centre for sustainable energy

Common concerns about wind power (2nd edn)

Chapter 6
Offshore wind turbines

This is one of a series of chapters of evidence-based analysis drawing on peer-reviewed academic research and publicly funded studies.

For other chapters, see
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Centre for Sustainable Energy, June 2017

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The first edition of Common Concerns about Wind Power was published in 2011 to provide factual information about wind energy, in part to counter the many myths and misconceptions surrounding this technology.

Since 2011, much has changed in the legal and economic sphere, and a second edition became necessary. Research has been carried out for this edition since 2014. Therefore, this edition is formatted as a series of individual chapters available for download at www.cse.org.uk/concerns-wind-power-2017

All chapters written and researched by Iain Cox.

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The Centre for Sustainable Energy is a national charity committed to ending the misery of cold homes and fighting climate change.

We share our knowledge and practical experience to empower people to change the way they think and act about energy.

We are based in Bristol although most of our work has relevance and impact across the UK. Our clients and funders include national, regional and local government agencies, energy companies and charitable sources.

Chapter 6
Offshore wind turbines

Summary

The UK is currently a world leader in terms of offshore wind capacity installed, and ambitious developments that are underway will cement this leadership role for some time to come. This impressive performance is a result of strong policy signals set by government, together with a fortuitous convergence of major energy company and non-governmental organisation support. Wind resources offshore are generally superior to those onshore, being more consistent and possessing higher average speeds. The harsher conditions at sea, however, make the construction, operation and maintenance of offshore wind farms particularly challenging, especially given lack of experience with the scale of installations currently planned. These and other factors, such as the infrastructure required to connect to the power system on the mainland, means offshore wind is still expensive by comparison to other commercially viable renewables, such as onshore wind and solar. In addition, there will be impacts on the marine environment that must be accounted for through strategies of avoidance, mitigation or offsetting. Care should be taken to favour more comprehensive avoidance or mitigation strategies during planning and development, rather than relying too much on perceived environmental offsets that may occur post-construction. In their haste to expand and develop, major actors like planning authorities and energy companies must also avoid bypassing important stakeholder interests, such as the fishing industry and coastal communities. Decarbonisation of the energy sector necessitates that the UK's wind resource is effectively utilised, so it is important that similar mistakes made in the past during the onshore 'windrush' are not repeated offshore, otherwise public support may quickly wane. Offshore wind is crucial to the government's renewable energy targets, and offers a valuable opportunity for the UK to expand its capacity to produce domestic, sustainable energy long into the future.

What is this based on?

By the end of 2013, the UK had a total installed capacity for offshore wind power of 3,696 MW (3.7 gigawatts, GW), and was the global leader in offshore wind deployment. The UK's dominance in this particular form of renewable energy is likely to continue for some time, thanks to ambitious plans to install as much as 16 GW in UK waters by 2020 and as much as 39 GW by 2030.[1] Offshore wind is crucial to the government's renewable energy targets and is seen by energy companies as a sector with considerable growth potential. The wind resource in open waters is generally superior in comparison to land-based sites, with higher average wind speeds and less wind shear.* Developers and planners alike are drawn by the advantage offshore installations offer in terms of a lower visual impact, and thus the lack of attendant planning issues and public resistance that have often beset onshore wind developments in the UK.[2]

Despite these perceived advantages, offshore wind remains the most expensive commercially viable form of renewable electricity,[3] and the challenges of operating in adverse conditions at sea are considerable for an industry that has only moderate experience with installations on the scale of those planned. The UK has possessed the largest offshore wind fleet since it surpassed Denmark in 2008, at which point the UK's total offshore capacity was just 590 MW – now it is more than six times as large and is set to increase again by another four times in the period 2014–20.[1] Such a large expansion in any industry will present problems, and the demands of building and operating equipment and infrastructure relating to wind turbines in the middle of the sea are something the wind sector is still learning to do. This is important to remember, because 'learning-by-doing' in any industry is typically a balance between growth rate and the time required for experience to feed back in the learning process.[4] For instance, early UK offshore developments have seen higher than expected component failure rates and significantly lower operational availability than projected. As reliability issues are identified and corrected through evolving industry practice this will improve availability and therefore lower maintenance costs and raise revenue.[5] As the volume of offshore development rapidly increases, this will also lead to more specialised designs and materials that better meet the demands of open water operations, rather than relying on adapting preexisting onshore technology.[5]

* Less wind shear means less difference between wind speed at different heights, so a more consistent and higher wind speed is typically found at a lower height above the sea surface than above land – the result is that the rotor hub for an offshore turbine does not have to be built as high to achieve the same power ratings as found onshore.

Furthermore, the accelerated expansion of offshore wind has come at a time when the cost of all energy infrastructure projects has risen, largely due to wholesale prices rises for commodities (such as steel) and energy in response to global market forces.[6,7] A fast-expanding industry will also lead to bottlenecks in supply, as manufacturers find their order books are full and there is a delay before the capacity of the supply chain can adjust to increased demand. This is something that has particularly affected the wind power sector, both on and off shore.[7,8]

One other aspect of rapid growth is that offshore developments may outstrip our knowledge of environmental impacts. There is the potential for significant impacts on marine flora and fauna both above and below the water at the site of offshore wind farms; it should be noted that in some cases there are site-specific positive benefits, but these, like the negative impacts, are not well understood at present and may be overstated. There is frequently too little emphasis placed on assessing the cost of these impacts, with developers overly reliant on the 'offset' in terms of alternative environmental benefits that may not always be equivalent.[9] One of the wider environmental benefits is, of course, the delivery of low-carbon electricity that reduces fossil fuel consumption in the energy sector.

The open waters surrounding the UK are also not free from other vested interests, such as the fishing industry and coastal communities, not to mention environmental groups. These will present potentially thorny issues that will require a careful balancing act by planners and policymakers to ensure that the best interests of the environment are served, whether that means decarbonisation of the economy or protecting particularly sensitive habitats and seascapes.[2,10] Planners and developers must take heed and not fall into a mode of operation that overlooks the interests of existing stakeholders, or face a potential backlash from the public. Offshore wind offers the UK a way to advance the decarbonisation of its electricity sector considerably, increasing its capacity to produce domestic, sustainable energy on a long-term basis. Careful strategic planning and paying due diligence to environmental and stakeholder concerns will ensure offshore wind can play a central role in a sustainable future.

What is the current evidence?

Offshore wind will form the cornerstone of Britain's efforts to meet its emissions targets, and will help the government achieve its EU-mandated goal to generate 20% of the country's electricity with renewables by 2020.[2] In all scenarios forecast by the grid operator (National Grid plc.), offshore wind will play a significant role in the UK's energy mix by 2035, making up roughly 50 to 70% of total installed wind capacity (i.e. onshore and offshore combined). Given the leading contribution wind power will make to the UK renewable energy sector between now and 2035, offshore wind alone may account for anywhere from one-quarter to two-thirds of the UK's total renewable capacity – in a 'gone green' scenario that is driven by offshore expansion, offshore wind could be almost 40% of the UK's total generating capacity for all forms of energy.[11]
Based on offshore wind projects that are operational, under construction, consented and in planning, the expansion of the UK's capacity should ensure it remains the leading country in offshore wind deployment for some years to come.[2] However, concerns over capital costs and operation and maintenance remain, and it is no secret that offshore wind remains the most expensive form of commercially viable renewable electricity available.[3,4] This is reflected in the renewable subsidy mechanisms currently available (see chapter 3), with offshore wind receiving more than double the level of support under the Renewables Obligation[1] and a 55%–66% higher strike price under the new Contracts for Difference scheme.[12]

Recent global economic trends have seen prices for all energy infrastructure projects rise; given offshore wind is a less established industry this price increase has affected offshore capital costs in particular.[5,7] Current costs are more than £3 million per megawatt (£3m/MW) of installed capacity, compared to just £1.5m/MW in the mid-2000s. This has affected the cost of generation, which has likewise increased, going from an estimated 9.9 p/kWh to 14.9 p/kWh between 2006 and 2010.[7]
Two matters of note within this trend are that the cost of major conventional forms of generation rose far more steeply over the same period, with gas-fired and nuclear generation both doubling (to 8 and 9.7 p/kWh, respectively), and that onshore wind experienced one of the lowest price increases of all with a rise of just 33%.[6]
Onshore wind has experienced a long-term downward trend in generation costs since the mid-1990s, largely due to policies that have supported onshore wind development and deployment that bridged the gap between its cost and that of established fossil fuel technologies.[13] By contrast, the general upward trend and historical volatility of fossil fuel energy prices means that gas and coal-fired generation are unlikely to return to their low pre-2007 prices, and the increased internalising of carbon costs (e.g. through carbon taxes or mandated carbon capture storage technology) will only push prices higher.[14]

The offshore industry is currently experiencing several major supply chain constraints, since the sharp increase in demand as the UK implements its ambitious plans up to 2020 has led to a shortage of new turbines and turbine components, as well as limited port facilities and installation vessels required (many of which are also used by the offshore oil and gas industry).[5] These 'growing pains' are typical of any industry that is undergoing such rapid growth, and learning-by-doing is expected to play an important part in lessening these issues. There is a risk that supply chain constraints may persist due to competition for vessels and other specialised resources with other offshore industries and offshore wind developments elsewhere in Europe.[6] Existing UK projects have shown that offshore wind developments can be profitable for their owners, but this is very sensitive to capital costs; hence, construction delays for future projects could easily cause an offshore wind farm to become economically unviable.[15]

Even with these challenges, there are several factors that make it reasonably certain that prices for offshore wind will fall. The large-scale projects commissioned in UK waters to be built over the next decade will boost supply chain confidence and increase competition, helping improve manufacturing and operating efficiencies, economies of scale, and standardisation as the industry converges on optimal designs for turbines and foundations.[6] This industry learning and a lessening of supply chain constraints will cause capital costs to drop significantly in the first decade, and even further by 2030 (possibly by as much as 30%).[8,16] Generating costs will also decrease, perhaps dropping fast enough to reach 10 p/kWh by the year 2020.[6]

Thus, despite current high prices, offshore wind is likely to become less expensive as today's subsidies support industry expansion and the technology becomes more cost-competitive. Indeed, offshore wind is likely to be more competitive than nuclear power,† even in European countries that have greater experience with running a nuclear fleet.[17,18] Under the new Contracts for Difference, which will have completely replace the UK's existing renewable energy subsidy scheme by 2017, new offshore wind will receive support in the form of a feed-in tariff that will degress (gradually reduce year-on-year). This reflects the assumption that a maturing offshore sector will become more cost-effective thanks to the stimulus received by present-day subsidies that allows the industry to rapidly expand.[12]

Although overall costs for offshore wind will probably decrease from their current high point, the costs are unlikely to compare favourably with onshore wind for several decades at least.[5] As the UK's offshore wind resources are exploited to their full, this will entail constructing wind farms further out to sea. Much like onshore wind, the lifetime costs associated with offshore wind are skewed towards the upfront construction and the capital needed to finance this.[7,16] There are notable differences in construction needs, however, since conditions are far more challenging when constructing out at sea (e.g. the requirement for specialised vessels, as mentioned above) and physical requirements to support the turbines mean larger foundations and more connector cables to feed electricity back to the shore. These factors can raise construction and connection costs significantly.[8,16] As may be expected for a relatively young industry, operation and maintenance costs for the UK's existing offshore wind farms have also been higher than expected due to equipment failure, one of the main reasons why capacity factors for these installations have been lower than the European average (see chapter 4). Component failure can be a serious problem for an offshore turbine operator, because the difficulty in effecting repairs out at sea can result in lengthy downtimes for the turbine in question and therefore lost revenue. There is a great deal of research in progress to improve remote condition monitoring of offshore turbines, which will result in significantly improved availability thanks to better maintenance scheduling to head off serious faults before they occur.[19]

As of 2013, most of the UK's existing complement of offshore wind farms can be found clustered along the east coast of England between Kent and Lincolnshire, in the Irish Sea, and a few sites situated off the Scottish coastline.[20] The distance from shore is typically from 5 to 17 km (about 3–10 miles), but there are some that are closer in and others more than 20 km (12.4 miles) out. One compelling argument for siting wind farms offshore is that they will be subject to fewer objections from the public, which has been identified as a major impediment to the expansion of the UK's onshore wind capacity during the 1990s and 2000s.[2,21] But this is very much a misconception, as evidenced by conflicts between planners and public during some of the UK's own offshore developments.[22] Studies conducted in various countries in Europe and the Americas have demonstrated that coastal residents often perceive offshore wind farms as a negative development, largely based on the visual impact.[23]

Residents and frequent users of coastal areas are typically more sensitive to the visual impact of an offshore development, especially if it is perceived to jeopardise the recreational potential of the area; respondents usually express the view that installations should be sited further out to sea.[24] This is by no means an isolated case for wind power, although it is the most familiar offshore technology. Neither is visual impact the sole reason for local resistance, although it does tend to be the dominant issue. Public concerns have been raised against various forms of offshore renewable energy development (e.g. wave power and tidal barrages) and common reasons that are raised include noise disturbance, ecological impacts, threats to tourism, employment opportunities, community harmony and general anti-developer sentiment.[25]

† For a discussion of the escalating costs of nuclear power and the reasons behind this trend, see Chapter 7.

There are also some 'marine specific' issues that are a cause for concern, in particular the view that the open sea is an unspoilt place where man-made structures do not belong; this objection to human-engineered structures contrasting with a primarily natural setting lies at the heart of many opposition movements to renewable energy developments, especially wind turbines (see chapter 9, 'Wind turbines and property prices').[25] These conflicts can often reveal complex and even contradictory views. For instance, many coastal communities have strong links to the fishing industry, an endeavor that in modern times frequently comes under scrutiny for overexploiting the marine environment. The ecological benefits that no-fishing zones (or 'no take' zones) around offshore wind farms has been identified as one issue that may bring the wants of local economic groups (i.e. fishing communities) into conflict with environmental groups.[2] A long-contested offshore development in the USA revealed ambivalence on the part of anti-wind residents towards long-standing industrial structures, even in cases where these have a demonstrable effect on people's health and environment.[26] An in-depth analysis of survey data from across many different countries relating attitudes to existing offshore wind farms suggests that respondents with more experience visiting or viewing turbines were more positive about them, in contrast to those who lived further away from wind farms and had limited experience. Interestingly, the same study demonstrated that offshore wind farms with a greater number of turbines evoked more positive support than those with fewer turbines, and this was independent of the size and height of the turbines themselves, i.e. independent of visual impact.[27] It is clear that residents are quite capable of analysing the benefits and costs of a wind farm installation, and will arrive at a more nuanced view than simply acceptance or rejection.

Whilst it is clear that developers and planners cannot assume moving wind farms offshore will circumvent public opposition, there is some evidence that installations further from shore are perceived as having less of an impact.[24] Even without this pressure, the continued expansion of the UK's offshore industry means that larger and more ambitious wind farms are to be built in the coming decades. In many cases, these will be a considerable distance out to sea, for example, a planned development at Dogger Bank in the North Sea will be 200 km (124 miles) from shore with water depths of up to 63 m (over 200 feet).[8] The impact offshore developments like this will have on marine ecology are not completely understood. It is possible, however, to anticipate effects turbines might have by learning from observations made for other human-made structures, like oil platforms and shipwrecks.[28] For instance, the large foundations required by offshore wind turbines can create new habitats in remote seabeds by providing a substrate for marine organisms such as anemones, barnacles and worm species (collectively known as benthic species). This colonisation can attract other marine species further up the food chain, including crabs and lobsters and fish that thrive on prey found in sea floor sediments, as well as other fish that in turn prey on those.[28,29] Large wind farms will have no-fishing zones (also termed 'no-take' zones) enforced due to the hazards presented by the turbines structures themselves to fishing trawlers and their nets. Although no-take zones can be viewed in a negative light with respect to commercial fishing and the communities that it supports, from an environmental perspective no-take areas can provide havens for fish species and other organisms, and may even serve to extend protected regions in cases where turbines are situated on the edge of an existing conservation area.[2,30]

It is important to remember, however, that ecological changes wrought by offshore installations are certainly not uniformly positive. The construction phase is notably detrimental, driving away many native species of fish, mammals and birds due to increased seagoing traffic on the surface (vessels associated with construction), sea floor dredging to prepare the site, and, especially so, the noise produced during pile driving and related activities as the foundations are put in place.[9] These are arguably short-lived disruptions since they only last during construction, but it is of more concern when one considers that it may be a decade or more before numbers of certain species return to their original levels.[9,31] Changes to the seabed may preclude certain species from recolonising at all, because the concrete foundations do not offer the same complex nooks and crannies that are favoured by some benthic species.[9,29] It is true that offshore installations do appear to attract increased numbers of some species at the top of the food chain, for example, grey seals in the North Sea have been observed to track between turbines at operating offshore wind farms. Whilst this may be viewed as a positive sign, it is still not clear whether such phenomena will be beneficial to ecological communities, since pressure on prey species may be greater if predators can more easily locate them where they are concentrated around wind farms.[32]

This highlights the uncertain nature of long-term impacts on marine ecology, and this is something that the wind industry must ensure remains at the heart of planning and development when considering offshore installations. Despite the dramatic increase in knowledge that has accompanied scientific surveys associated with offshore wind developments over the last decade,[33] it is clear that many measures touted by developers as 'biodiversity offsets' are neither calculated benefits (i.e. they are consequences of the development, but were not designed in advance by developers with conservation in mind) nor are they equivalent in terms of the ecological benefits that may be provided.[9] Thanks to the vast amount of data accumulated from the offshore oil industry over the decades, the need for an environmental impact assessment (EIA) is well understood, but many EIAs have been noted to make much of potential positive benefits at the same time as underplaying negative impacts.[9] There is certainly a great deal of momentum behind the UK's offshore wind industry at present, and the underlying reasons with respect to the wider issues of climate change are compelling, but care should be taken not to give so much weight to these initiatives that important biodiversity conservation goals suffer as a result.[2,9] Striking this balance is no trivial matter – for example, decarbonisation of the energy sector can help reduce the acidification of oceans that is happening due to CO_2 emissions, hence overall biodiversity is improved at the same time as local marine species are reduced. The environmental problem is complex, but it is certainly possible to apply sophisticated methods that best model offshore wind farm developments to maximise the exploitation of clean energy whilst maintaining, possibly even benefiting, marine conservation.[30,33,34]

Conclusions

The UK's offshore wind industry is poised to enter what is likely to be a defining age. Although offshore wind has experienced rising prices since the mid-2000s, this is largely due to wider macroeconomic trends that have similarly affected all forms of energy, and there are good reasons to project falling costs over the coming decades as the industry matures and expands. This optimism should be tempered with the realisation that offshore wind will not be as cheap as onshore wind for several decades, but the sheer scale of the wind resource in British territorial waters means that offshore wind power is quite capable of making one of the largest contributions in terms of decarbonising the UK's energy sector up to 2030 and beyond.

Whilst offshore developments are not immune from similar public opposition movements that have been experienced with onshore wind, there is greater scope for locating large installations far enough out to sea that visual disamenities can be reduced or avoided altogether. The danger with pursuing this policy is that other stakeholder interests may be overlooked or dismissed, such as concerns over the environmental impact of wind farm construction on marine ecology, and commercial interests relating to fishing zones and shipping lanes that may adversely affect certain communities which rely on them.

The planning process for offshore developments in UK waters is somewhat unique, in that the Crown Estates exercises ultimate control over the sea floor and decides where offshore developments are permitted. The Crown Estates is following a pragmatic policy that weighs the merits of any development on a case-by-case basis, which confers a flexibility on the UK's wind industry that is likely to foster its expansion and maintain the nation's status as the global leader in offshore wind. However, planned and future developments are likely to require a delicate balancing act between the conflicting demands of wider environmental goals (reducing national carbon emissions) and the localised concerns that may arise should a specific development negatively affect marine ecosystems and those communities which rely on them. There are certainly benefits that can accrue from exploiting offshore wind, in terms of both climate change mitigation and local biodiversity conservation efforts. Despite this, developers too often overstate biodiversity benefits in relation to the negative ecological effects, and it is up to the wind industry and policymakers to be clear with the public about the trade-offs that are necessary to pursue climate change and marine conservation aims at the same time. It is important that the government, through the Crown Estate, continues to act as a responsible landlord.

The current UK offshore wind programme has been described as enjoying 'a heady confluence of positive pressures in its favour'.[2] These auspicious circumstances will almost certainly translate to sustained and rapid growth for the UK's offshore wind industry. At the same time, it is hoped that the steady accumulation of scientific knowledge relating to the environmental impact on marine ecology will continue to inform the industry. Further to this, stakeholder engagement is crucial to ensure that the UK's offshore programme continues to enjoy the legitimate support of enviromental organisations and the general public. With these provisos in mind, offshore wind has the potential to deliver a significant portion of the UK's electricity demand in a low-carbon and sustainable manner.

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