leader in offshore wind. It has a pool of experienced developers, a proven regulatory regime and a growing supply chain.

There is a major opportunity for the country to build on this track record to get increasingly low cost, renewable energy and hence establish a competitive advantage in a carbon-constrained world, less dependent of the need to buy energy from overseas. It also has the opportunity to build a strong supply chain that can export service skills and products around the world.

To do this however, the UK needs to commit to supporting a sustainable market size.

An annual average UK deployment rate of 1.5GW offers significant cost of energy reduction

The UK Government has already set out scenarios for future deployment, with capacity between 12GW and 40GW installed by 2030, but it will now benefit by being clearer about its expectations.

Our analysis suggests an ambition of an annual average UK deployment rate of 1.5GW (giving approximately 25GW of installed capacity in UK by the end of 2030) offers a sensible balance between supporting cost of energy reduction while minimising risk for UK energy users, if there is uncertainty about the approach in the rest of Europe.

An average annual UK deployment rate of up to 2GW in a strong European market offers significantly more benefits

A concerted European strategy to support higher levels of deployment means the cost of offshore wind energy could even fall so quickly that it is almost cost equivalent in absolute terms for energy users than a more modest programme.

A European market with an annual average deployment rate of 4GW to 5 GW would stimulate strong competition through the supply chain and significant investment in infrastructure, skills and R&D, as well as establishing offshore wind as an attractive asset class for investors.

As the UK would be the largest national market, it would be in the prime position to get the greatest benefit from such a strategy, both in terms of cost of energy reduction and industrialisation.

Even if the market in the rest of Europe slowed, a higher UK deployment programme would still support strong cost of energy reduction and industrialisation.

The UK Government should therefore proactively engage with other European countries to support strong offshore wind deployment programmes and should work together to harmonise these, where beneficial, and address potential barriers that could restrict future cost of energy reduction at an international level. Such engagement should be in parallel with, and recognising the objectives of, other international collaboration activities, such as the Seastar Alliance.

Further benefits of providing a larger market as part of a strong European market:

- **35% more generation in "Strong support" compared with "Balanced" scenario at only 4% more cost of support to UK energy users, and**
- **Significantly more UK benefit from industrialisation.**

6.1.3 Refine the CfD regime

Industry is generally supportive of the UK's CfD regime and now expects regulatory stability following the uncertainty of Electricity Market Reform.

Within this CfD regime, however, there are still opportunities to reduce the cost of energy by reducing risk and improving confidence.

Investigate ways to reduce the impact of CfD allocation risk

There is strong awareness among developers about the impact of the allocation risk they face because of the combination of high completion for a low CfD budget and high cost of getting to the point at which one can enter the auction, only a year ahead of FID. This is compounded by the costs of sustaining a project so close to FID in order to re-enter the auction in subsequent years.

Greater visibility of future budgets will help, but the other structural change that could be made relates to the timing of auctions in the wind farm development process. Industry considers that the Danish system offers advantages as developers bid for a consented site, with the cost of consenting and front-end engineering design covered centrally, hence removing the vast majority of pre-allocation spend.

The Government should investigate these alternative arrangements to see if there are any practical improvements to the CfD process that could be implemented without undue disruption. Changes could be made to the provision of further leases for offshore wind wind sites.

Review the timing of the CfD milestone delivery date

The requirement for developers to make significant investment within a year of signing a CfD restricts the opportunity for any detailed post-award engineering investigations.

Introducing greater flexibility into this arrangement for offshore wind projects is an inexpensive way of facilitating vertical collaboration within projects.

Ensure the assumptions underpinning the CfD process are fit for purpose

There is a risk that inaccurate modelling could mean DECC spends its budget more quickly than anticipated, driving a future restriction in the pipeline.

As such, the Government needs to address concerns about the robustness of the assumptions it uses to calculate budget drawdown for all technologies under existing and previous support mechanisms.

This includes assumptions around technology-specific load factors and the accuracy of the modelled future reference price.

Compare clearing prices in CfD auctions with elsewhere in Europe

The introduction of auctions for offshore wind projects in the first CfD allocation round proved they are important means of getting good value for energy uses.

The competitive auction in the first CfD allocation round seems to have had a positive impact on cost to UK energy users. The success of future auctions will be dependent on maintaining sustainable levels of competition between developers.

As well as monitoring and responding to levels of competition for CfDs in the UK, the Government should compare prices in UK and overseas auctions, taking into account the differences between markets and specific sites, to ensure that it is obtaining value for money for energy users and to enable exploration of any possible inefficiency. If such inefficiency is identified, then the reasons can be investigated and best practice can be implemented, thereby further reducing the cost of energy.

Provide clear and timely advice about how the regime will evolve in the future

The Government has said it intends to move to technology neutral auctions at some point in the future. In the current arrangement, offshore wind will, at some point, make a transition from CfD Pot 2 to Pot 1. Industry advises that, even if these changes are only likely in the long term, the fact that there is no information about how or when they may happen reduces confidence.

In addition, based on the analysis in this study, developers will start modelling UK projects where the reference price will climb above the cost of energy from offshore wind. Government needs to make sure that there are no mechanism anomalies that will introduce uncertainty around this event.

Support the harmonisation of support mechanisms across key national markets

As the offshore wind market matures, there are efficiency savings from countries standardising the way their support mechanisms operate. This will reduce unnecessary costs for developers and suppliers acting in multiple markets and allow for easier sharing of best practice, hence reducing the cost of energy.

There is already some progress toward this goal as there are similarities between the support mechanisms of some of the key North Sea markets but, with the benefits available to the UK, it should take a leading role in working with other countries for greater harmonisation.

6.1.4 Maximise the benefit of targeted R&D funding

Public funding for R&D has an important role to play in reducing the cost of offshore wind energy and moving economic benefit, but it is not a substitute for deployment.

Investigate the potential impact of increased R&D funding

This study suggests there is a potentially good business case for increasing R&D funding to accelerate cost of energy reduction and encourage industrialisation, but there is little documented, specific evidence of how public R&D funding has leveraged private funding and achieved eventual cost of energy reduction in offshore wind.

The Government should investigate in more detail the drivers behind the R&D activities that have had the most impact on cost of energy, including the role of public and private funding. It should then explore the potential impact of increased funding on the cost of energy and UK economic benefit. This should take account of:

- The delivery method (through enabling bodies like the Offshore Renewable Energy Catapult or directly through grants to companies)
- The relative spend on different sectors and innovation types, and
- The timing of intervention in the technology development cycle.

6.1.5 Help reduce the cost of capital

Supporting and providing visibility of a sustainable market as described above will have a significant impact on the cost of capital during the 2020s.

In addition, Industry recognises that the UK Government has already taken positive steps to address a number of key market risks, which has helped to reduce the cost of capital. It suggests, however, that it can do more relatively easily, particularly when there is an increased use of project finance and UK suppliers.

Provide Treasury-backed infrastructure guarantees for offshore wind developments and export credit support for UK suppliers

Via Infrastructure UK, the UK Government has already provided guarantees for infrastructure projects, like the Hinkley C nuclear power station, and other European countries have provided guarantees for their offshore wind projects. The use of export credit agencies has already been proven to be effective on Continental projects.

The provision of such guarantees and export support is unlikely to be politically sensitive because energy users will benefit from lower cost electricity and the build out of offshore wind farms aligns with other Government objectives, such as increasing levels of renewable energy and industrial development.

6.1.6 Use Supply Chain Plans to drive positive behaviour

Industry is generally wary of supply chain intervention but the UK Government should use its influence over the industry through DECC's supply chain plans to encourage and support best practice.

Develop the use of Supply Chain Plans as a tool for steering positive market behaviour

The requirement for developers of large offshore wind projects to produce "supply chain plans" before they apply for a CfD is an important opportunity to encourage them to take proactive steps to support collaboration, competition and skills development.

There is a risk that this becomes a form-filling exercise all developers complete but which does not stimulate real change.

The Government should give clear guidance about the kind of commitments it wants and set robust, open assessment criteria. It should also ensure that developers feel pressure to deliver on their commitments after winning a CfD and provide clear evidence of their results.

Further benefits of the interventions described in Sections 6.1.3 to 6.1.6 above:

- **Aggregate 6% reduction in cost of energy (equivalent to £1.4 billion saving between 2021 and 2030), and**
- **More UK jobs benefit from technology and supply chain development.**

Appendix A: Methodology for cost of energy modelling

Summary

The cost modelling for this study, presented in Section 2, involved the following steps, before exploration of the impact of policy drivers:

- Development of cost of energy forecasts for projects with first generation in 2015, 2020 and a baseline "Upper bound" scenario, based on a literature review, and
- Verification of results through industry consultation to get feedback about the assumptions and levels of cost of energy and cost of energy reduction.

Development of forecasts for 2015, 2020 a baseline scenario to 2030

Cost model

We based the cost analysis of this report on BVGA's in-house offshore wind cost model. This cost model has been used for the *Offshore wind cost reduction pathways study* published by The Crown Estate in 2012 and *Future renewable energy costs: Offshore wind* published by KIC InnoEnergy in 2014. The latter follows closely the former but includes some important evolutions in technology and understanding of industry costs and looks further ahead in time.

Literature review

In addition to The Crown Estate and KIC InnoEnergy studies, we also undertook a literature review of more than 15 industry reports and analyses from across Europe focused on offshore wind cost of energy reduction.

We used this process to verify our assumptions and ensure our forecasts are consistent with previous industry analysis (or understand any causes of discrepancies).

Source reports include:

- *Denmark - Supplier of competitive offshore wind solutions* (Megavind, 2010)
- *Offshore wind cost reduction pathways study* (The Crown Estate, 2012)
  - *Offshore wind cost reduction pathways- Finance work stream* (PricewaterhouseCoopers, 2012)
  - *Offshore wind cost reduction pathways- Supply chain work stream* (E C Harris with BVG Associates, 2012)
  - *Offshore wind cost reduction pathways- Technology work stream* (BVG Associates, 2012)
- *Offshore wind power: Technology innovation needs assessment* (Low-Carbon Innovation Co-ordination Group, 2012), including informal input based on updates
- *Cost reduction potential of offshore wind power in Germany* (Stiftung Offshore WindEnergie, 2013)
- *Next steps on Electricity Market Reform - securing the benefits of low-carbon investment* (Committee on Climate Change, 2013)
- *Technology supply curves for low-carbon power generation* (Pöyry, 2013)
- *Future renewable energy costs: Offshore wind* (KIC InnoEnergy with BVG Associates, 2014)
- *European offshore wind 2014; Financing the opportunities* (Freshfields Bruckhaus Deringer, 2014)
- *The UK offshore wind supply chain: A review of opportunities and barriers* (Offshore Wind Industry Council, 2014)
- *Cost Reduction Monitoring Framework; Summary Report to the Offshore Wind Programme Board* (ORE Catapult 2015)
- *Cost Reduction Monitoring Framework: Qualitative Summary Report* (DNV GL, 2015)
- *Cost Reduction Monitoring Framework: Quantitative Summary Report* (Deloitte, 2015), and
- Other published sources such as from Bloomberg New Energy Finance, DNV GL and Make Consulting.

The findings of the Cost Reduction Monitoring Framework programme are particularly important evidence as they reflect industry's latest understanding of the current cost of offshore wind energy and its progress in achieving future reductions.

Modelling assumptions

We based all analysis on a set of global assumptions, a set of typical project characteristics and a set of time-related assumptions. These are generally in line with Site Type B in The Crown Estate's *Cost reduction pathways study* published in 2012.

Global assumptions

- Real (end-2014) prices
- Commodity prices fixed at the average for 2014, and
- Exchange rates fixed at the average for 2014 (£1 is equivalent to €1.25).

Site assumptions

General site assumptions are:

- Turbines are spaced at nine rotor diameters (downwind) and six rotor diameters (across-wind) in a rectangle, and

- The lowest point of the rotor sweep is at least 22 metres above MHWS.

The Main site characteristics are:

Category	Typical site
Average water depth (MSL) (m)	35
Distance to nearest construction and operation port and point of grid connection (km)	40
Average wind speed at 100m above MSL (m/s)	9.4
Maintenance strategy	Shore-based
Transmission	HVAC

The metocean regime assumptions are:

- A wind shear exponent of 0.12
- Rayleigh wind speed distribution
- A mean temperature of 10℃
- A tidal range of 4m and the significant wave height of 1.8m is exceeded on 25% of days
- No storm surge is considered, and
- Ground conditions are "typical" for UK Round 3 zones, namely 10m dense sand on 15m stiff clay, only occasionally with locations with lower bearing pressure, the presence of boulders or significant gradients.

Construction assumptions are:

- Wind farms are developed in 500MW (0.5GW) phases
- A wind farm design is used that is certificated for an operational life of 25 years
- The development and construction costs are funded entirely by the project developer, and
- The developer uses a multi-contract approach for construction.

Time-based assumptions

We have described the anticipated state of the industry at the end of 2015, 2020 and in an "Upper bound" scenario at the end of 2030 in Table 12.

An "Upper bound" scenario

To assess the impact of policy drivers on the cost of energy during the 2020s, we developed an "Upper bound" baseline scenario of cost reduction. This is a P20 scenario in which we assume there is only a 20% chance of exceeding this level of cost of energy reduction.

The derivation of this cost of energy trajectory was a relatively high-level task that built on previous work. This is because accuracy is only required to the extent that it enables rational comparison of the impact of different drivers on cost of energy reduction and industry-verifiable overall cost of energy reductions.

We based this scenario on a European market with an average annual deployment rate of 5GW to 7GW in the 2020s. The precise market size and visibility is less important than setting the scenario as positively as possible while remaining realistic.

We assumed all relevant European governments (including the UK, Denmark, France, the Netherlands and Germany) give clear commitments about their 2030 delivery aspirations and there is cross-party support for offshore wind. We assume there is also similar positive progress elsewhere in the global market, especially in US and Asia.

Table 12 State of the industry for projects with first generation in 2015 and 2020 and in 2030 in the "Upper bound" scenario.

Element	First generation in 2015	First generation in 2020	First generation in 2030 (in the realistic "Upper bound" scenario
Project	• Relatively manual optimisation of wind farm layout based on part-verified modelling to optimise energy production, and • Single, conventional fixed meteorological mast used to assess site wind conditions.	• Some progress in optimising site layout based on multi-variable modelling, with limited verification of models, and • Partial use of floating LIDAR to improve understanding of site conditions.	• Routine optimisation of site layout based on advanced, well verified models • Routine use of floating LIDAR to improve understanding of site conditions, and • Increased use of advanced geophysical and geotechnical methods to better characterise conditions.
Turbine	• 4MW to 6MW turbines with part-optimised rotor size • Drive trains developed for onshore use, or first generation of designs for offshore use, and • Many features to improve reliability and serviceability not yet implemented.	• A majority of 6MW to 8MW turbines with optimised rotor size and designed to maximise onshore pre-commissioning • A range of drive train solutions, evolved from existing solutions, and • An improvement in reliability and serviceability, but with much progress still to make.	• A majority of 8MW to 12MW turbines, with some larger in the market • Advanced aerodynamic control giving significant load reduction and energy benefits, and • Significant improvement in reliability and serviceability, taking methodologies from other sectors.
Balance of plant	• A dominant use of monopiles, with improvements based on learning from early projects, and • 33kV array cables.	• A dominant use of jackets and monopiles, with some novel jacket solutions, concrete gravity bases (CGB) and suction buckets • More holistic design of tower with foundation, but tubular tower retained • Improved modelling of support structure/soil interface, and • About 50% use of array cable solutions, including ~66kV AC.	• Significant serial production of standardised solutions • Foundation design optimisation based on significant industry track record, and • Use of higher voltage, lower frequency and DC array cables.
Installation	• Installation of foundations and cables followed by turbines the year after.	• Increased use of floating foundation installation vessels but all turbines are still installed using jack-up vessels, and • Early use of optimised installation methods, using bespoke fleets of vessels that can operate in a wider range of operating conditions.	• Frequent use of float-out-and-sink installation methods, with minimised offshore activity.
Wind farm OPEX	• Use of early offshore-wind specific access systems and advanced crew transfer vessels from shore-based operations base.	• Use of improved access systems, but still with significant weather downtime, and • Partial use of purpose-built maintenance mother ships that can remain permanently stationed at far-from-shore sites with the capacity to undertake larger component replacements and	• Minimal remaining weather downtime due to access issues (i.e. technicians can generally access turbines when desired), and • Routine use of permanent offshore OMS bases to minimise travel time.

		service operation vessels for closer-to-shore work.	
Transmission OPEX	• Full-functionality substation mounted on separate foundation.	• Early reductions in transmission use of system charges due to reduced transmission infrastructure (including using turbine foundation), and • Some increase in efficiency of condition monitoring and repair of both export cables and substation equipment.	• Routine use of reduced transmission infrastructure, and • Optimised use of remote monitoring and rapid repair of transmission assets.
Energy production	• Energy production significantly increased compared with onshore projects due to higher wind speed and first generation of increased rotor diameters.	• Increased energy production through contracting focused on maximising energy production, combined with the use of next latest turbines with optimised rotor diameter and increased reliability.	• Further increased production through the use of larger and more reliable turbines with advanced control and further improved reliability.
Cost of capital	• Balance-sheet financed construction with recycling of capital during operation.	• An increase in confidence and decrease in reliance on equity, reducing WACC.	• Sophisticated risk sharing structures in place, decreasing WACC to that of other more mature infrastructure sectors.

Verification of results through industry consultation

As part of our industry consultation, we asked consultees for their views about the overall level of cost of energy and cost of energy reduction forecast in the step between 2015 and 2020 and between 2020 and 2030 (in the “Upper bound” scenario). Where relevant, we also asked about the level of cost of energy reduction associated with a particular element of a wind farm.

We also asked for consultees’ views about the assumptions behind the forecast, including the scale of deployment and the particular innovations likely to take place in the 2020s.

Overall, there was strong industry agreement about the step-changes proposed between each point in time, with any call for greater reductions balanced by the call from a minority for lesser reductions.

Feedback on our baseline costs and anticipated reductions supported our initial assumptions in most areas. We made adjustments in response to feedback, where needed. The greatest range of views related to the cost of finance. This is a dynamic area, currently with much less consistency across national boundaries than in other areas of supply.

Some consultees highlighted the effect that changing site characteristics has on the cost of energy of particular projects. They said the industry trend towards deeper projects further from shore would have an important impact on the future cost of energy of offshore wind projects. In this case, however, most consultees agreed that using fixed site conditions was more appropriate when assessing industry progress over time and the impact of policy drivers, where changing site characteristics may hide relevant trends. We consider the effect of not modelling such changes relatively minor.

Some consultees argued strongly that they expected to achieve greater levels of cost of energy reduction by 2020 and by 2030. Overall, however, they agreed that the forecast accurately reflected a P20 assessment of an industry average in which some market leaders will achieve lower costs of energy on some projects than the average.

Appendix B: Methodology for assessing the impact of each driver

Summary

The methodology for assessing the impact of each driver involved:

- Identification of a comprehensive set of drivers
- Industry consultation on driver definitions and gathering qualitative and quantitative views about the impact of drivers in the "Upper bound" and negative market conditions, and
- Assessment of impact of individual drivers in the "Upper bound" scenario, such that the combined effect of all drivers matches the overall cost of energy reduction anticipated by industry.

Identification of a comprehensive set of drivers

Prior to any industry consultation, we prepared a list of drivers that covered all areas of influence of governments in the UK and the rest of Europe. We based this on our extensive experience of working in the industry.

We identified six main drivers:

1. Market scale, visibility and confidence
2. Confidence in future levels of own supply
3. Public funded R&D and skills development
4. De-risked investment in projects
5. A well-structured supply chain
6. A cost-efficient support mechanism

We also identified two further interventions:

- The availability of lower cost of energy UK sites, and
- Strategic transmission planning.

We explored these final two interventions separately as it was harder for industry to comment on the cost of energy reduction available from them.

We then sought early stage feedback from the Committee on Climate Change's advisory group for this study and The Crown Estate about the proposed drivers and their definitions.

Industry consultation

To assess the impact of different drivers, we undertook a structured and documented quantitative and qualitative engagement programme with more than 20 senior individuals in the industry. The individuals represented key developers, supply chain companies, the finance community and other enabling organisations. The list of consultee organisations is set out in Table 13. One organisation that provided detailed input that we have used requested that it remain unnamed. We also held discussions about particular issues with DECC, the Scottish Government and The Crown Estate. The list of consultees was agreed in advance with the Committee on Climate Change and was established based on consideration both of individuals' hands-on knowledge of the industry and their organisations position in the sector.

Table 13 Industry consultees

Organisation	Type
Areva (now Adwen)	Turbine supplier
Climate Change Capital	Financial advisor and asset manager
DONG Energy	Developer
EC Harris	Built asset consultancy
Green Giraffe	Financial advisor
Mainstream Renewable Power	Developer
MHI Vestas Offshore Wind	Turbine supplier
ORE Catapult	R&D organisation
RenewableUK	Industry trade body
RES Offshore	Developer and consultancy
ScottishPower	Developer
Seajacks	Installation contractor
Siemens	Turbine and transmission infrastructure supplier

In each case, we sent a pre-read document to the consultee before the interview. This set out:

- Cost of energy forecasts for projects with first generation in 2015 and 2020

- The "Upper bound" cost of energy reduction for a project with first generation in 2030 and the underlying assumptions behind it
- Sources of the cost of energy reductions between these points, broken down by wind farm element and opportunity, and
- Descriptions of each driver, including a short definition of its implementation and its effect on industry activity.

For each consultee, we asked them to:

1. Provide feedback on the cost of energy forecasts and sources of cost of energy reduction provided in the pre-read
2. Allocate a contribution to their forecast of cost of energy reduction between 2020 and 2030 in the "Upper bound" scenario to each of the six drivers, providing justification
3. Assess what further reduction in cost of energy reduction is possible in the "Upper bound" scenario due to the other two interventions identified
4. Repeat steps 1 and 2 in a negative scenario in which Driver 1 was only weakly affecting the market
5. Describe their companies' likely investment opportunities in R&D, infrastructure and equipment in the 2020s and how these might be affected by the drivers, particularly the different elements of drivers 1 and 2
6. Provide feedback on the dynamics between UK and other markets, and
7. Give recommendations on future policy options relating to offshore wind and feedback on suggestions from other consultees that we shared.

We took notes during each interview and sent these to the consultee afterwards. This gave them the opportunity to review them for accuracy, mark the level of sensitivity and answer follow-up questions.

Quantitative and qualitative feedback on the relative importance of different drivers and the level of deployment and visibility required to ensure investment and competition was relatively consistent across players, with the different aspects of driver 1 dominating most conversations.

Assessment of driver impact

In deriving the "Upper bound" cost of energy reduction between 2020 and 2030, we identified sources of the cost of energy reductions, broken down by wind farm element and opportunity.

Based on the feedback from industry, we adjusted the cost of energy forecasts for 2015, 2020 and 2030 and the sources of the cost of energy reductions.

Again, based on consultee responses, we then allocated a contribution of each of the six drivers to the cost of energy reduction between 2020 and 2030 in the "Upper bound" scenario.

We then used a combination of industry knowledge and feedback to define the source of cost reduction for each driver, split by the wind farm elements and opportunities.

These results are presented in Section 4.

Appendix C: Methodology for assessing the cost of energy in each scenario

Summary

The methodology for assessing the cost of energy in each scenario involved:

- Identification of scenarios, each made up of a realistic combinations of drivers, and
- For each scenario, assessment of cost of energy impact of that combination of drivers.

Identification of scenarios

We modelled 10 scenarios to explore the following four key themes:

- The impact of confidence and visibility
- The relative importance of the size of the UK market
- The impact of public R&D funding, and
- The impact of other Government policies.

For each scenario, we prepared a description using the language of the different drivers including the market scale in the UK and the rest of Europe, levels of visibility and industry confidence, and the amount of progress in other policy areas.

We intended these scenarios to be as "real life" as possible, based on the feedback from the industry consultation and our experience of current market behaviour.

Assessment of cost of energy impact

Assigning the relative impact of each driver in each scenario

For each scenario, we made a judgement about the relative impact of each driver, which turned out to be between 10% and 90% of the impact in the "Upper bound" scenario, where all drivers had their full effect.

In doing this assessment, we took into account the state of the market in each scenario compared with the assumptions made for the "Upper bound" scenario. We were also careful to ensure we considered the impact of changes on cost of energy of UK projects, so that changes in the rest of Europe only affected the cost of energy indirectly.

In most scenarios, we chose to change the influence of more than one driver. A risk of this approach is it obscures the effect of individual drivers but it also avoids a large number of extreme and unrealistic scenarios.

Calculating the cost of energy achieved under a scenario

We derived the impact of each scenario on cost of energy reduction between 2020 and 2030 from linearly combining the impact of each driver. We present these results in Section 5.

Appendix D: Methodology for calculating support cost to UK energy users

Summary

The process of calculating the support cost of offshore wind activity to UK energy users in the study involved:

- Using the outputs of the scenario analysis and an adapted version of DECC's methodology to create trends in Strike Prices
- Using the Strike Price trends and an adapted version of DECC's methodology to calculate the support cost of deployment programmes, and
- Calculating the support cost to energy users of offshore wind projects that are not CfD projects installed in the 2020s.

Modelling Strike Prices

This section sets out the approach we used to calculate a Strike Price for a project with first generation in a given year.

A Strike Price is the minimum value per megawatt-hour that generators with a CfD receive for the 15 years of the contract. An optimum (fully competitive) Strike Price for a given project is one that gives a neutral net present value (NPV) over the lifetime of the project, taking into account of the following:

- Expenditure profile
- Revenue profile, and
- WACC.

All values are in 2012 prices, with the actual payments to generators adjusted to take account of inflation.

> **BVGA variations**
>
> In a number of areas, we decided to vary the baseline assumptions used by DECC, while maintaining the same calculations. We did this either to:
>
> - Reflect industry research and opinion about future trends in offshore wind activity, or
> - Extend trends where DECC has not currently given information.
>
> We have explained these variations in boxes underneath our description of DECC's methodology.

Expenditure profile

DECC has published its forecasts of offshore wind capital and operational expenditure (CAPEX and OPEX) for the years 2016, 2017 and 2020).[16] DECC distributes this expenditure over a spend profile that involves eight years of development and construction and 23 years of operation.[17]

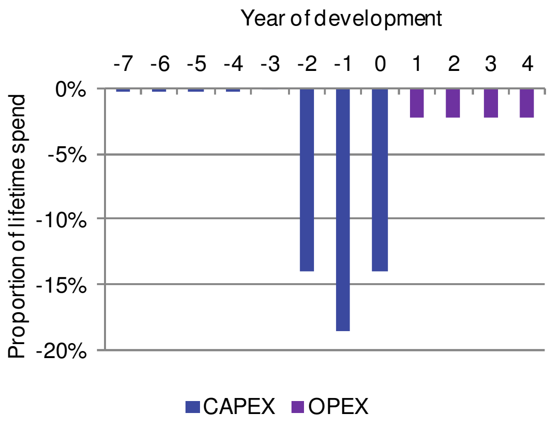


Figure 20 DECC spend profile for offshore wind projects. (OPEX spend continues to Year 23).

> **BVGA variations**
>
> As described in Appendix A, we forecast CAPEX and OPEX using our in-house cost model for all scenarios.
>
> For convenience, we use the same spend profile as defined by DECC.

[16] DECC, *Electricity Generation Costs*, December 2013, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/269888/131217_Electricity_Generation_costs_report_December_2013_Final.pdf, last accessed June 2015.

[17] DECC, *EMR Delivery Plan consultation workshop*, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249823/Draft_Delivery_Plan_Consultation_28_8_13.pdf, last accessed June 2015.

Revenue profile

DECC calculates the average revenue profile for a project with first generation in a given year based on:

- The forecast energy yield of a project
- The forecast project life
- Wholesale revenue
- CfD revenue
- Other revenue (including LEC and capacity market revenue), and
- WACC.

Energy yield

DECC calculates energy yield in megawatt-hours (MWh) by multiplying the installed megawatt capacity by a fixed capacity factor (37.7%), the average hours in year (8,766) and the year specific transmission loss multiplier.

DECC has published transmission loss multipliers for the years 2015 to 2020.[18]

BVGA variations

As part of modelling the cost of energy for different scenarios, we replace the DECC assumption with specific forecasts of the average capacity factor for projects with first generation in that year.

Beyond 2020/21, we have assumed DECC's transmission loss multiplier remains stable at 2020 levels.

Project life

DECC assumes a CfD contract life of 15 years and an overall project life of 23 years

Wholesale revenue

DECC uses a forecast "reference price" to estimate the wholesale revenue that generators will receive. To date, DECC has officially published the CfD reference price in 2012 values for 2015 to 2020.[19]

DECC assumes a generator will secure a fixed-price power purchase agreement (PPA) that lasts the duration of the project. It assumes the PPA price is the reference price five years after the first year of generation (Year 1) with a discount of 5%. This discount reflects the price penalty that generators need to accept to obtain a PPA and covers route to market costs including trading and imbalance costs.

For the purposes of calculating the Strike Price, DECC assumes that wholesale revenue is the lifetime energy yield multiplied by the PPA price.

BVGA variations

For the reference price for 2021 to 2030, we use DECC's "Reference scenario" in *Annex M: Growth assumptions and prices* of DECC's *Updated energy and emissions projects: 2014*.[20] We have adjusted values from 2014 prices to 2012 prices using CPI indices.[21]

DECC does not forecast reference prices beyond 2030 so we have extended the trend forecast in the "Reference scenario" in the 2020s.

CfD revenue

For the purposes of calculating the Strike Price, DECC assumes that Government will pay the generator an uplift per MWh from the PPA price to the agreed Strike Price.

DECC assumes that CfD revenue is the lifetime energy yield multiplied by this uplift.

In reality, the Government will pay the generator an uplift per MWh based on the difference between the Strike Price and the GB day ahead hourly price, rather than the actual price the generator achieves through a PPA or otherwise.

Other revenue

DECC says the price of a Levy Exception Certificate (LEC) was approximately £5 per MWh in 2014 and says this will rise ahead of inflation in the future. DECC assumes that LEC revenue is the annual energy yield multiplied by the specific LEC price in a given year.

DECC assumes generators will also secure revenue from the capacity market (CM) regime once their CfD has expired. DECC assumes that 22% of an offshore wind project's capacity is eligible for CM revenue and the clearing price for capacity is £25,000 per megawatt per year in 2012 terms.

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[18] DECC, *Contract for Difference: Final Allocation Framework for the October 2014 Allocation Round*, October 2014, available online at https://www.gov.uk/government/ups/system/ups/attachment_data/file/373002/Final_AF_11_Nov_2014.pdf, last accessed June 2015.

[19] Ibid.

[20] DECC, *Annex M: Growth assumptions and prices; Updated energy and emissions projections: 2014*, October 2014, available online at https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014, last accessed June 2015.

[21] Office for National Statistics, *Consumer Price Index*, available online at http://www.ons.gov.uk/ons/datasets-and-tables/data-selector.html?cdid=D7BT&dataset=mm23&table-id=1.1, last accessed June 2015.

BVGA variations

Due to uncertainties about the degree to which developers will take account of these revenue streams, we have not included these revenue streams in our calculations.

Weighted cost of capital (WACC)

DECC assumes a pre-tax real WACC of 9.7% for offshore wind under the CfD regime.[22]

BVGA variations

As part of calculating cost of energy for different scenarios, we make specific assumptions about the average WACC for projects with first generation in that year starting at 11% for projects with first generation in 2015 to 8.3% for projects with first generation in 2030.

Modelling the support cost to UK energy users

This section sets out the approach we used to calculate the support cost of offshore wind deployment to UK energy users.

We do this by multiplying an uplift that energy users pay the generator per megawatt-hour produced by the energy yield of the project during the 15-year CfD period.

DECC forecasts the uplift that a project receives in a given year using:

- The Strike Price awarded to the project, and
- The reference price in each year of the project.

Strike Price

For the years 2015 to 2018, DECC has given headline Strike Prices for projects with first generation in a given year.[23] These are in 2012 prices.

Projects with FIDER contracts receive these headline Strike Prices. The Strike Prices for CfD projects will be lower than these headline levels if there is an oversubscription for the Pot 2 budget in the year of application. This will trigger an auction in which developers competitively submit bids that must be beneath the headline levels.

BVGA variations

We assume there is always oversubscription for Pot 2 budgets so all Strike Prices are determined by auction.

As described above, we assume developers that are successful in auctions will have submitted the optimum (fully competitive) Strike Price, based on the forecast cost of energy for projects in their year of first generation.

Reference price

DECC uses a forecast reference price to estimate the wholesale revenue that generators receive. To date, DECC has published the official CfD reference price for 2015 to 2020.

[22] DECC, *Electricity Generation Costs*, December 2013, available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/269888/131217_Electricity_Generation_costs_report_December_2013_Final.pdf, last accessed June 2014.

[23] DECC, *Contract for Difference: Final Allocation: Framework for the October 2014 Allocation Round Updated Oct 2014,* October 2014, Available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/404405/Contract_for_Difference_Final_Allocation_Framework_for_the_October_2014_Allocation_Round.pdf, last accessed June 2015.

BVGA variation

DECC's reference price reflects the wholesale price of electricity but not the marginal cost of new build capacity. For the purposes of this report, we assume the support cost of offshore wind is the uplift from the cost of the lowest cost alternative. We assume this is the long run marginal cost (LRMC) of electricity from CCGT with the carbon price uplift.

Our forecast of the LRMC for gas uses a methodology established by the Committee on Climate Change. This is based on DECC's "Reference" scenario of wholesale natural gas prices (adjusted to 2012 prices). We add an additional 2p per therm to reflect transportation costs and an additional 1.2p/kWh to reflect the capital cost of the generating plant.

The carbon price uplift is based on Committee on Climate Change in-house models.[24]

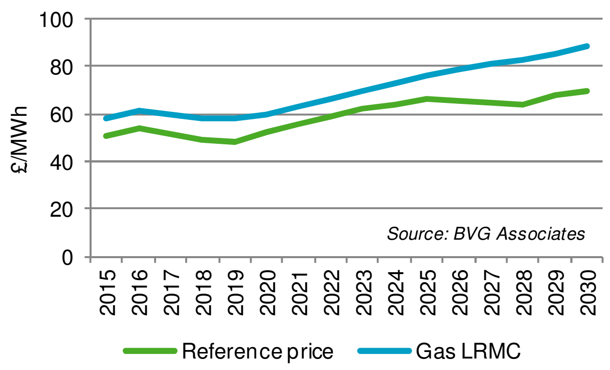


Figure 21 Comparison of DECC forecast reference price and CCC gas LRMC. Values in 2012 terms.

Energy yield

DECC calculates energy yield in megawatt-hours (MWh) by multiplying the installed megawatt capacity by a fixed capacity factor (37.7%), the average hours in year (8,766) and the year specific transmission loss multiplier.

DECC has published transmission loss multipliers for the years 2015 to 2020.[25]

BVGA variations

As part of calculating cost of energy for different scenarios, we replace the DECC assumption with specific forecasts about the average capacity factor for projects with first generation in that year.

Beyond 2020, we have assumed the transmission loss multiplier remains stable at the 2020/21 level.

Support cost to energy users of other offshore wind projects

In this study, we focus on the impact of drivers on offshore wind projects built in the UK under the CfD regime in 2020s. Importantly, UK energy users in the 2020 will also bear support costs for offshore wind projects built under:

- The RO regime
- The FIDER regime, and
- The CfD regime with first generation before the end of 2020.

We show our forecast of capacity installed under these categories in Figure 22.

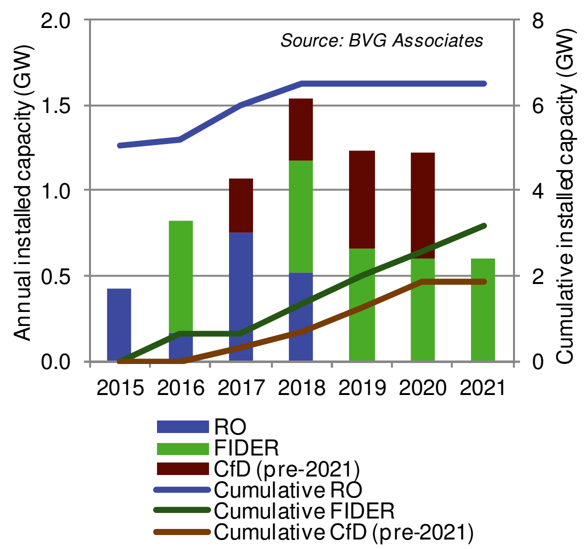


Figure 22 Forecasts of projects installed under the RO and FIDER regime and projects installed under the CfD with first generation before the end of 2020.

Support cost to energy users of offshore wind projects built under the RO regime

For projects installed under the RO regime up to the end of 2014, we used a Committee on Climate Change projection of cost that takes into account the effect of early projects passing out of contract.

For projects forecast to be installed under the RO regime after 2014, we used Committee on Climate Change projections of ROC prices to 2030 in combination with our

[24] Committee on Climate Change, *Costs of low carbon generation technologies 2011 renewable energy review – technical appendix*, August 2011, available online at http://archive.theccc.org.uk/aws/Renewables%20Review/RES%20Review%20Technical%20Annex%20FINAL.pdf, last accessed June 2015

[25] DECC, *Contract for Difference: Final Allocation Framework for the October 2014 Allocation Round*, October 2014, available online at https://www.gov.uk/government/ups/system/ups/attachment_data/file/373002/Final_AF_11_Nov_2014.pdf, last accessed June 2015.

capacity forecast of the remaining projects likely to progress under this regime.

Support cost to energy users of offshore wind projects built under the FIDER regime

For projects forecast to be installed under the FIDER regime, we assume each projects is awarded the Government-stated Strike Prices appropriate for the year of its first generation and use the same support cost methodology as the CfD regime.[26] We base our forecast of the installation programme of the FIDER projects on public statements by the relevant developers and market intelligence gathered from industry discussion.

Support cost to energy users of offshore wind projects built under the CfD regime before the end of 2020

For projects forecast to be installed under the CfD regime up to the end of 2020, we use our baseline cost analysis to derive the Strike Prices and then use the standard cost model to calculate the support cost to energy users.

This process generates Strike Prices that are closely aligned with those announced in the first CfD allocation round.

Results

As shown in Figure 23, the support cost of capacity installed under the RO regime is the largest cost at £16.5 billion between 2021 and the end of 2030.

The support cost of the capacity installed under the FIDER regime is approximately £9 billion between 2021 and the end of 2030 and the capacity installed under the CfD regime with first generation before the end of 2020 has a support cost of just over £3 billion between 2021 and the end of 2030.

The annual cost of these projects peaks in 2021 at approximately £3.4 billion and comes down to £2.1 billion in 2030.

[26] DECC, *Contract for Difference: Final Allocation: Framework for the October 2014 Allocation Round Updated Oct 2014,* October 2014, Available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/404405/Contract_for_Difference_Final_Allocation_Framework_for_the_October_2014_Allocation_Round.pdf, last accessed June 2015.

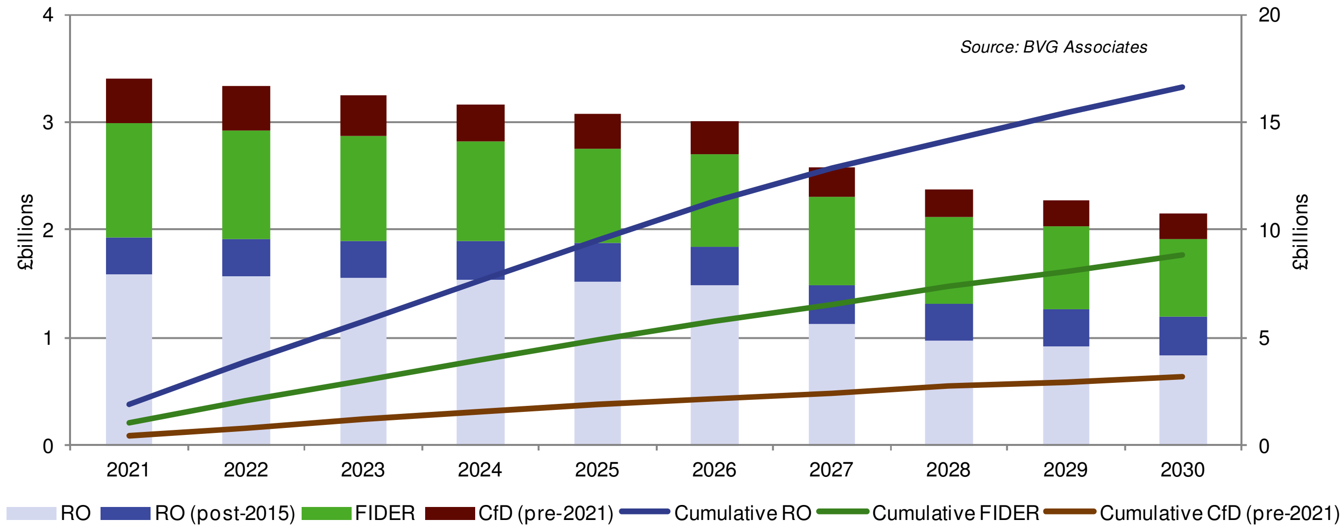


Figure 23 Forecast of support cost to UK energy users of all projects installed under the RO and FIDER regime and projects installed under the CfD with first generation before the end of 2020.

Appendix E: Typical technology development lifecycle

Summary

This appendix discusses typical technology development lifecycles in offshore wind, reflecting on the impact of these on reducing the cost of energy. It focuses on wind turbines, as these have the longest development life cycle and the greatest impact on lifetime costs. It is adapted from *Offshore wind cost reduction pathways - Technology work stream.*

Turbine development stages

The typical development lifecycle for a wind turbine consists of a number of stages, as shown in Table 14. In moving from each stage to the next, it is normal to have a gate review, at which a company may decide to halt development or change the scope, pace or direction of development.

The decision to develop a new turbine platform (new scale of main components) or variant (where most components are unchanged) is driven by the opportunity to gain a competitive advantage by reducing the cost of energy for customers. Due to the long development cycle for a new turbine platform, the reduction needs to be quite significant (about 10%) to justify investment in a new design instead of stepwise improvements of an existing design through supply chain and individual component innovations.

There is a strong history of cost reduction in the onshore wind industry, linked to innovation and new product introduction. For example, see the trends discussed in the United States Department of Energy *2010 Wind Technologies Market Report* published in June 2011.[27]

[27] U.S. Department of Energy *2010 Wind Technologies Market Report,* June 2011, available online at www1.eere.energy.gov/wind/pdfs/51783.pdf, accessed June 2015.

Table 14 Typical development life cycle for a wind turbine platform, incorporating variants.

Development stage	Typical scope
Concept design	This covers the development of a design basis and basic turbine parameters and a justification of the business case. It defines the test, certification and supply chain plans.
Detailed design	A detailed load and stress analysis and development of a full set of drawings, specifications and manuals enables purchasing, installation and operation of the prototype turbine. There is typically also a third-party design approval element of type certification.

Prototype turbine testing and certification	The procurement, assembly, installation and operation of a prototype turbine are funded either by the wind turbine supplier, or by a developer specifically for test purposes. They are likely to install the prototype onshore as this lowers the cost and enables easier access. This means that it will have less downtime compared with an offshore prototype and the testing process can run faster. Turbine suppliers generally do not consider differences in wind conditions offshore and onshore to be important in verifying the turbine design. Offshore demonstration is most useful in assessing the dynamic interaction between the turbine and support structure, and understanding how this affects turbine control.
	
	This stage also covers:
	• Component-level testing (for example of blades and drive train)
	• On-site load and performance measurement, and
	• Third-party type certification.
	
	Generally, the characteristics of attractive prototype and demonstration sites (in addition to planning consent and grid connection) are:
	• **High average wind speed.** Hours in operation with above rated wind speeds, especially towards cut-out wind speed, are ideal for proving new turbines. Key activities on a prototype turbine, with associated ideal wind speeds include:
	    • Commissioning and early turbine functional testing, which needs winds speeds of 6m/s to 15 m/s
	    • Safety testing, which needs winds of 6m/s to 20 m/s
	    • Noise measurements, which need winds of 6m/s to 10m/s
	    • Power curve measurements, which need winds of 3m/s to 20 m/s
	    • Controller tuning and loads measurements, which need winds of 6m/s to 25 m/s, and
	    • Rapid fatigue life accumulation, which needs winds of 10m/s to 25 m/s
	• **Reasonable logistics access**. This is important not only to facilitate installation but also in case of a major component exchange during its early operation. There is also value in prototypes being located sufficiently close to the key engineering bases of manufacturers.
	• **Clean topography**. Measurement campaigns in particular are run for type certification, as local topographical conditions need to meet specific requirements. For a turbine designed for offshore use, conditions as similar to these as possible are preferred.

Demonstration turbines	A number of demonstration turbines are supplied and operated, likely with some onshore and some offshore to demonstrate the turbine / support structure interaction.
Early commercial turbines	This refers to the supply and operation of a first commercial offshore wind farm that may have smaller number of turbines than full commercial scale farms. A smaller proportion of risk resides with the asset owner than in a full commercial project, though the terms of such arrangements are often opaque and, externally, the project may seem fully commercial. Typically, FID on such a project may be reached after about three years of operational experience on a prototype turbine (15 per cent of design life) on a high-wind speed site. A customer would also anticipate at least 15 turbine-years experience across a fleet of demonstration turbines. Acceptable pedigree is also dependent on: • The experience of the wind turbine supplier and of its main component suppliers, including the operational track record of other turbines • The quality and extent of testing, including the harshness of test site conditions and the performance of the company in addressing issues relating to reliability

Development stage	Typical scope
	• The risk involved in new designs, relating to the extent of changes in scale and technology compared with previous designs, and • The financial strength and commitment of the turbine manufacturer.
Full commercial implementation	This refers to the supply and operation of offshore turbines in quantity for commercial projects. Typical product (sales) life is anticipated to be longer than for onshore turbines due to the length of the wind farm development cycle, offshore.
Upgrade models during product life time	Most turbine manufacturers incorporate incremental design improvements in specific components in new upgrade model releases of a given turbine. In some cases, suppliers will retrofit existing turbines with these improvements. Upgrades are evolutionary changes that do not involve a change to turbine rating or rotor diameter. Turbine suppliers introduce most of the innovations relating to turbine concept, nacelle layout or major component design on a new wind turbine platform, rather than on an upgrade model.
Introduction of variants	Frequently, once a turbine supplier has obtained commercial operating experience with a given turbine, one or more variants will be developed. An example of this is the development of Siemens SWT-7.0-154, with higher power rating than the original SWT-6.0-154. Such variants, though requiring full type certification, have a lower associated risk than a new turbine platform, and can extend the sales life of a turbine model considerably. Design changes may be limited to specific components or may affect most key components in some way.

Historically, the timescales for introducing new turbine platforms has varied quite considerably. Faster times have occurred when there is a close relationship between the turbine supplier and developer of sites where early commercial turbines are installed. We show typical timescales and an approximate indication of cumulative cost in Figure 24. Based on industry feedback, development costs (including those incurred by the wind turbine supplier for new production facilities, but excluding supply chain investment) typically range from £300 to £750 million for a 6MW to 8MW-Class turbine, depending on the scope of in-house supply, the depth of component life verification and the scale of early production plans. This equates between about 4% to 10% per cent of lifetime revenue, depending on the scope and product sales. Its supply chain and installation contractors may also incur significant costs in delivering efficient component supply and installation.

The key decision points for the wind turbine supplier in terms of committing spend are at the start of the prototype turbine testing and certification stage and, after some operating experience, at the point commitments are made to new manufacturing facilities and tooling for series production.

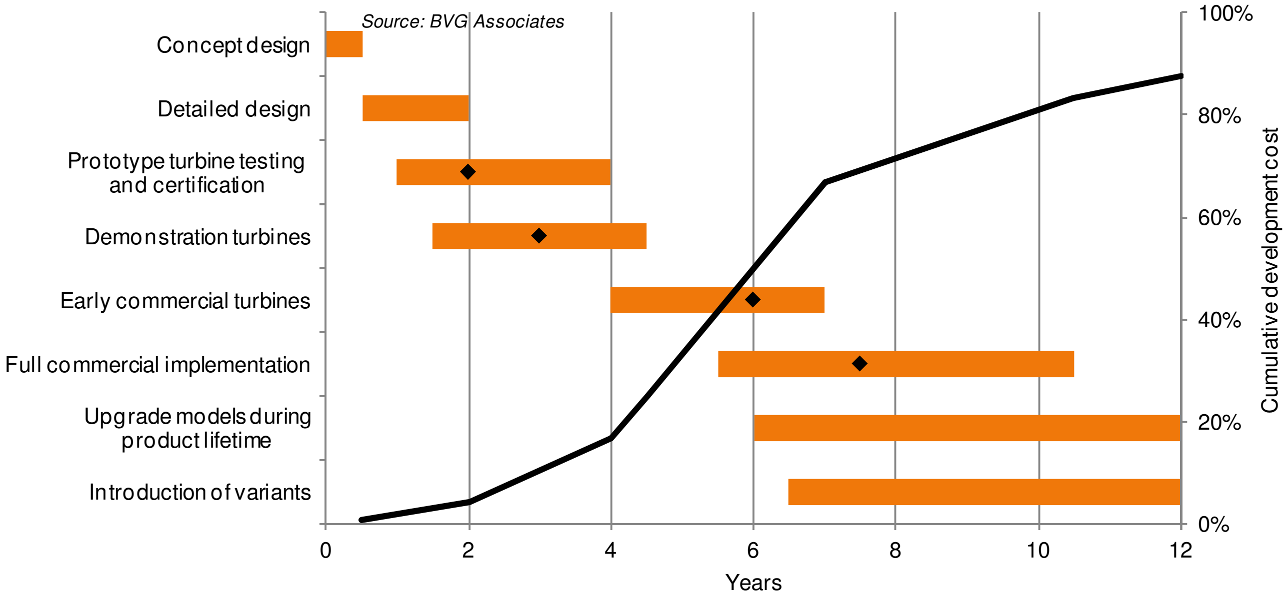


Figure 24 Summary of typical timescales and cumulative spend on new offshore wind turbine development. Diamonds indicate first turbine installation in stage.

A large wind turbine supplier employs a significant in-house engineering team, which it treats as an overhead cost. When deciding on a new product, it will look at the existing and upcoming product landscape and compare which new products are the most likely to provide best future earnings, onshore and offshore. It will assess the resources required to develop and mature the product. A sales lifetime of eight or more years is expected for a turbine platform, supported by the release of variant turbines, such as one with a larger rotor diameter. Depending on the changes in scale of the turbine design, a manufacturing facility may be used for one or more turbine platforms.

It is not only wind turbine suppliers that have to invest to supply new turbines. It is common that key components suppliers also need to invest, both in the parallel development of components and in manufacturing capability. Typically, in offshore wind, a wind turbine supplier will work with a single supplier with an existing supply relationship in developing a component for early turbines, with additional suppliers being integrated during or after the demonstration turbines stage.

It is relevant to note in considering investments by wind turbine suppliers that some development and facility costs may only yield returns from the offshore market while others may also apply onshore. The development of other elements or of components within a wind turbine costs may be relevant to other sectors, but development costs for many large components such as blades, gearboxes and generators are offshore-wind specific.

Other elements

The technology development lifecycle for other elements varies quite considerably. Notable examples are discussed below.

Foundations

Two specific cases are relevant for support structures: the novel concept development and the evolution of existing designs. In both cases, this technology development may be driven by:

- The development of projects in deeper water with more challenging metocean conditions or different seabed types
- The introduction of turbines with greater top tower mass and rotor diameter, or
- The incorporation of support structure innovations to reduce the cost of energy. This may be focused on streamlining the manufacturing or installation processes or reducing the amount of steel that is required.

The first case is where there is a significant step change in the design concept. There are few (if any) truly novel concepts for offshore support structures available but there are many that have been used in the oil and gas sectors that have not yet been used in offshore wind. There are key differences between the two sectors that are of importance: offshore wind structures have to withstand more dynamic loading, and are required in higher volume and with more optimised designs.

Novel offshore wind foundation designs have tended to originate in specialist engineering consultancies or start-up companies. Following early stage assessments, promising designs have then tended to be picked up by large companies with greater financial backing and/or fabrication capability. For example, Keppel Offshore & Marine acquired a large stake in jacket designer OWEC Tower and Fred. Olsen owns a majority share of Universal Foundation (formerly MBD Offshore), which is developing a suction bucket.

As a method of demonstration, a number of novel foundation designs have been used to support meteorological stations installed during the development stage of a wind farm. For example, Keystone Engineering has developed a twisted jacket foundation design that been developed through the Carbon Trust Offshore Wind Accelerator programme and was selected by Mainstream Renewable Power for this purpose.

While this use provides information on the manufacturing and installation processes of the structure, feedback from industry suggests that this type of demonstration does not provide sufficient evidence to fully justify use in commercial quantities. This is because it is not built at full scale and is not subject to the dynamic loadings of a turbine. Such activity is therefore seen as a stepping stone to a full-scale demonstrator.

For full-scale demonstration, a test site is required and this has typically required involvement of a major utility/developer. For example, DONG Energy used a site on its commercial Borkum Riffgrund 1 project to demonstrate its own suction bucket jacket design.

For designs that involve a novel seabed connection, such as suction buckets, demonstrator projects need to prove the behaviour of the foundation under dynamic turbine loading over a period of at least two years. A further challenge is that there may still be concerns about locating such a design in different seabed conditions to those in which they have been demonstrated.

Historically, there has been a gap of several years between the successful demonstration of a foundation design and its first commercial use. For example, OWEC Tower began the development of its Quadrapod jacket design in 2001. The first full-scale construction and installation of two foundations was in 2006 at the Beatrice Demonstrator Project. This was followed by a further six at the German Alpha Ventus project in 2009 and it was not until 2010 that the first fully commercial project, Ormonde, was installed.

Feedback from industry suggests there is strong pressure to reduce this lag through close cooperation between the design teams of suppliers and developers so that project planning can start before the completion of trial and full-scale production can start much more quickly, potentially within a year or two.

Where an existing design is in place, an evolution may be required to meet new requirements. In contrast to turbines, designs are typically project-specific so the development cycle is short. Costs are either paid separately or incorporated into the sales price for a batch of foundations.

It is believed that future development cycles for the evolution of jacket designs will be considerably quicker than that describe above. This is because the quadrapod was a novel design for the offshore wind industry when it was first proposed and required significant demonstration before the industry was confident of its long-term performance. There was also little commercial demand for foundations for 5MW turbines during the development period for OWEC designs. A range of variations on the jacket theme have been proposed in recent years and are likely to be accelerated through to commercial readiness in order to meet the growing market demand.

Early design stages are inexpensive, with more advanced designs often receiving public support through grant programmes or enabling bodies. Full-scale demonstration projects have typically required public funding to proceed.

In terms of investment in manufacturing facilities, early projects have been built in existing oil and gas fabrication yards, which have required relatively little investment. Feedback from industry suggests that investment in advanced, large-scale manufacturing facilities is likely to range from £50 million to approximately £160 million for a throughput of about 100 units per year. Feedback is that such investment will not be speculative with some companies suggesting that a firm pipeline of two to three large commercial-scale projects may be sufficient given confidence in wider industry progress while others would require commitment for up to five years of production.

Installation

Innovations in installation are primarily linked to the introduction of new vessels, driven by the trend towards larger monopile foundations and jackets and by the benefits from working in a wider range of weather conditions.

For turbine installation vessel designs, there is a degree of certainty over the turbine size and technology, and ship designers such as GustoMSC have developed designs for turbine installation jack-ups, a number of which started entering service from 2012. This is less true for foundation installation and, while the vessels will probably be floating, heavy lift vessels, there are fewer concepts under development. It is likely that the foundation installation fleet in 2020 will include a mixture of new build vessels and modifications of existing vessels from other sectors. In both cases, investment is hampered by the lack of market clarity on required specifications, due to uncertainty about what vessels will be installing and what the optimum installation method(s) will be.

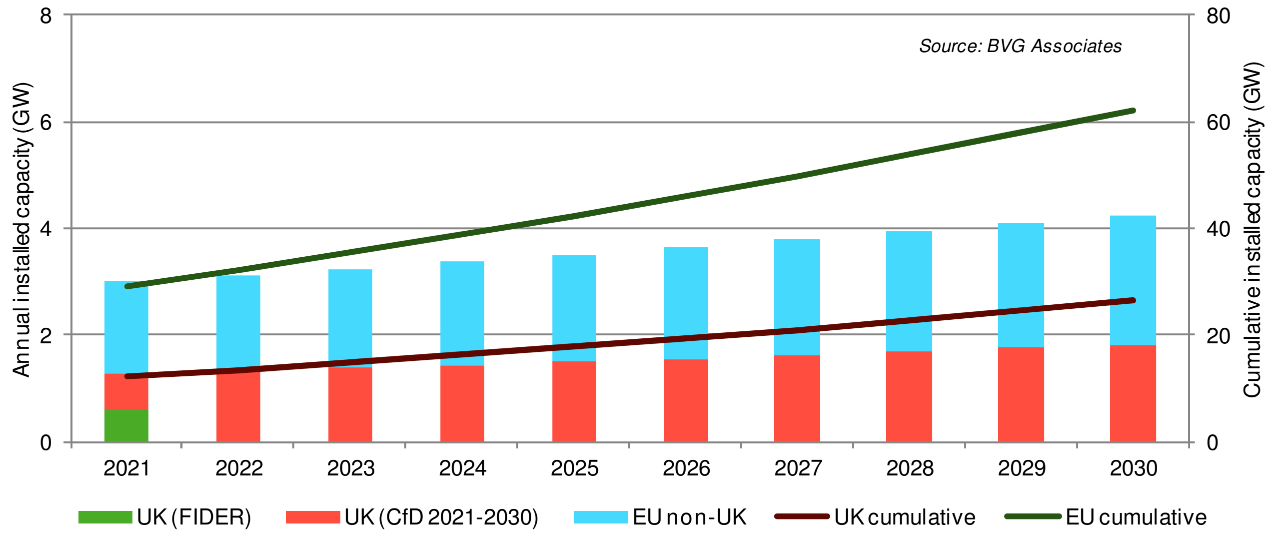
The lead time from vessel investment decision to operation is typically three to four years. For example, following the success of the Resolution, MPI Offshore decide to construct two new, larger jack-ups in 2008, and it took delivery of MPI Adventure and MPI Discovery in March and November 2011 respectively. In May 2007, Master Marine engaged Labroy Shipyard in Batam, Indonesia, to construct the jack-up Nora, which was subsequently contracted to install turbines at Sheringham Shoal starting in January 2011. The contract was cancelled when it became apparent that the vessel would not be ready in time. There is a shorter lead time for conversions.

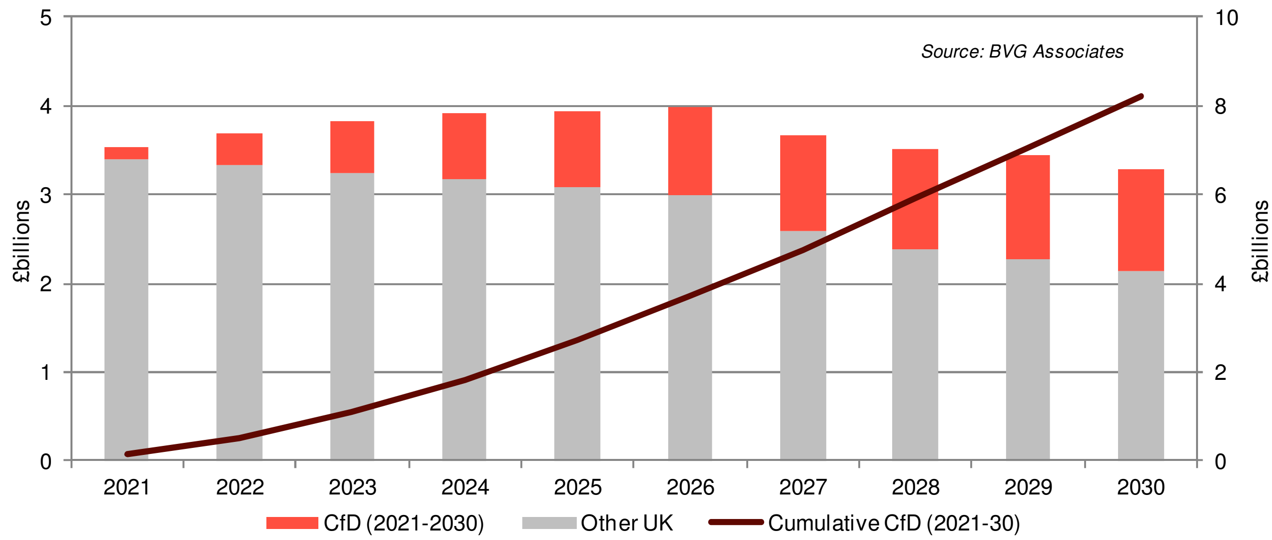
For innovative installation equipment or processes such as blade lifting systems, sea fastenings or cable pull-in processes, lead times are lower than typical times from contracting to construction.

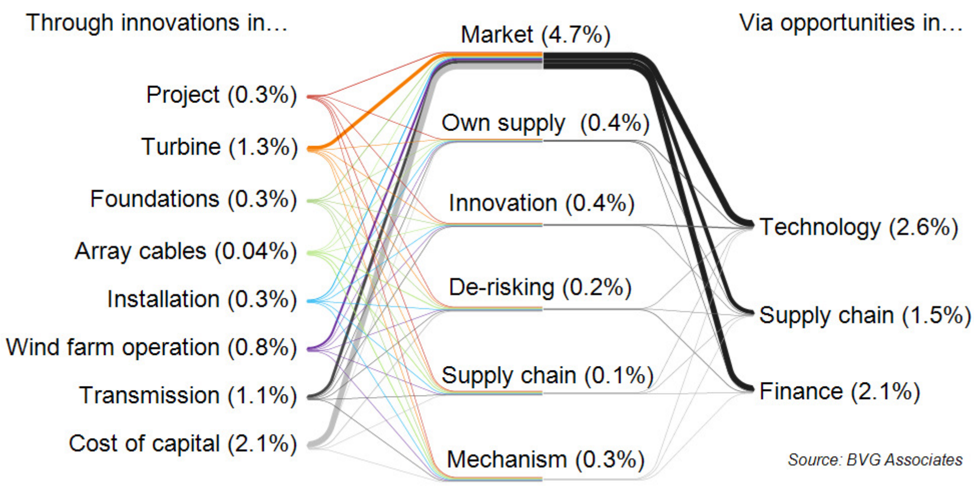
The development of facilities for the manufacture and installation of CGB foundations has an additional barrier in that developers view the practical application of CGB foundations for 500MW projects as unproven and are likely to look for a significant demonstration project of at least 10 turbines before committing to the technology. Unlike turbine demonstration projects, customers of CGB foundations are more concerned with the logistical issues surrounding fabrication and installation and suppliers are optimistic that investment in a full-scale facility could follow immediately after the demonstration installation and be ready to supply a full-scale project 12 months later. This could only be achieved, however, if a customer was prepared to commit ahead of the demonstration. Where the concrete gravity base is being used as part of a float-out-and-sink turbine and support structure installation, the investment for the demonstration site is higher as the process requires that a bespoke vessel be constructed.

Appendix F: Detailed output for each scenario

1. Current approach

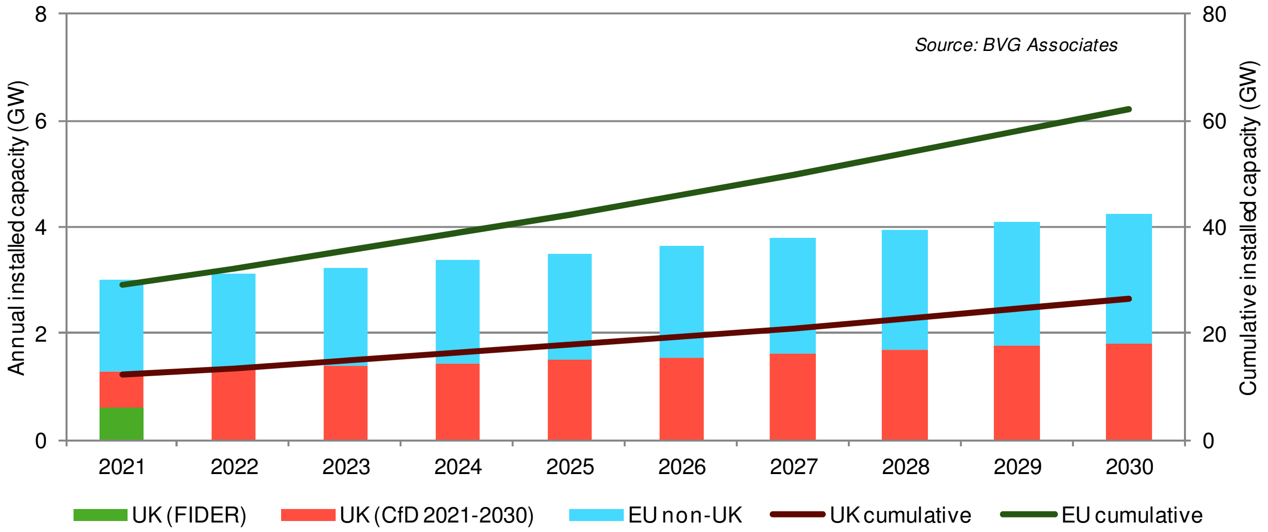


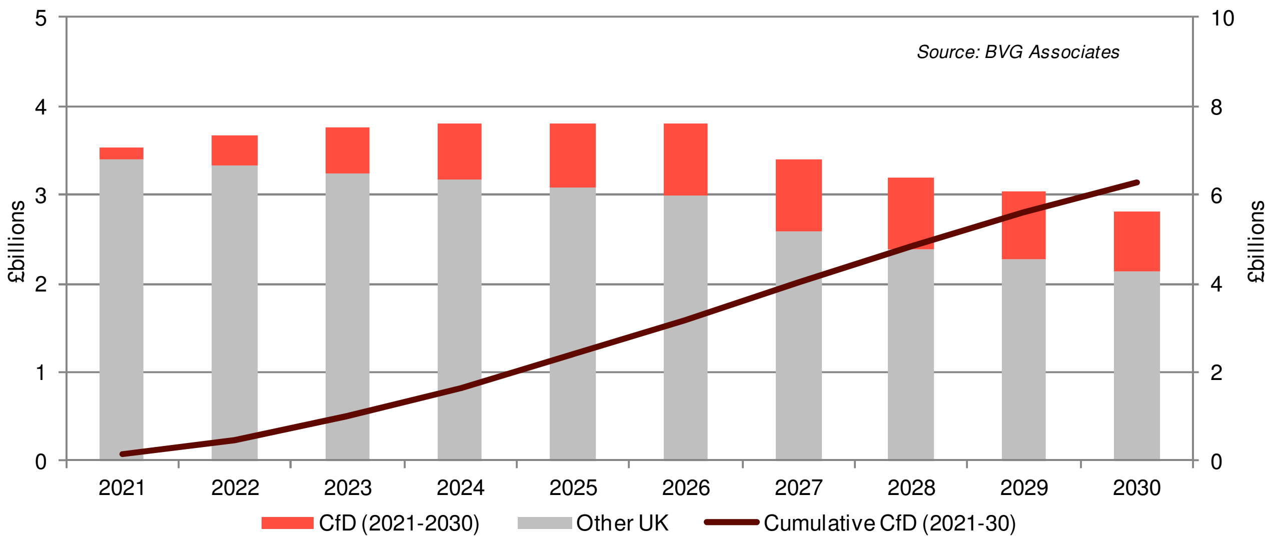


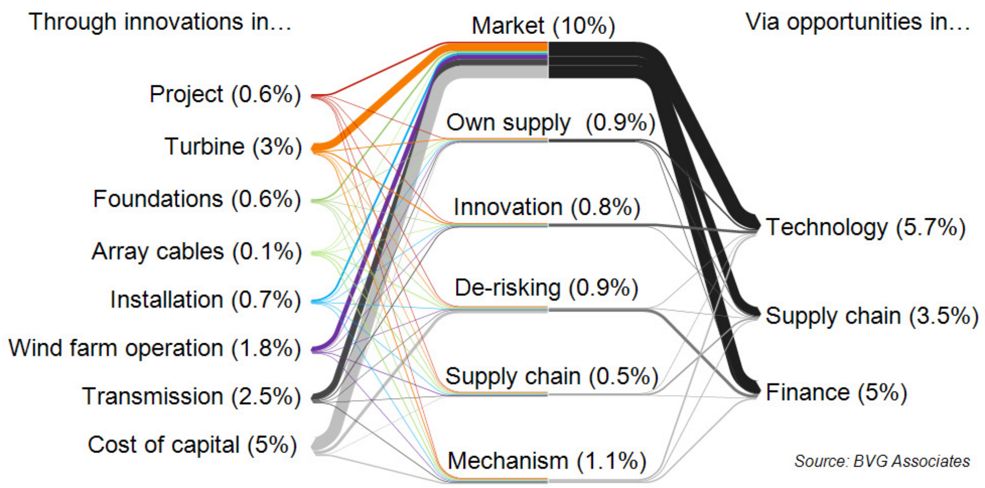


See Section 5.1.3 for details about each graph.

2. Balanced

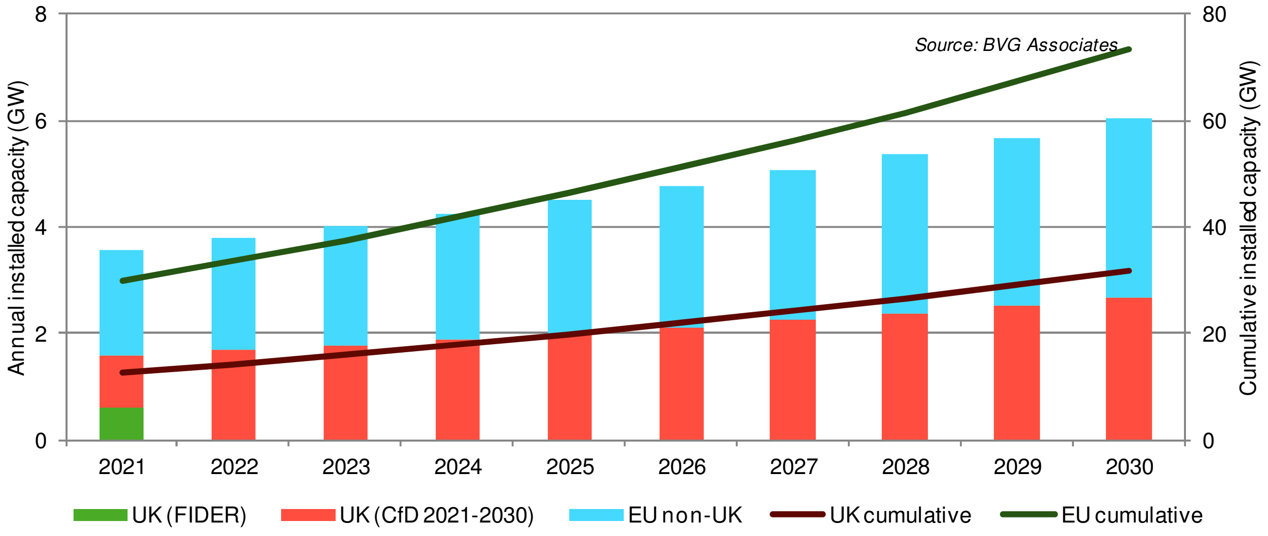


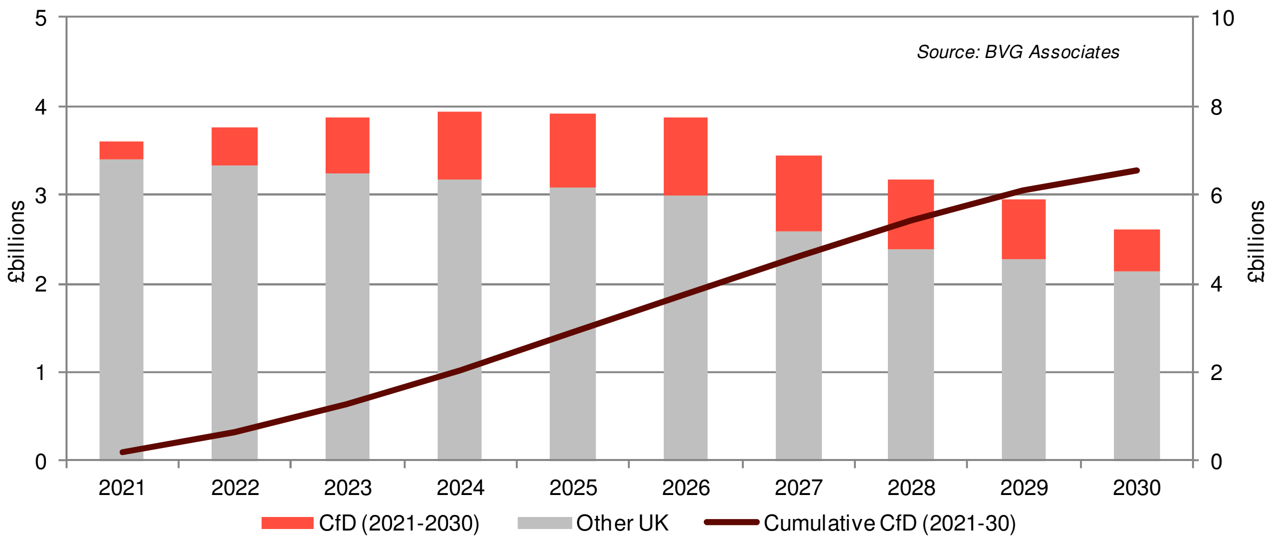


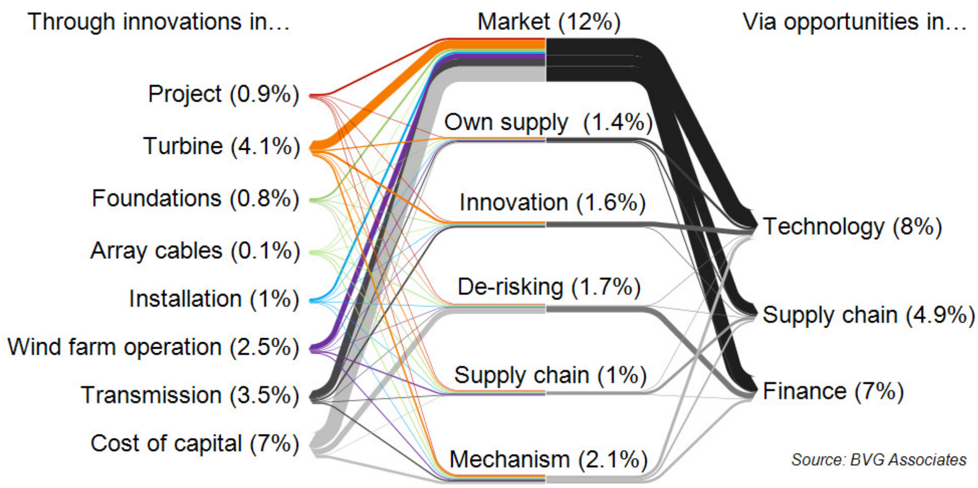


See Section 5.1.3 for details about each graph.

3. Strong support

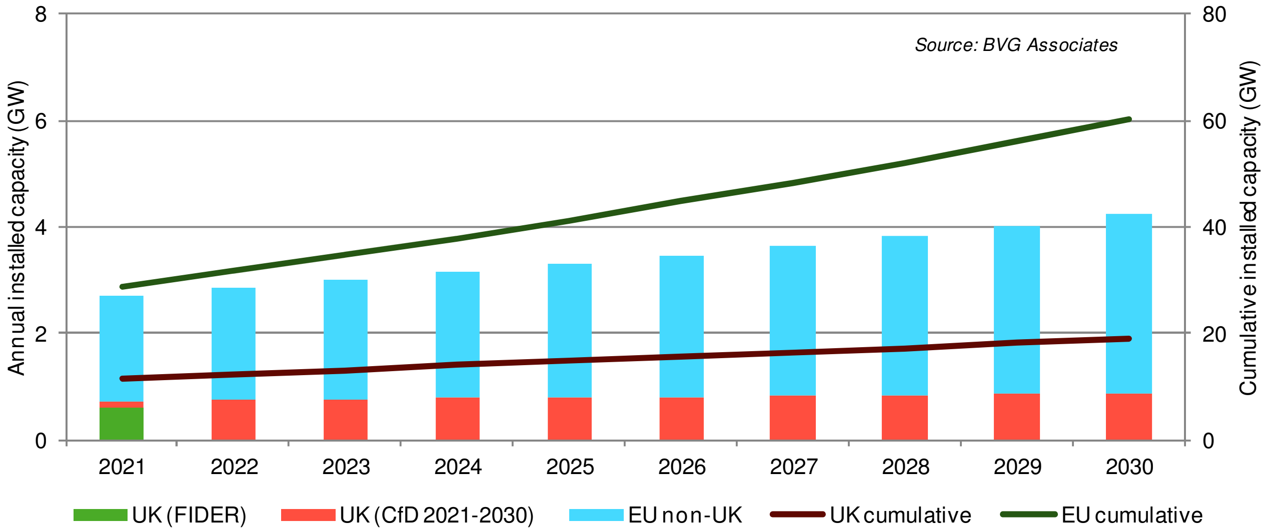


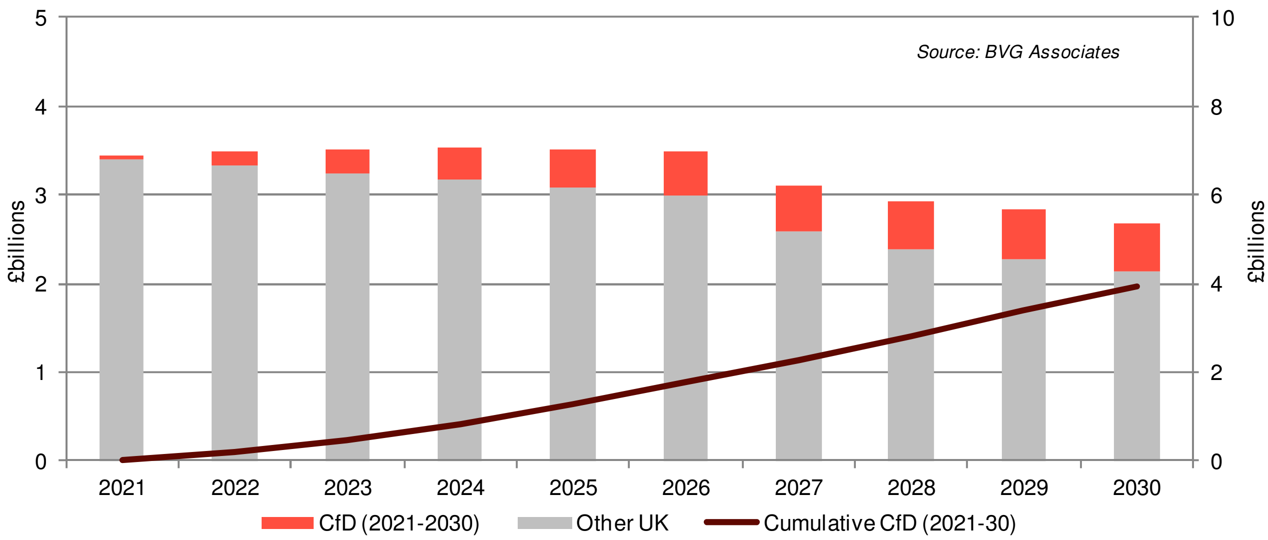


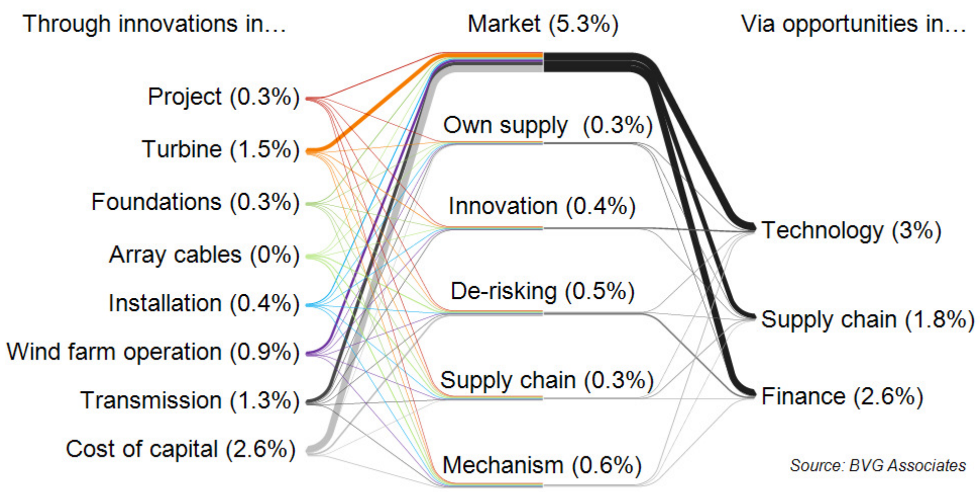


See Section 5.1.3 for details about each graph.

4. UK slows

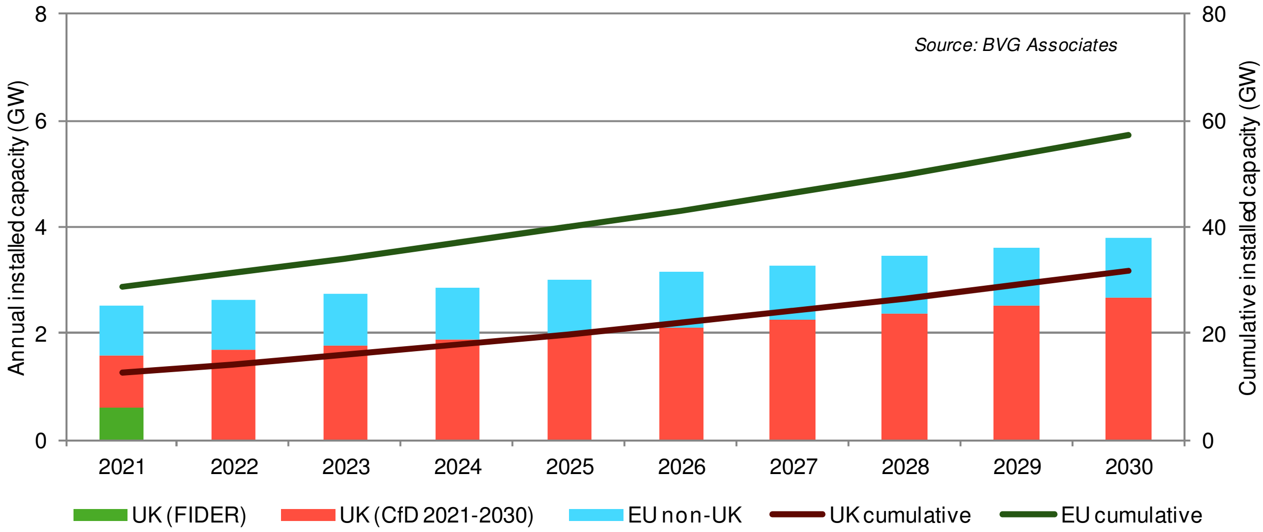


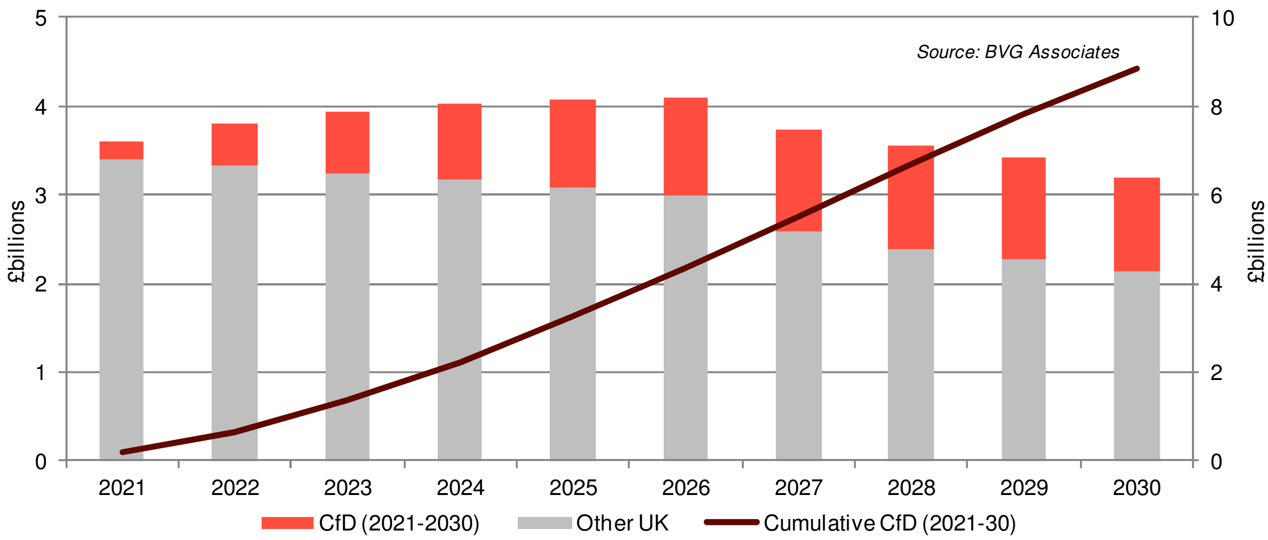


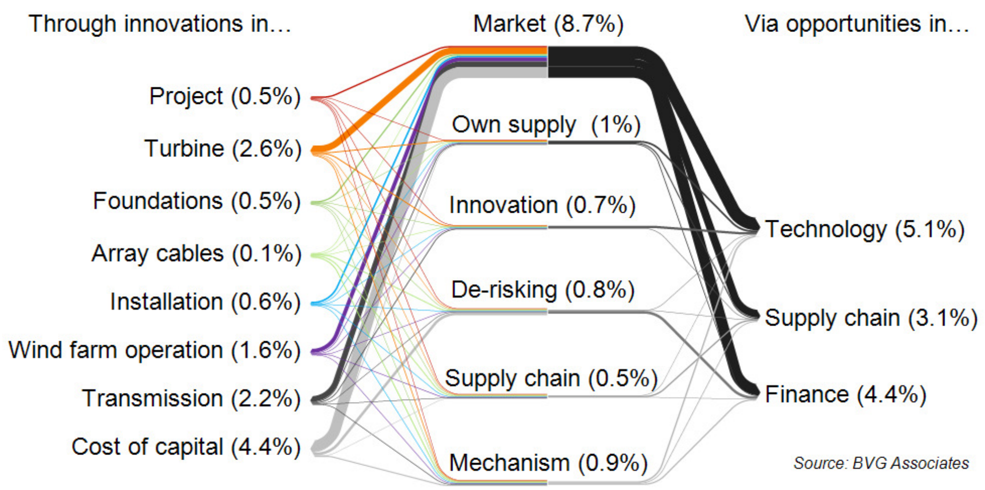


See Section 5.1.3 for details about each graph.

5. Rest of Europe slows

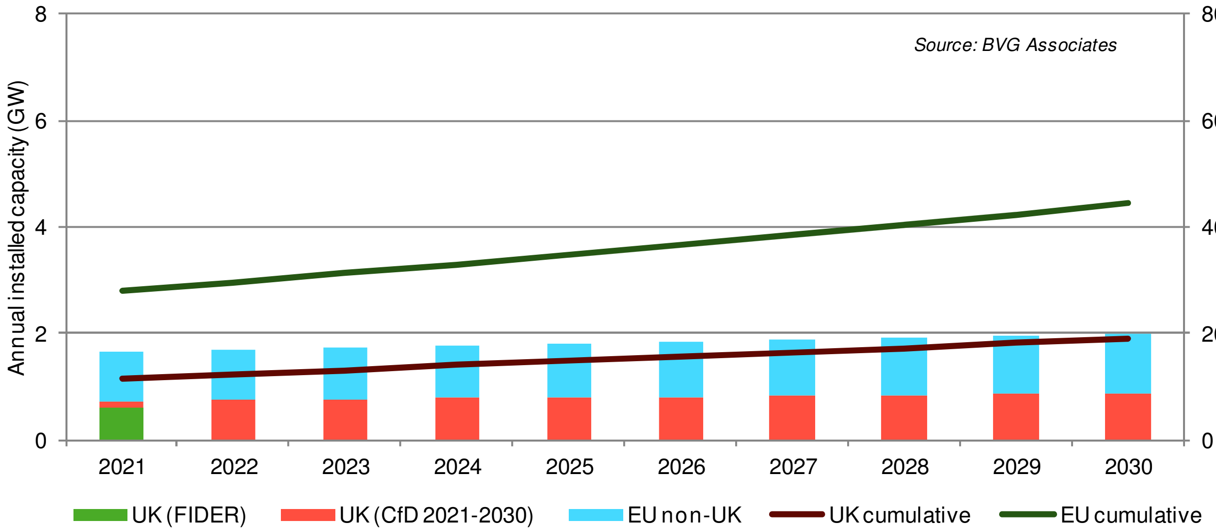


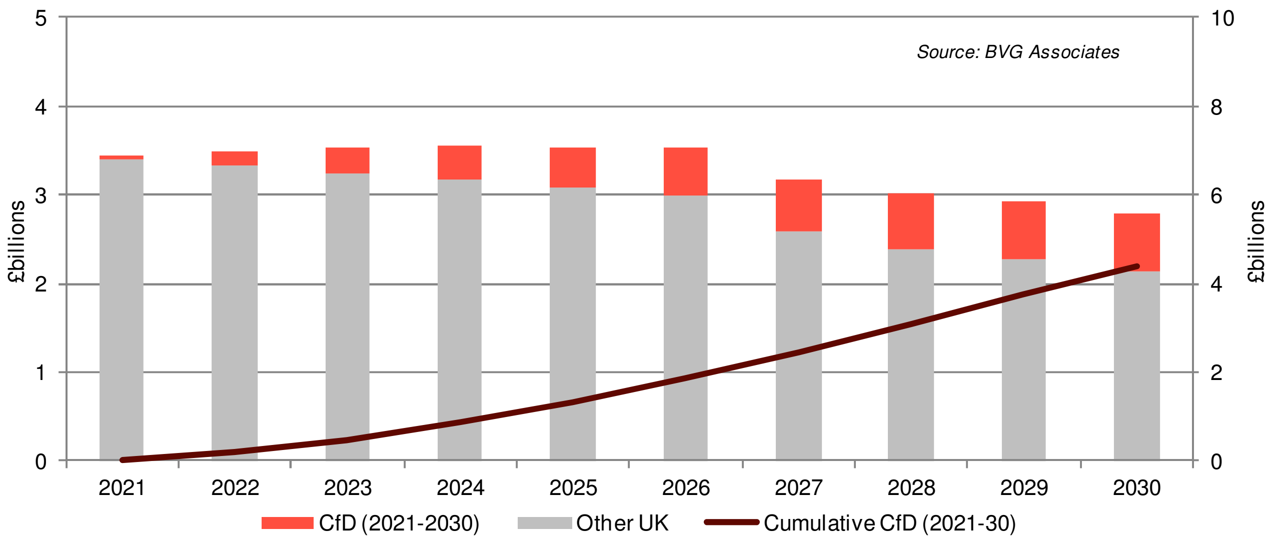


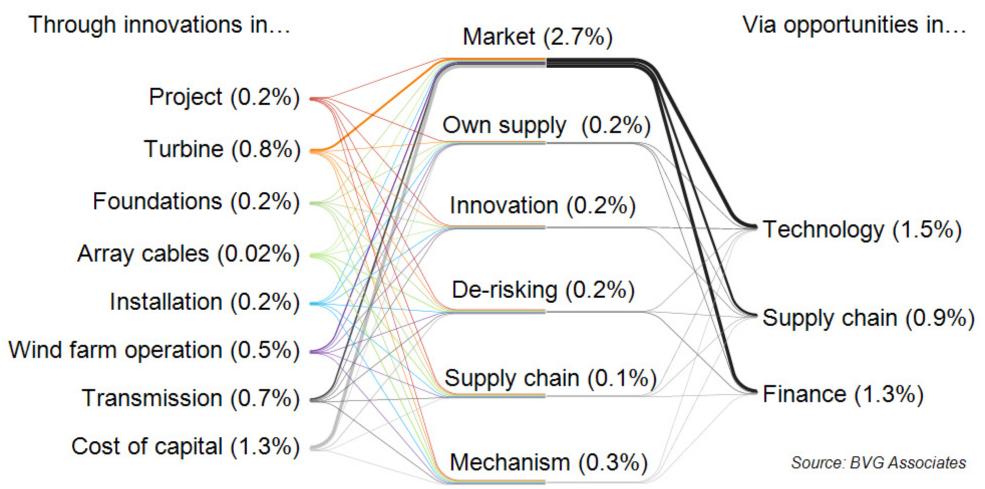


See Section 5.1.3 for details about each graph.

6. Market stagnation

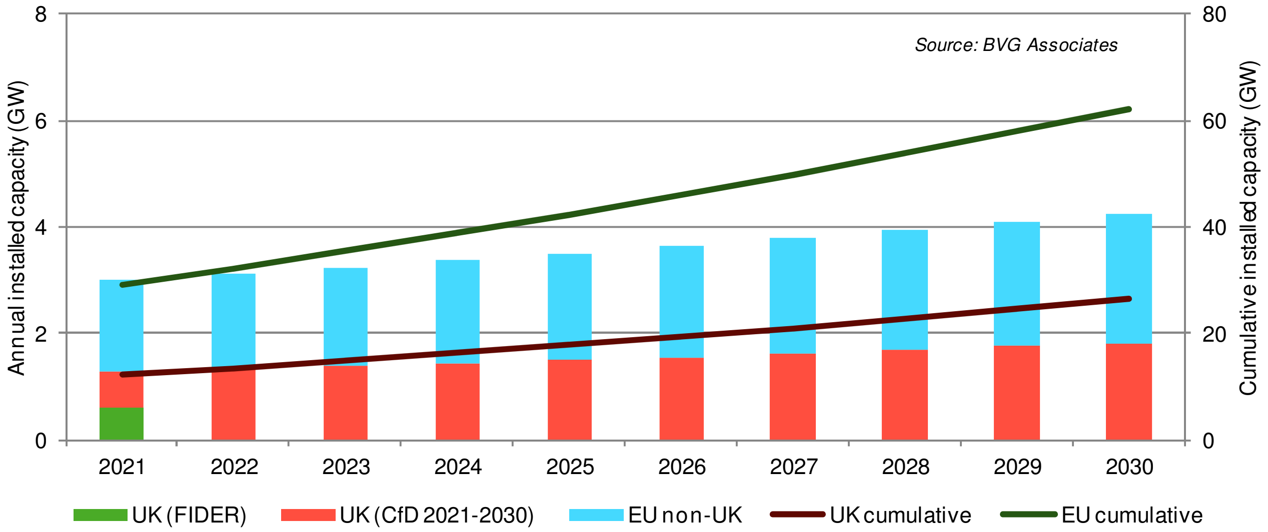


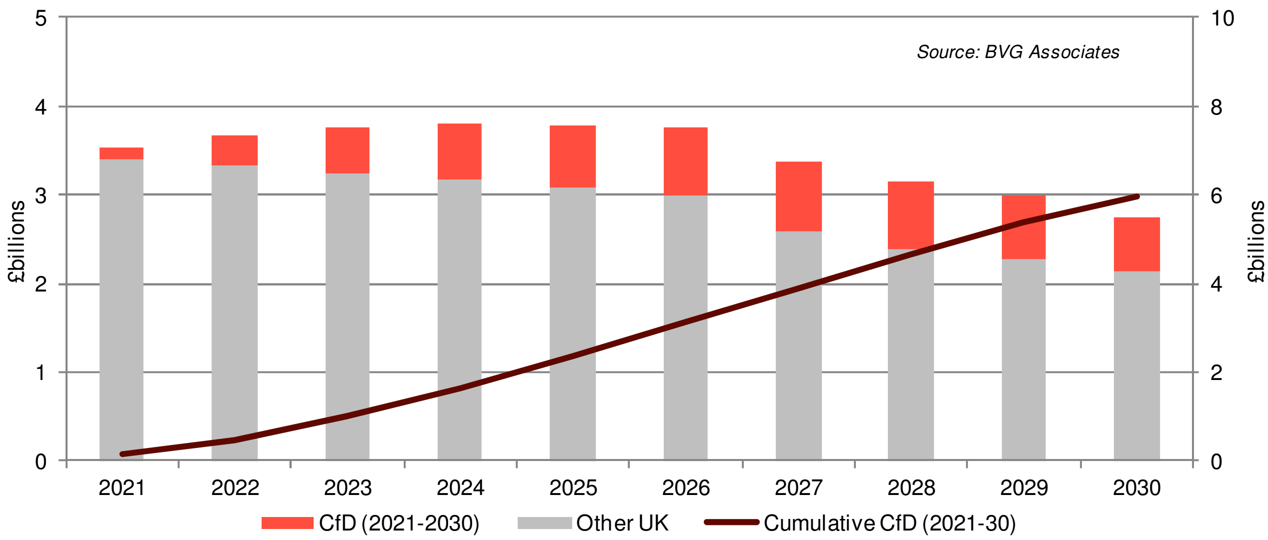


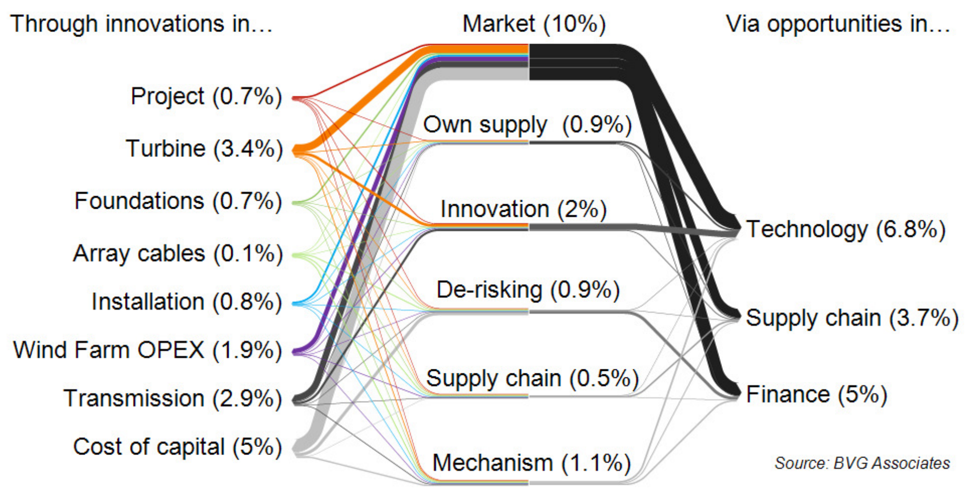


See Section 5.1.3 for details about each graph.

7. Balanced with enhanced R&D

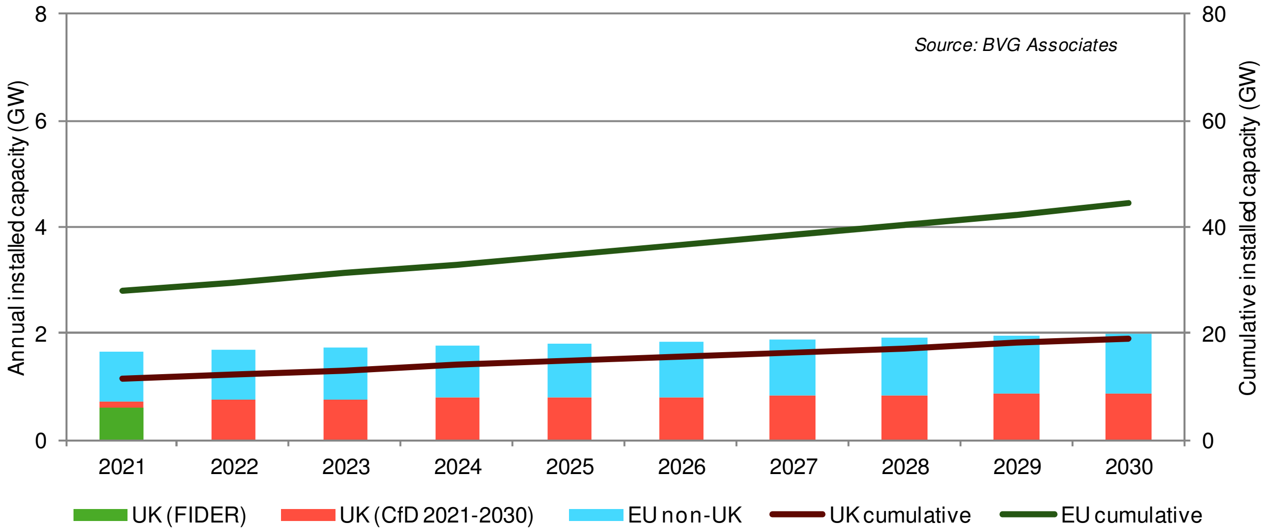


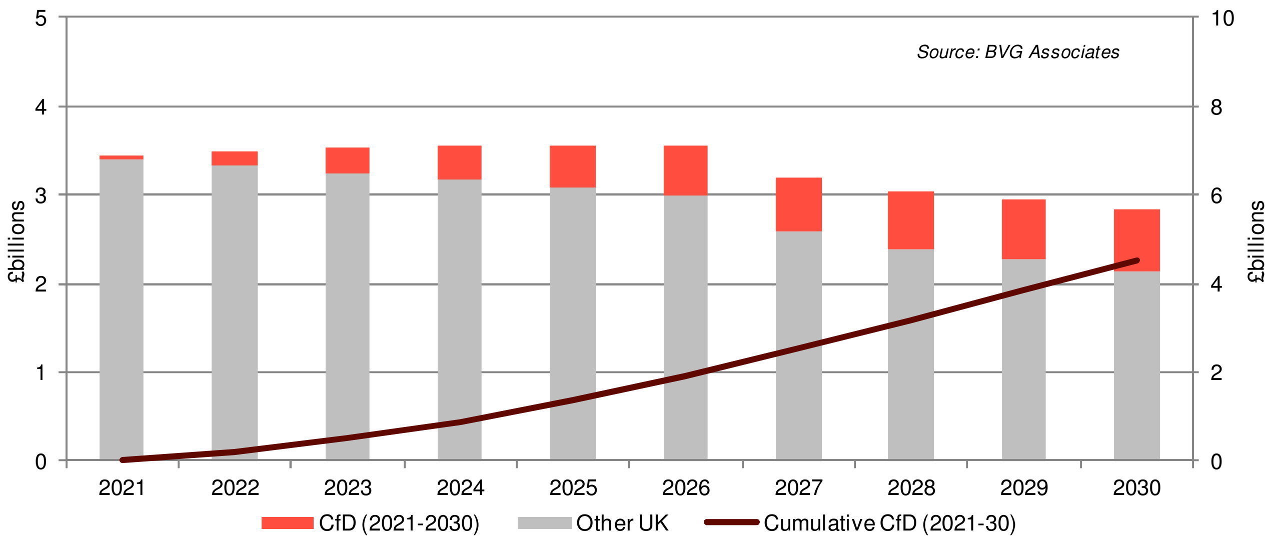


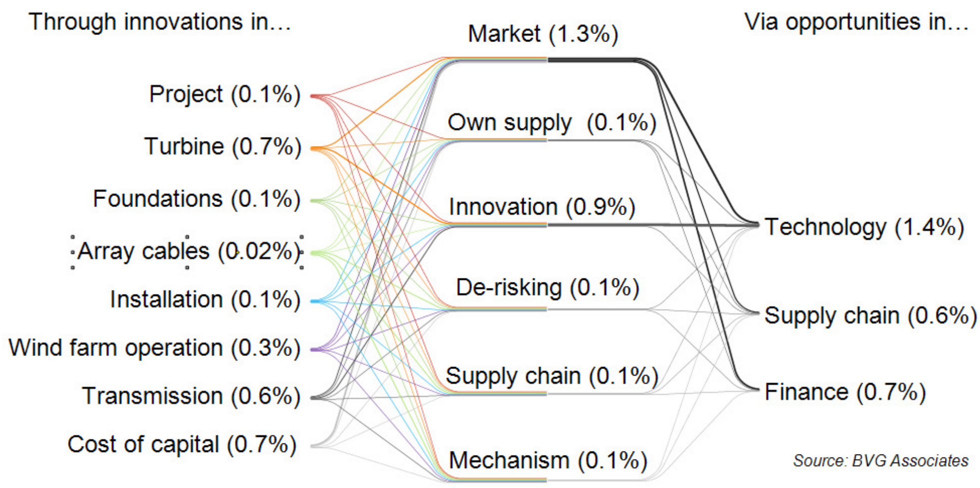


See Section 5.1.3 for details about each graph.

8. R&D only

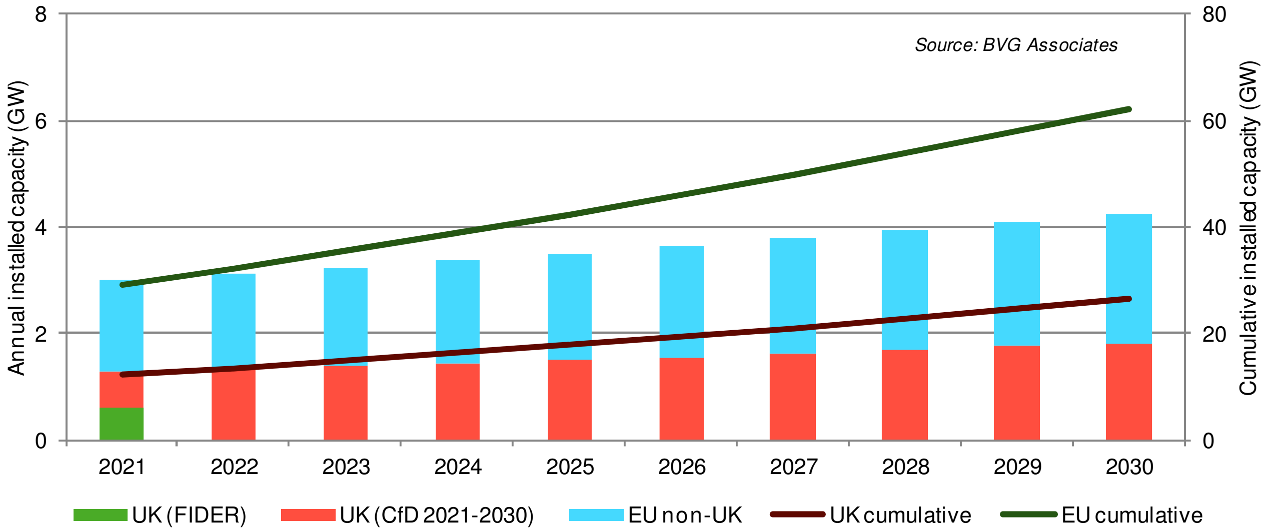


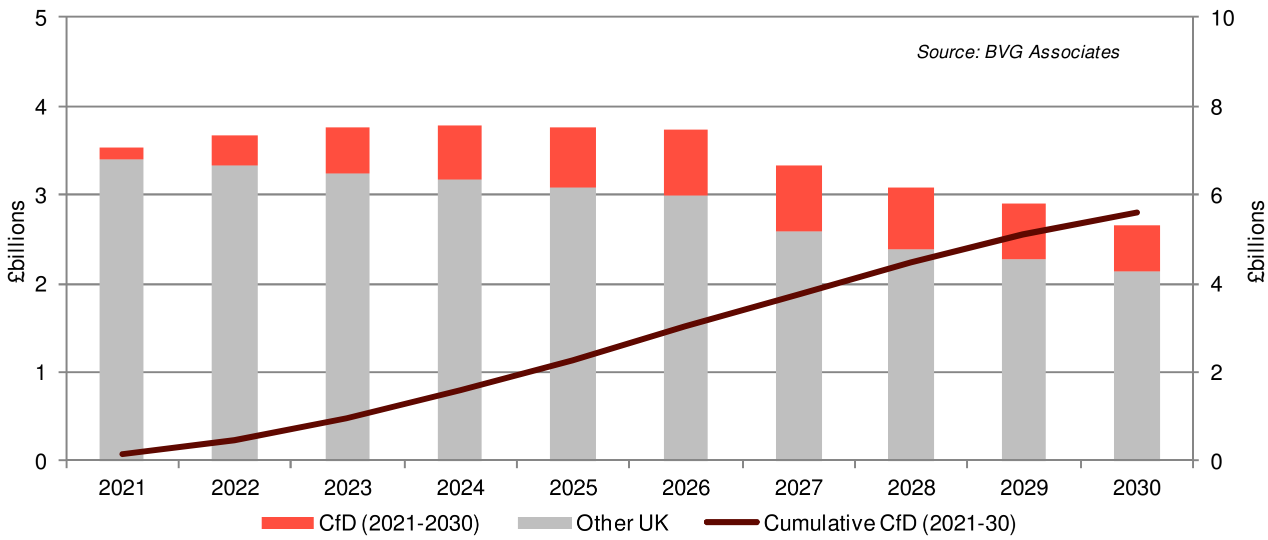


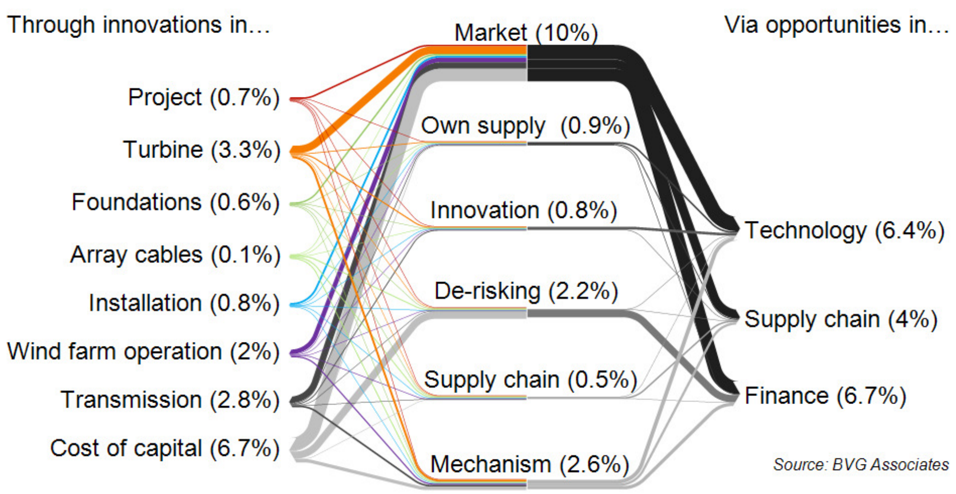


See Section 5.1.3 for details about each graph.

9. Improvements to market design

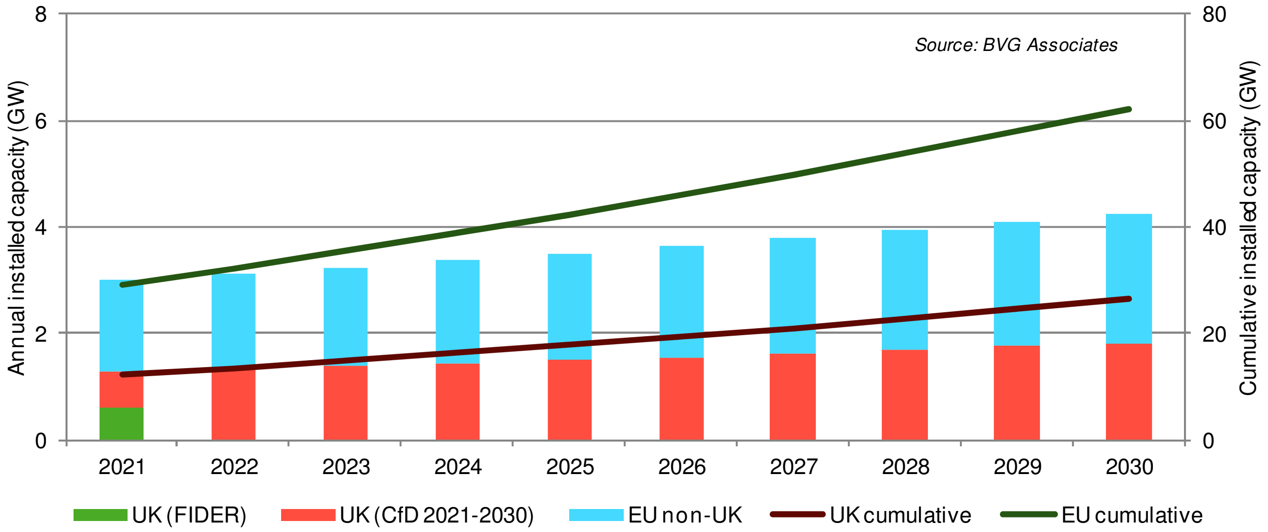


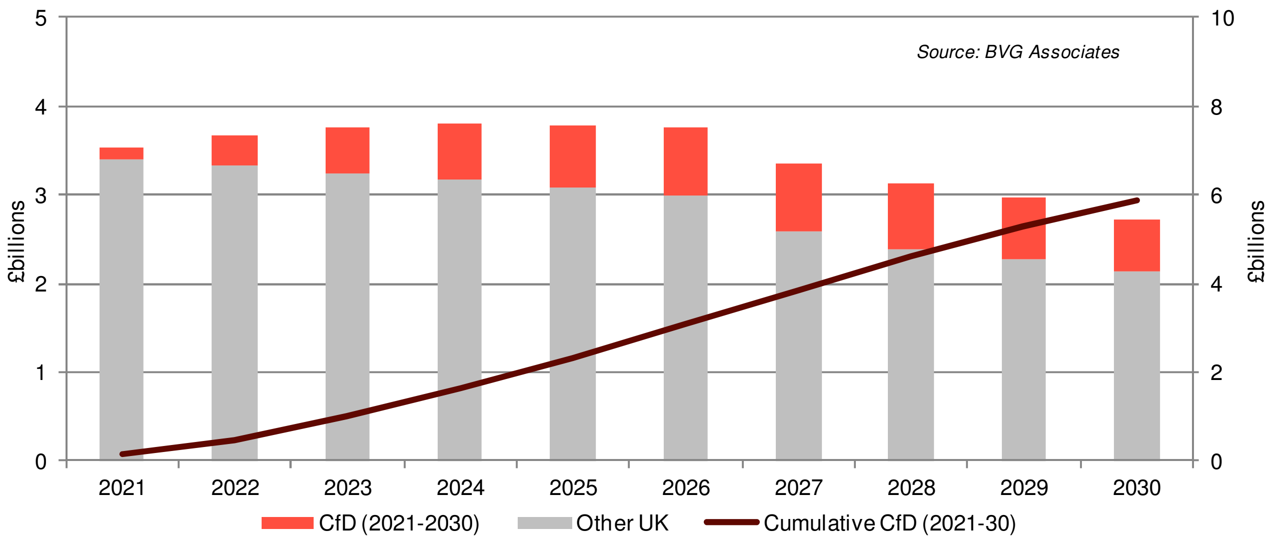


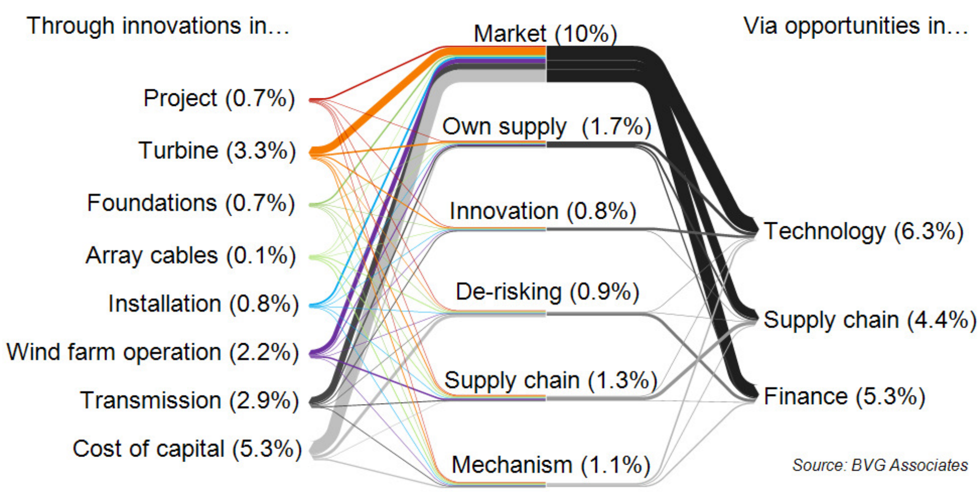


See Section 5.1.3 for details about each graph.

10. Government-led supply chain interventions







See Section 5.1.3 for details about each graph.