Understanding the Impacts of Offshore Wind Farms on Well-Being

Caroline Hattam, Tara Hooper and Eleni Papathanasopoulou (PML)

Marine Research Report

Understanding the Impacts of Offshore Wind Farms on Well-Being

Caroline Hattam, Tara Hooper and Eleni Papathanasopoulou

Plymouth Marine Laboratory (PML)

ISBN: 978-1-906410-65-0

Published by The Crown Estate

The basis of this report was work undertaken by Caroline Hattam, Tara Hooper and Eleni Papathanasopoulou of the Plymouth Marine Laboratory, Plymouth, UK, on behalf of The Crown Estate.

Disclaimer

The opinions expressed in this report are entirely those of the authors and do not necessarily reflect the view of The Crown Estate. The Crown Estate is not liable for the accuracy of the information provided or responsible for any use of the content.

Dissemination Statement

Suggested Citation

Hattam, C., Hooper, T. and Papathanasopoulou, E. 2015. 'Understanding the Impacts of Offshore Wind Farms on Well-Being', The Crown Estate, 77 pages, ISBN: 978-1-906410-65-0

This report is available on The Crown Estate website at www.thecrownestate.co.uk

Contents List

Executive Summary

This review aims to explore the positive and negative impacts arising from the UK offshore wind industry in terms of well-being. The emphasis is placed on objective measures of well-being relating to material living conditions, such as personal income and jobs, and issues relating to quality of life, such as health (OECD 2011).

Drawing on both peer reviewed and grey literature, actual impacts of the offshore wind industry are reported, although anticipated future impacts are noted where relevant. As there is no established baseline against which change can be measured, in most cases only a qualitative assessment of the direction of change is possible; where quantitative information is available this is also reported.

The framework developed for use in this review combines the five capitals model (Forum for the Future, 1990) and an ecosystem service approach (Millennium Ecosystem Assessment, 2003) with the Office for National Statistics well-being domains. The five capitals included are: financial, manufactured, human, social and natural capital. Governance is added as a structure in which decisions about the five capitals are made, but it is also an important driver of well-being. Natural capital is subdivided into provisioning, regulating and supporting, and cultural ecosystem services. The well-being domains included are: economy, what we do, where we live, personal well-being, education and skills, personal finance, health, our relationships, the natural environment and governance. How these capital stocks affect well-being is unclear but it is assumed that each of the well-being domains is impacted by changes in capital and that the relationship is positive, i.e. an increase (decrease) in capital will increase (decrease) well-being. The key findings from this assessment are summarised in the table below.

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
Financial capital (e.g. investments)	The economy	**Positive impact** • Investments in the region of £4bn to date in innovation support, supply chain programmes and financing but could be higher if all on-going investments and unpublished investments were included. • £2bn paid in price support and subsidies per year. • Regional investments in areas which have been identified as Assisted Areas • Stability in market providing an environment for further investment and long-term operation
Manufactured capital (e.g. infrastructure)	The economy	**Positive impact, although currently limited** • Many turbine components are imported but supply chain support is seeing investment in turbine component manufacture. • Investment is being made in port facilities to support the offshore wind industry, but in line with port investments made by other

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
		industries. • Development of the electricity transmission network will support future energy security.
	What we do	**Positive impact** • Investments in turbine manufacturing and port facilities are bringing new jobs to areas where these investments are made.
	Where we live	**Impact unclear** • The construction onshore of infrastructure relating to the offshore wind industry has implications for the communities where construction occurs. Whether this is positive or negative is not reported. • Associated community projects can be assumed to have a positive impact on where we live.
Human capital (e.g. skills and education)	What we do	**Positive impact** • 3,151 direct jobs created in the manufacture, construction, operation and maintenance of offshore wind turbines. • An estimated 7,000 indirect jobs created along the offshore wind supply chain. • Induced employment effects reported. • Considerable investment in knowledge generation through R&D.
	Education and skills	**Positive impact** • Jobs created in the offshore wind industry are reported to be high skilled. These skills are in demand outside the UK, allowing the export of skills and knowledge transfer. • A number of dedicated training courses have been developed to meet the rising demand to appropriate skills.
	Personal finance	**Positive impact** • Wage levels for jobs associated with the offshore wind industry range by skill with scope for career development.
	Health	**Impact unclear** • There are concerns over the safety of offshore workers but protocols for offshore working are well established in the oil and gas industry and can be adopted. • There are potential health gains resulting from the mitigation of CO_2 emissions and future climate change. • Mental health impacts related to offshore wind are uncertain but could be influenced by falling house prices, transient work force and buying energy from green sources.
Social capital (e.g. social networks)	Personal well-being	**Mixed impacts** • Generally strong support for offshore wind farms (OWFs) motivated by beliefs about environmental impact, job creation and local economic growth. • Opposition exists, motivated by concerns over profitability, decreases in property values and impacts on wildlife.
	Where we live	**Mixed impacts** • Community funds can have positive impacts, but some view such funds as bribes.

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
	What we do	**Impact unclear** • Evidence is anecdotal and suggests tourism continues to exist alongside the offshore wind industry with some new recreation opportunities (e.g. boat trips to OWFs). • Effects on the view and the restorative nature of environment could affect engagement with the coastal environments and ultimately health.
	Our relationships	**Positive impact** • Industry groups and networks developed to support supply chain and national and regional capabilities. • Formation of opposition and supporter groups builds relationships and social capital within communities.
Natural capital (e.g. natural resources)	The natural environment: provisioning ecosystem services	**Impacts unclear** • Data are limited but evidence suggests some commercial species negatively affected by EMF and noise. • Artificial reef effects may have a positive effect on commercial species.
	Supporting and regulating ecosystem services	**Mixed impacts** • Benthic communities appear to be resilient to impacts during the construction phase. • Turbine communities and associated fish assemblages are different to those in surrounding area. • Concerns over role of OWF in the spread of invasive species.
	Cultural ecosystem services	**Impacts unclear, but mixed effects emerging** • Research on impacts of marine mammals is inconclusive as population level effects have been little studied. • Birds demonstrate avoidance behaviour and collision risk is low. • Impacts on bird populations around OWF vary with some showing increases and others decreases.
Governance (e.g. participatory decision making)	Governance	**Mixed impacts** • Government policy is reducing planning and financial uncertainty, but policy is still creating uncertainty leading to a slow-down in investment by industry. • Opposition to offshore wind farms stems from distrust in government/local authorities and concern about erosion of the democratic process. • Community funds have been viewed as bribes. • The fishing industry is unhappy with the consultation processes and relationships can be strained with both developers and regulators.
	Where we live	**Mixed impacts** • Community funds can have a positive impact on local communities, but extent to which they compensate for visual impacts is unknown.

The paucity of data relevant to well-being limits the extent to which these impacts can be assessed. Further analysis of existing data could provide additional insights. Attention also needs to be given to individual well-being effects, evidence for which is largely absent. In addition, the well-being trade-offs individuals are willing to make to ensure a clean, secure supply of energy in the future is largely unexplored.

When considered primarily at the regional/national level, the well-being impacts emerging from this review are mixed for social and natural capital, and for governance, with both positive and negative impacts emerging. Although not unequivocal (especially in the context of health), the impacts on financial, manufactured and human capital are primarily positive. On balance, however, this review indicates that the offshore wind industry has a largely positive impact on well-being.

1. Introduction

There is a clear link between energy consumption and human well-being (Pasternak 2000), and this improves with the reliability of supply (Castro-Sitiriche and Ndoye 2013). Following concerns over climate change, goals to decarbonise the UK economy, and national and international targets for renewable energy generation, the production of electricity in the UK is changing. The development of the offshore wind industry is part of this change. It is anticipated that offshore wind energy will make an important contribution to the decarbonisation agenda and the UK's renewable energy targets (DECC 2013). It is little understood, however, how the offshore wind energy sector influences human well-being.

1.1 Well-being and the five-capitals approach

Well-being is a complex, multi-dimensional concept for which no unified definition has been agreed (Dodge et al. 2012; La Placa et al. 2013). It is assumed to be comprised of both objective and subjective domains distinguishing between material living conditions and quality of life (OECD 2011). It is considered a superior measure to indices such as Gross Domestic Product (GDP) because GDP does not capture the full cost of economic activity (Stiglitz et al. 2009). Many governments, international and supranational bodies are now committed to measuring well-being more broadly (e.g. OCED 2011; Commission of the European Communities 2009). At a national level, the UK Government aims to measure well-being to ensure its policies can be tailored towards 'things that matter'. Through the UK's Office for National Statistics (ONS), the Measuring National Well-being Programme (Randall et al. 2014) has focused on measuring well-being through the domains of health, relationships, job satisfaction, economic security, education, environmental conditions and measures of subjective well-being (see Figure 1.1).

Each of these well-being domains is affected by changes in stocks of capital (IISD 2008; Forum for the Future 1990) which include:

- **Financial capital**: derived from revenues generated through sales and is determined by production rates, market prices and costs of production (Moran et al. 2013).
- **Manufactured or engineered capital**: comprising goods or assets that contribute to the production process or the provision of services, rather than being part of the output itself. It includes for example tools, machinery, buildings and infrastructure (Moran et al. 2013).
- **Human capital**: constitutes health, knowledge, skills and capabilities of individuals, the workforce and related communities (Schultz 1961).
- **Social capital**: refers to networks together with shared norms, values and understandings that facilitate cooperation within or among groups (Cote and Healy 2001).

- **Natural capital** (also called environmental or ecological capital): encompasses natural resources as well as the processes needed to sustain life and produce goods and services (Forum for the Future 1990).

Links between these five capitals and wellbeing have been captured in the works of Costanza (2003) and interpreted by Walker et al. (2007). They are adapted here to consider the well-being indicators monitored by the ONS (Figure 1.1). It is often unclear how capital stocks actually impact well-being and whether positive changes in the five capitals result in positive impacts on well-being. It can generally be assumed, however, that there is a positive relationship between changes in capital stock and well-being and that increases (decreases) in capital stocks will increase (decrease) well-being. In the context of offshore wind farms in Germany, Busch et al. (2011) make this positive relationship assumption noting that offshore wind-farms could lead to increases in employment, which could in turn lead to an increase in the demand for housing, education and public transport.

Based on this assertion the ability to capture change in the five capitals as a consequence of the offshore wind industry provides a first step towards understanding the impacts of the industry on well-being. The five capitals approach also encourages balanced assessments of the sustainability of interventions (Forum for the Future 1990). Each of these capital stocks is interrelated and sustainable development depends upon maintaining, and in some cases enhancing, the stocks of these five capitals, rather than depleting them. In terms of the more familiar ‘three pillars of sustainability’, financial and manufactured capital can be combined as the economic pillar, human and social capital form the social pillar while natural capital equates to the environment pillar.

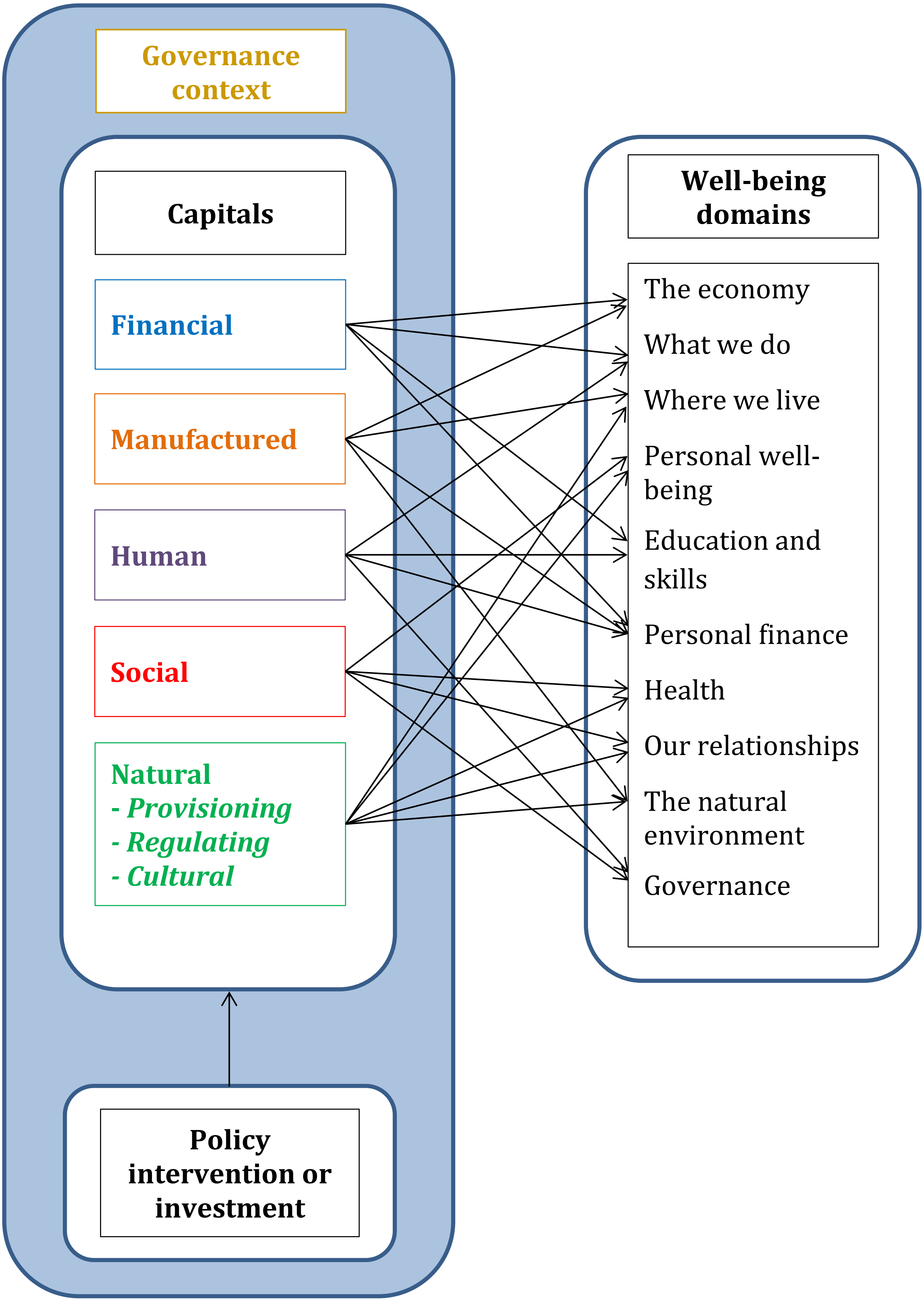

Figure 1.1: Well-being and the five capitals approach (arrows are only illustrative and are not comprehensive). The domains listed under well-being correspond to the domains used by the ONS as indicators of well-being.

The relationship between natural capital and well-being can be further explored through an ecosystem service approach. Ecosystem services are the direct and indirect contribution of ecosystems to human well-being (TEEB 2010) and the approach aims to identify explicitly the links between environmental change and human well-being (Millennium Ecosystem Assessment 2003). According to the Millennium Ecosystem Assessment (2003), ecosystem services can be divided into four functional groups:

- **Provisioning services**: the products obtained from ecosystems, including food, fibre, fuel, genetic resources, medicines and pharmaceuticals, ornamental resources, and freshwater.
- **Regulating services**: the benefits obtained from the regulation of ecosystem processes including air quality, climate regulation, water regulation, erosion control, water purification and waste treatment, regulation of human diseases, biological control, pollination, and storm protection.
- **Cultural services**: the nonmaterial benefits people obtain from ecosystems including cultural diversity, spiritual and religious values, knowledge systems, education values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, and recreation and ecotourism
- **Supporting services**: the services that are necessary for the production of all other ecosystem services, including primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and the provision of habitat.

All five capital types (including ecosystem services) sit within a governance framework, which relates to the way in which decisions are made by the actors involved in the use of the different capitals. Indicators of governance are also used as indicators of well-being. This suggests that governance is both a driver as well as an indicator of well-being. This situation is not unique to governance, but is the case for many well-being indicators (e.g. education and income). It highlights a further difficulty in undertaking well-being assessments.

Using offshore wind as a case study, these well-being domains are assessed through their association with the five capital types and changes due to future offshore wind development. The outputs can be used to ensure more informed policies and improved policy appraisal (Dolan and Metcalfe 2012).

1.2 Offshore wind energy generation in the UK

The UK is the global leader in offshore wind energy generation (Higgins and Foley 2014). By the end of 2014, the UK had 24 offshore wind farms containing 1,301 turbines and with an installed capacity of 4.5 GW (55.9% of existing European offshore wind energy generation capacity) (EWEA 2015). It is expected to achieve over 10 GW by 2020 (UKTI 2014). Putting this in context, 5GW will power all the homes in Scotland (Ochieng et al. 2014).

Offshore wind energy generation has a history dating back to the 1930s. The first offshore wind turbines, however, were only installed in Europe in the 1990s (Bilgili et al. 2011). Since then there has been considerable growth, initially led by Denmark, but latterly by the UK. 90% of the world's offshore wind energy generating capacity can now be found in the North Sea, with much of the rest coming from two demonstration sites in China (GWEC 2012). Other countries, such as the US, Japan, South Korea and India are now showing interest.

Growth in the UK offshore wind energy sector is in response to three key drivers: climate change, energy security and affordability (Gibson and Howsam 2010). The need to replace existing electricity generating infrastructure (both fossil fuel and nuclear) within the next 50 years is an additional pressure. The availability of open space with good wind speeds for large-scale energy generation makes offshore wind energy generation of particular interest (Markard and Petersen 2009).

CO_2 emissions reductions targets are particularly pressing and have been set by the European Union and subsequently adopted at the national level. The Europe 2020 growth strategy (launched in 2010) committed the EU to a reduction in emissions levels to 20% below 1990 levels, however, the climate and energy policy framework for 2030 proposes a reduction to 40% below 1990 levels. In the UK, the Climate Change Act 2008 commits the UK to more significant reductions (80% on 1990 levels by 2050).

Together with other initiatives aimed at reducing emissions, legislation has been adopted committing the EU to increase the share of renewable energy consumption to 20% by 2020 (Renewable Energy Directive (2009/28/EC)). The target for the UK has been set at 15% and offshore wind energy is considered the main resource for reaching this target (DECC 2013). In support of this target, the UK Energy Act 2013 established targets for the decarbonisation of the UK and paved the way for reform of the electricity market. The 2011 UK Renewable Energy Roadmap sets out how the 15% renewable energy target will be achieved.

Within the UK, developments in offshore wind have occurred in three rounds, defined by The Crown Estate (Higgins and Foley 2014). Round One began in 2000 with the Blyth offshore wind farm, and saw 13 projects installed and fully operational by 2012. These projects typically had no more than 30 turbines, but combined had a generating capacity of 1.2GW. Round Two began in 2003, with the first offshore wind farm, Walney Phase 1, becoming operational in 2013. Round Two comprises 16 projects which, once complete, will have an operational capacity of 6GW. These projects are larger in scale and generally further offshore than Round One projects. Since 2010, four Round One and Two projects have been granted developmental rights to extend their geographical areas. Round Three is currently in progress and follows the identification of 33GW potential offshore wind capacity by the UK Offshore Energy Strategic Environmental Assessment (DECC 2009). Nine zones of different sizes were identified within UK waters and renewable energy developers were invited to bid for rights to develop offshore wind farms within those zones. Eight of these zones are currently under active development (The Crown Estate 2015).

Despite advancements in offshore wind energy generation, the industry is still considered to be in its infancy (Higgins and Foley 2014). If further development is to be supported, a thorough review of the known impacts of the industry is timely, together with an assessment of how those impacts affect the well-being of individuals, communities and the UK as a whole. Some of the impacts of offshore wind energy generation are widely recognised, for example, its contribution to CO_2 emission reduction, positive impact on jobs, potentially negative impacts on seabirds, and current higher cost of energy per unit. Others, such as impacts on local communities, on infrastructure and financial performance are less well understood. All of these impacts have implications for well-being and it is these implications that are the focus of this review.

1.3 Aims and scope of this review

This review aims to explore the positive and negative impacts arising from the UK offshore wind industry in terms of well-being. Despite the vast body of literature examining and documenting the determinants of well-being (see e.g. Stiglitz et al. 2009; Dolan et al. 2008; Cote and Healy 2001), identifying the reasons behind changes in well-being remains challenging. All well-being indicators are closely linked and change in one may lead to changes in another. For example, employment, education and economic status are known to have a relationship with health (Smith 1999; Ross and Wu 1995; Bartley 1994) and there is a consistently strong relationship between health (both physical and psychological) and subjective well-being (Dolan et al. 2008). The direction of causation and why the relationships occur are hotly debated (Dolan et al. 2008; Smith 1999) and it is beyond the scope of this study to identify causal links.

As specific impacts of the offshore wind industry on well-being are not well documented, this review focuses primarily on the impacts on the five capitals, which are assumed to have a positive relationship with well-being (Costanza 2003; Walker and Pearson 2007). The five capitals framework acts as a structure to help identify and support the assessment of well-being impacts resulting from offshore wind energy industry.

Drawing on both peer reviewed and grey literature, the emphasis is on actual impacts of the offshore wind industry, although anticipated future impacts are noted where relevant. The body of evidence for impacts on natural capital is more extensive than for other areas, and so a more formal, systematic approach was taken to extracting and recording the information identified. The focus is on UK wide and regional benefits, however, where insufficient evidence exists in-depth case studies are provided. As there is no established baseline against which change can be measured, in most cases only a qualitative assessment of the direction of change is possible; where possible, quantitative accounts are given.

Each capital is now considered in turn and increases and decreases as a result of offshore wind farm development are recorded and tentatively linked to specific well-being domains.

2. Financial capital impacts

Financial capital provides an indication of the productive ability, viability and stability of a company, sector or economy (Forum for the Future 2007). It can be estimated using the value, for example, of shares, bonds and profits to signal the ability of a sector to be self-supporting and sustainable. Estimating the wider value of financial capital to include the economic and societal benefits associated with its use can provide further insight into the contribution industries and sectors make to individual and societal well-being. The benefits of sound financial capital can be assumed to directly impact the economy domain of well-being with anticipated indirect links to personal well-being and personal finance domains.

Financial capital → **Well-being domains potentially impacted:** economy

The cost of offshore wind farms depends on a number of elements including the location of the windfarm, the number and type of turbines. Private investments by energy companies in offshore wind energy construction and production in the UK have ranged between £4.6 million for the pilot project of 2 turbines at Blyth, to £725 million for the 54 turbine Lynn and Inner Dowsing Wind Farm, to £1.8 billion for the 175 turbine London Array. A recent report estimated that the contribution of offshore wind to the UK economy in 2013 was circa £1 billion (ORE Catapult 2014). However, private investment is not the only investment in offshore wind. Over the last 15 years, the UK government has supported the development of this fledgling technology using public funds (UKTI 2014) to create a secure and appealing investment environment for companies. This has been achieved by setting up programmes to ensure competitiveness in UK supply-chains, support innovation to reduce costs of construction and operation, and financing to ensure companies can access finance at a reasonable cost (HM Government 2013).

Investment in offshore wind between 2010 and 2013 (in 2012 prices) has been estimated at £6.9 billion based on DECC's Energy Market Reform scenarios (REA 2014). Compared to estimated investments in onshore wind (£7.6 billion), biomass and bioenergy (£6.3 billion), tidal and wave (£0.1 billion), solar (£6.4 billion), hydro (£0.2 billion), and other renewables (£1.4 billion) it is at the top end of the range (REA 2014). In comparison with other energy investments over the years (see Figure 2.1) electricity production has been increasing since 2004. Of the total investment (£23 billion) in the energy industry between 2004 and 2013, "53% was in oil and gas extraction, 39% in electricity, 7% in gas with the remaining 2% in coal extraction and coke, refined petroleum products." (DECC 2014a:5).

It has also been estimated that operating offshore wind contributed approximately £1 billion to the UK economy in 2013 representing 0.2% of GDP (ORE Catapult 2014). The whole of the UK energy system contributed 3.3% to the UK economy in 2013 with oil and gas extraction contributing 1.4%, electricity 0.9% (of which the 0.2% of offshore wind is included), gas 0.5%, coal extraction 0.26%, refining 0.18% and nuclear processing 0.08%.

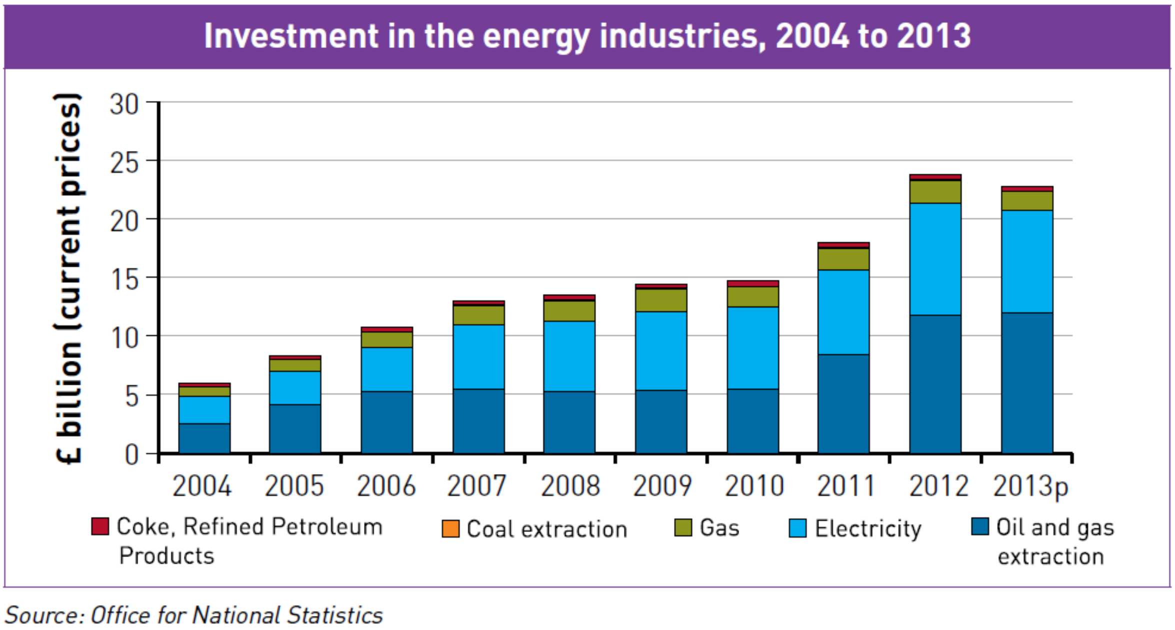

Figure 2.1: Investments in the UK energy industry (source: DECC 2014a)

An overview of some actual investments in offshore wind, including on-going and fixed investments (detailed in subsequent subsections), are summarised in Table 2.1. The largest assistance given to offshore wind is from the Green Investment Bank investing directly into the development of offshore wind farms and subsidies granted to the energy companies. Investment by energy companies into local communities is also noted for its contribution to the UK economy.

Table 2.1: Overview of offshore wind investments in 2010-2014*

Programme/Scheme	***Amount (£ million)***
Public investment in offshore wind	**£3,793**
• ***Supply-chain programmes*** *(of which)*	***£450***
Supply-chain development	*£430*
Regional growth fund	*£20*
• ***Innovation support*** *(of which)*	***£308***
UK wide application	*£90*
Regional investment	*£65*
Research councils	*£100*
Catapult centre	*£53*
• ***Financing schemes*** *(of which)*	***£3,035***
Entrepreneur funds	*£35 (plus Enhanced Capital Allowances of up to £100 million per company)*
Green Investment Bank	*£1,000*
Subsidies	*£2,000 (per year)*
Investment by offshore energy companies into local communities	**£51.6**

* Investments made in construction of offshore wind farms and related infrastructure are excluded.

2.1 Supply-chain programmes

Only 43% of lifetime costs associated with the operation of UK offshore wind is maintained domestically within the UK, the remaining component parts are imported (ORE Catapult 2014). The development of the domestic supply-chain could provide contributions to the UK economy in the future. Public funds are therefore being used to ensure that capital expenditure on offshore wind has UK content and can equal the North Sea oil and gas sector, which has over 70% of its capital expenditure supplied by UK-based suppliers (HM Government 2013). Numerous programmes and schemes have been created by UK Government departments in light of this goal (HM Government 2014), examples of which are provided below.

Supply-chain development and Advanced Manufacturing Supply Chain Initiative (AMSCI): Over £200 million of public money and £300 million of private money was invested in supply-chain development over the period 2012-2014 assisting suppliers to locate in the UK (HM Government 2014). An additional £100 million of public funds has also been made available through AMSCI since 2014. UK companies are now beginning to win contracts with recent successes including a £100 million contract for a UK company to supply cables for various offshore wind farms, a £90,000 grant for a new offshore wind service vessel, an £8 million contract for the assembly and testing of component parts, and a £100 million contract for the construction and development of Alexandra Dock, Hull (Chinn 2014). The Government has also established the Offshore Wind Investment Organisation (OWIO), within UK Trade and Investment (UKTI), which aims to increase elements within the supply-chain with greatest value added.

Additional plans had been made by the Department for Energy and Climate Change (DECC) to invest £60 million over the period 2010-2015 (DECC 2010) in support of offshore wind manufacturing port sites in English Assisted Areas (i.e. where GDP per capita is less than 75% of the EU average). A further £70 million from the Scottish Government were also earmarked for similar investments in Scotland. This funding, however, has largely not materialised.

Centres for Offshore Renewable Engineering (CORE): are partnerships between central and local government and Local Economic Partnerships (LEPs) (HM Government 2011a). The objective of CORE status is to enable rapid growth within the offshore wind sector. Six COREs have been strategically placed in England to capitalise on land, infrastructure, skills, and supply chain expertise (HM Government 2012). They are located in the North East, Tees Valley, Humber, Liverpool City Region, Great Yarmouth and Lowestoft, and Kent and overlap or are in close proximity to the concentration of offshore wind farms (OWFs) shown in Figure 2.2. Five of the CORE areas also contain Enterprise Zones which are eligible for particular financing schemes (see section detailing Enterprise Zones below). All six COREs are also situated in Assisted Areas which allow businesses to benefit from Regional Aid, other forms of State Aid and certain tax allowances (UKTI 2014). The direct benefits from offshore wind farms are location-specific and depend on the particular regional waters in which they are installed, operated and maintained. The location of the majority of the direct regional benefits can be identified from the map of OWFs that are operational, under construction, consented and in planning together with the communities that will benefit from their construction (Figure 2.2).

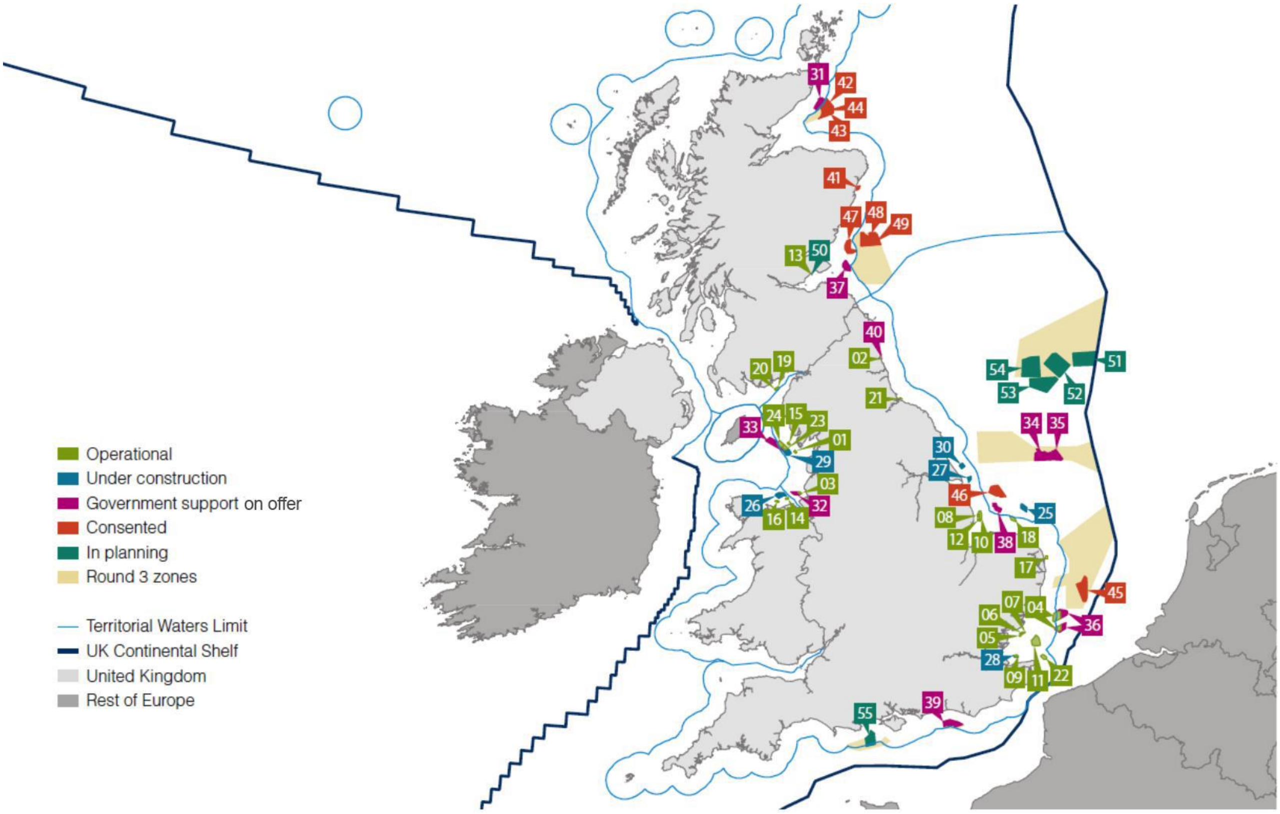

Figure 2.2: Offshore wind farm location (sourced from: UKTI 2014:17)

Regional growth funds: provide extra funding for businesses looking to set up in particular areas within the UK. The GROW:Offshore Wind fund has been set up to assist small and medium enterprises wanting to enter the offshore wind supply chain in England. The fund is worth £19.9 million and was secured from the Regional Growth Fund which is a £3.2 billion fund helping companies in England to become established by leveraging private sector investment (HM Government 2014).

Networking and expert advice: There are a number of offices and organisations that have been created by the UK government to support offshore wind by providing expert advice, one-to-one support, training, insight into manufacturing techniques, business strategy options and development of new products (HM Government 2014). Some of these include:

Manufacturing Advisory Service (MAS), Scottish Manufacturing Advisory Service (SMAS), Invest Northern Ireland and Offshore Wind Expert Support (Scotland). Each of these requires funds to operate. The MAS, for instance, was funded with £57 million of public funds for a three year period beginning in 2012, with £7m earmarked to maximise supply-chain opportunities (HM Government 2014). It is not clear what proportion of this fund was intended for offshore wind and therefore has been excluded from Table 2.1.

2.2 Innovation support

A number of funding opportunities are available to support technological development from a national and regional perspective.

UK wide application: to promote innovation within the UK offshore wind industry, funding has been targeted specifically at technological development. The Department of Energy and Climate Change (DECC) has allocated £30 million to offshore wind to promote innovation in, for example, offshore wind component technologies, structural lifecycle analysis and foundation improvements. Other public-private partnerships also have been set up to accelerate knowledge building. A recent announcement from the Energy Technologies Institute (ETI), a partnership of global energy and engineering companies (see also section 4.3.1), has committed approximately £60 million to technology development projects in offshore wind (HM Government 2014). Other European research, development and demonstration funding has also been available through the FP7 programmes and now the Horizon 2020 programme (which includes structural funds).

Regional focus: In Northern Ireland various initiatives have been created including a £10 million industry led research centre (Northern Ireland Centre for Advanced Sustainable Energy, CASE) promoting collaboration between industry and the research community. Invest NI offers advisory and financial support for research and development activities. It also offers innovation vouchers to businesses with less than 50 employees. These vouchers are worth £4,000 each, but can be pooled by up to ten companies, generating a maximum of £40,000. The vouchers fund them to work with a knowledge provider to help solve innovation issues. Scotland has created a number of initiatives through its enterprise agencies to promote technological innovation. A £40 million fund is available through Prototyping for Offshore Wind Energy Renewables Scotland (POWERS) for turbine development, while a £15 million funding pot promoting innovation in turbine foundations is being promoted through the Scottish Innovative Foundation Technologies Fund (SIFT). Wales is also supporting Welsh-based businesses through non-repayable financial assistance for research and development of innovative products and processes (HM Government 2014).

Research councils: The UK government departments (including DECC, BIS), research councils (e.g. EPSRC) and networks (Energy Technology Institute, Technology Strategy Board, and the

Carbon Trust) have spent in excess of £100m (2011-2015) to support offshore wind through the Low Carbon Innovation Coordination Group (LCICG) (LCICG 2012). The LCICG carries out Technology Innovative Needs Assessments (TINAs) to identify the key innovation opportunities to enable prioritisation of public sector investment. The Research Councils have spent approximately £2.5 million per year in energy research with an additional £4.8 million being channelled through the EPSRC SUPERGEN Wind programme. In the next phase of the latter programme, £3 million will be used to support a research Hub to enable more efficient networking. A collaborative Marine Renewable Energy research programme worth £2.4 million has also been jointly funded by NERC and DEFRA aimed at understanding the environmental benefits and risks of offshore wind.

Catapult Centre: £53 million was allocated to the Offshore Renewable Energy (ORE) Catapult Centre by the UK government (with an additional £97 million from private businesses and the European Union) to act as the go-to-place for innovation organisations. It recently merged with the National Renewable Energy Centre "incorporating world class research, test, demonstration and assurance assets with the engineering expertise, industrial and academic reach of the Catapult" (HM Government 2014). It can help accelerate the design, deployment and commercialisation of energy technology (ORE Catapult 2015a).

2.3 Financing schemes

Initiatives to facilitate access to finances for companies cover a range of products such as small business loans, growth loan funds, and development funds. Specific funds have also been identified for high growth businesses worth between £100k and £1m.

Entrepreneur funds and Enterprise Zones: DECC has a £35m Energy Entrepreneurs fund that has been running since 2012 (and due to conclude in 2016) supporting businesses that contribute to energy security and climate change objectives. Establishment of enterprise zones by the Department for Communities and Local Government (DCLG) encourages business to locate in these designated areas by providing government support, financial incentives - such as business rate discount - and simplified planning procedures (HM Government 2012). Five of England's CORE sites (North Eastern, Tees Valley, Humber, Liverpool City Region and Great Yarmouth & Lowestoft) are Enterprise Zones. Within these zones Enhanced Capital Allowances worth up to £100 million per company and business rates discounts for 5 years up to £55,000 per year are available.

Green Investment Bank: is a £3.8 billion commercial investment bank, originally set up by the Government, which supports key environmental sectors to enable the transition to a green economy. It has invested £1 billion in offshore wind at construction and operation phases. Its aim is to build confidence in the offshore investment market by investing on fully commercial terms. It also enables developers to re-invest their capital in other development and construction phases of projects.

Electricity price support and subsidies: The UK government is using subsidies to support renewable technologies to provide certainty and incentives for investment in offshore wind (see Box 1 for comparison with other technologies). Currently, the main subsidy scheme for large scale renewable energy is the Renewables Obligation Certificate (ROC). ROC requires that electricity suppliers source a certain portion of their electricity from renewable resources. Small-scale generators are given a fixed price feed-in tariff (Environmental Audit Committee 2014). However, according to Higgins and Foley (2014) the ROCs have not been effective in reaching targets and the prices paid to renewable energy providers fluctuate because ROCs are tradable in the market. The ROCs are therefore being replaced by a feed in tariff through the Contracts for Difference scheme. Contracts for Difference (CfD) pay the renewable energy supplier the difference between a long-term strike price and the market price. To encourage cost reduction within the industry, contracts are awarded through a reverse auction, whereby only the lowest cost projects receive support. The first auction of CfD contracts allocated a strike price of £114/MWh and £119/MWh to two offshore wind farms. These prices are considerably lower than the previously published strike price of £140/MWh and are potentially explained by falling costs within the offshore wind industry (RegenSW 2015). Currently, an estimated £2 billion is paid a year in subsidies for energy from onshore and offshore wind (The Telegraph 2015).

Box 1: Subsidies per energy type (source: Environmental Audit Committee 2014)

Energy subsidies have been used in the UK to satisfy a number of goals including support for fledgling technologies as well as support for fuel poor households (i.e. households which spend more than 10% of income on fuel). Total UK energy subsidies in 2013 were: £3.6bn for gas, £2.3bn for nuclear and £3.1bn for renewables. These totals result from a range of subsidies including tax reduction for the construction of fossil fuel plants and extraction of oil and gas from the North Sea, reduced VAT for households and small business on their energy bills, renewables obligation and legacy nuclear costs subsidies. Relative subsidies are estimated by dividing the total value of the energy subsidy by its total use and summarised in the table below.

Type of Energy	Subsidy per MWh*
Coal	20p per MWh
Oil	55p per MWh
Gas	£4 per MWh
Domestic electricity	£6 per MWh
Nuclear	£33 per MWh
Renewables	£50 per MWh

*As noted above, the relative subsidies are estimated using the total value of subsidies for each energy system which includes producer (e.g. PRTs, ROCs) and consumer (reduced VAT) instruments.

2.4 Wider economic impacts

British coastal communities: Revenue from The Crown Estate's marine activities (which includes income from offshore wind farms) contributes to the Coastal Communities Fund managed by the Big Lottery Foundation. As of March 2014, the Coastal Communities Fund had awarded £53.8m to 103 initiatives (CCF, 2014). A further £45 million was committed in 2015, to be invested in 63 seaside towns in England and Scotland (RenewableUK, 2015a). It is estimated that this latest tranche will create 3,000 jobs and 1,500 apprenticeships. In addition, £6.1 million worth of community funds is to be invested in Wales and Northern Ireland (RenewableUK, 2015a) taking the national total pledged for 2015 to £51.1 million.

The Centres for Offshore Renewable Engineering (COREs, see Section 2.1) that are being established on the east coast of England, have generated investment through the Growing Places Fund of between £5.7 million and £33 million for infrastructure in CORE localities. These include £16.7 million for North Eastern, £5.6 million for Tees Valley, £5.8 million for Humber, £12 million for New Anglia (Great Yarmouth and Lowestoft), and £32.5 million for the South East (Kent) (HM Government, 2011). The Growing Places Fund supports projects such as transport and housing, and so brings benefits to the wider community (DCLG, 2014).

In addition, individual developers provide financial support to communities local to specific OWFs, examples of which are given in Table 2.2. Further details of the activities supported by developers in this way are provided in Section 5.2.

Table 2.2. Examples of Community Funds established in association with offshore wind developments

OWF	Developer	Beneficiary communities	Fund details	Reference
North Hoyle	RWE	Rhyl, Prestatyn, Meliden	£1.5 million	RWE, 2013
Gwynt y Mor	RWE	North Wales	£19 million (including £690,000 for tourism development	RWE, 2014a
Rhyl Flats	RWE	Rhyl, Conwy	£2 million	RWE, 2014b
Humber Gateway	E.ON	East Riding of Yorkshire, Grimsby	£2 million	E.ON, 2015a
Robin Rigg	E.ON	Cumbria, Dumfries and Galloway	£1 million	E.ON, 2015b
Dudgeon	Statoil/ Statkraft	Great Yarmouth, North Norfolk, Breckland	£100,000 per annum from 2017	Dudgeon offshore wind farm, 2012
Sheringham Shoal	Scira	North Norfolk	Awards totalling £280,000 made since 2010	Sheringham Shoal, 2014
Burbo Bank extension	DONG energy	within Liverpool Bay	£235,000 per annum	Grantscape, 2015
London Array	E.ON, DONG energy, Masdar	Graveney	£200,000	London Array, 2015

3. Manufactured capital impacts

Manufactured capital refers to the goods or assets that contribute to the production process or the provision of services, rather than being part of the output itself. It includes for example tools, machinery, buildings and infrastructure (Moran et al. 2013). In the context of the ONS well-being indicators, manufactured capital contributes directly to the domains of economy (e.g. through income generation for the country), what we do (through employment), where we live (e.g. through access to new infrastructure and transport services). It also potentially indirectly affects other domains such as personal finance (through income generation per household) and education and skills (through demand for more highly skilled individuals) as well as health, personal relationships and natural environment.

Manufactured capital	→	**Well-being domains potentially impacted:** economy; what we do; where we live.

Limitations in manufactured capital and the necessary supply chains are recognised as an obstacle to the development of the offshore wind energy sector. In conjunction with other factors, such as the move to deeper waters and increasing commodity prices, the absence of appropriate centres of manufacturing and the necessary infrastructure has led to increased costs. This has resulted in the importation of turbine components from elsewhere in Europe and high energy prices per unit of electricity generated. The Offshore Wind Cost Reduction Task Force (2012) and The Crown Estate's Offshore Wind Cost Reduction Pathways study (The Crown Estate 2012) both emphasise the role that investment in the supply chain may have on reducing the construction, operation and maintenance costs. Through the Offshore Wind Industrial Strategy (HM Government, 2013), the UK Government committed to supporting future supply chain development through energy policy (via DECC), industrial growth (via BIS) and by encouraging inward investment (via UKTI). During the period 2005-2010, for a UK offshore wind farm, it was estimated that up to 80% of it would have come from elsewhere in Europe (Greenacre et al., 2010). By 2014, turbine manufacture was still largely occurring in Germany and Denmark, but 43% of lifetime costs of a UK offshore wind farm were spent in the UK with the capacity to manage and install projects having grown considerably in the UK (Chinn, 2014). Some investment in manufacturing is emerging, however, with £110bn expected by 2020 (HM Government 2014). This investment is likely to have implications for the well-being of the communities in which it is made, and nationally, through its contribution to the economy.

3.1 Manufacturing facilities currently operating in the UK

Turbine components: Within the UK, only Siemens is currently producing and assembling turbine components, although turbines of up to 2MW have been assembled in the UK in the past (BVG, 2014). There has, however, been some port development for manufacturing in the UK such as JDR Cables Systems Ltd (Hartlepool), TAG Energy Solutions Ltd (Tees Valley), Steel Engineering Ltd (Renfrew), Global Energy Group (Nigg) and Burntisland Fabrications Ltd (Burntisland and Arnish sites) (HM Government, 2012).

Tower production facilities: To date there is only one tower production facility in the UK (Wind Towers Scotland) at Campeltown, Argyll; the majority of towers are imported primarily from Europe. Capacity within Europe itself is limited, and future demand will outstrip supply. This indicates a significant opportunity within the UK supply chain for tier 1 (e.g. blades, towers, gearboxes, generators) suppliers, if current plans for offshore wind are to be met. There are also opportunities in the supply chain for cables, foundations and substations (UKTI 2014).

The situation for onshore wind: This picture is similar for onshore wind, with 55% of the construction expenditure going to non-UK companies (RenewableUK 2012). Onshore wind turbine towers, hub control and converters are manufactured in the UK, but most are imported from Europe. There are only two UK tower manufacturers (Maybe Bridge and Wind Towers Ltd), although many components are manufactured in the UK. Tata Steel, for example has a dedicated Wind Tower Hub in Scunthorpe which supplies plate steel for the onshore wind industry. It also supplies engineering and electrical steel for turbines.

3.2 Manufacturing facilities committed in the UK

Tower production facilities: The absence of offshore wind turbine tower production facilities is likely to change in the near future. An overseas subsidiary of South Korean CS Wind Corporation has recently been granted a Regional Growth Fund through the Department for Business, Innovation and Skills (BIS) to build an offshore wind turbine tower manufacturing facility on Humberside. It is anticipated that this facility will support up to 200 direct jobs with others in the supply chain (HM Government/British Embassy Seoul 2015).

Other manufacturing facilities: Other recent investments include Siemens committing to a new manufacturing facility on the Humber (see Box 2). This facility will produce blades and nacelles (UKTI, 2014). Vestas has recently re-opened its blade manufacturing facility in Newport, Isle of Wight following its closure in 2009. Manufacturing will commence in May 2015 producing blades that have been developed and tested at their research and development site, also on the Isle of Wight. The facility will produce blades for DONG Energy’s Burbo Bank extension project as well as future offshore projects (BBC, 2015).

Box 2: HUMBER Enterprise Zone – one of the world's largest renewable energy clusters

The Humber Enterprise Zone is one of six CORE (Centre for Offshore Renewable Engineering) areas in England. It has seen increasing investment in the offshore wind industry in terms of infrastructure including:

Green Port, Hull: Siemens in association with the Association of British Ports (ABP) are investing in Green Port Hull. This includes a £310 million regeneration programme of Alexandra Dock and the construction of a blade manufacturing facility. Building on lessons learnt from a sister site in Denmark, redesign of the original plans has allowed blade manufacturing facilities to be located on the same site as the installation and servicing facilities, helping to reduce costs. The development will also see the creation of new footpaths and a permissive cycle route. This will be complete with information boards and art installations, created in association with Hull College of Art and Design. It is anticipated that this development will see the creation of 1000 new jobs with more in construction and the supply chain. Planning consent has been granted for the first phase (pre-assembly, project construction and logistics, distribution facilities and offices), while the application for the manufacturing facility will be submitted in 2015 (GreenPortHull 2015).

Royal Dock, Grimsby: DONG Energy has joined Centrica, E.ON and RES by siting its operations and maintenance activities in Grimsby. Together with ABP, DONG Energy has invested in a new harbour in Grimsby's Royal Dock. This will support the Westermost Rough windfarm during construction, operations and maintenance. Developments include the reinstatement of a second entrance to the port, new floodgates and a causeway separating the harbour from the rest of the dock. Two new pontoons have also been built to support fast craft that ferry people between Grimsby and the offshore wind farm (Grimsby Telegraph, 2013a). The £11 million development is expected to bring 100 new jobs to the town (Grimsby Telegraph 2013b).

Able Marine Energy Park (AMEP): Able UK is investing £440 million in port facilities south of the Humber to attract wind turbine manufacturers. It will offer bespoke facilities for the manufacture, storage and deployment of renewable energy technologies. The site will include 1389 m of new heavy duty deep water quays (available in 2017) and 336.7 ha of developable land, the UK's largest developable land bank (ABLE, 2015). In 2014 AMEP, working with Humber LEP (Local Enterprise Partnership) and North Lincolnshire Council, was awarded a £14.9 million Enterprise Zone Capital Grant Fund towards this initiative, which will help kick-start the project and mitigate some of the risk. The first phase was due to be completed by March 2015 and is expected to create approximately 350 jobs in construction. It is anticipated that the project as a whole will create 4,100 direct jobs and 1,250 jobs in construction (Humber LEP 2014).

3.3 Test facilities currently operating in the UK

Purpose built test facilities in England: Developments in the offshore wind energy generation have required the development of new technologies, which require testing before full-scale deployment. Purpose-built test facilities have therefore been constructed. This includes those of the Offshore Renewable Energy Catapult[1] (formerly the National Renewable Energy Centre, narec). The ORE Catapult is the result of a £150 million investment by the UK Government, private business and the European Union, and is home to accredited testing and research facilities. This includes the National Offshore Anemometry Hub (NOAH); 15 MW capacity wind turbine drive train test facilities (plus a 3MW drive train test facility for tidal stream installations); 100 m and 50 m wind turbine blade structural test facilities; electrical and materials test laboratory; and wet and dry dock test facilities. This facility also supports the onshore wind industry and marine energy more widely. In addition, ORE Catapult has a service agreement with EDF for collaboration on the 100 MW capacity Blyth Offshore Wind test facility and demonstration site.

Test facilities in Scotland: In 2012, Scottish and Southern Energy's (SSE, 2015) planned offshore wind turbine testing facility at Clydeport's Hunterston site in North Ayrshire was consented. This was an extension of SSE's existing Centre of Engineering Excellence for Renewable Energy (CEERE), a partnership with the University of Strathclyde, Glasgow. The test centre itself is a partnership between SSE and leading turbine suppliers. Construction began in 2013 and the first assembled turbine, a 6 MW Siemens SWT-6.0-154, began generating energy in 2014. The second turbine, a 7 MW Mitsubishi SeaAngel turbine was assembled in October 2014. Both turbines will undergo long-term operational testing and assessment.

3.4 Improvements to port facilities

Port investment in England and Wales: HM Government (2012) reports that a number of ports have already seen some investment in support of the offshore wind energy industry, especially in areas designated as COREs (Centres for Offshore Renewable Engineering). For example:

- Barrow in support of construction, operations and maintenance of Barrow, Walney 1 and 2, West Duddon Sands and Ormonde wind farms.
- Grimsby in support of construction, operations and maintenance of Westermost Rough.
- Lowestoft in support of construction of Greater Gabbard, Scroby Sands and Gunfleet and is Scottish and Southern Electricity's permanent O&M base.
- Mostyn in support of construction, operations and maintenance of North Hoyle, Rhyl Flats and Gwynt y Môr.
- Ramsgate in support of operations and maintenance of Thanet and the London Array.
- Workington in support of operation and maintenance of Robin Rigg.

[1] https://ore.catapult.org.uk/

Regional investments: Investment is not restricted to England and Wales. Belfast Harbour has invested £53m in the UK's first dedicated port facility for the offshore wind sector, in support of a 10 year lease to DONG Energy and Scottish Power Renewables (Belfast Harbour, undated). This is reported to be benefiting the local economy with many Belfast firms contributing to the construction of the West Duddon wind farm. DONG Energy is also using Belfast as its base for the construction of other offshore wind farms including the extensions to Walney and Burbo Bank and during its investigations for the now defunct Celtic Array (OffshoreWIND.biz 2014).

Future port investments: Much more investment in ports is needed however. The size of future turbines indicates the need to manufacture them as close as possible to their final location as transportation will be both costly and difficult. Facilities for storage will also be necessary given the seasonal nature of offshore wind farm construction. One of the difficulties facing port development in the UK is that ports are privately owned often with restrictions on their expansion. To encourage expansion, the UK Government, via DECC, has in the past offered financial support for port infrastructure development in England and Wales (HM Government, 2014). Similarly, the Scottish Government was offering £70 million in support of Scottish port infrastructure development (through the National Renewables Infrastructure Fund). As noted in section 2.1, much of this funding did not materialise, but any investment will have knock-on effects on employment within these areas.

Other port investments: To place this port investment in context, it is important to note that the offshore wind industry is not the only reason for investment in UK ports. Excluding offshore wind development, the Department for Transport (2012) estimates substantial investment will be needed to meet the 182% forecast increase in containers between 2007 and 2030, the 101% increase in roll-on roll-off traffic and the 4% increase in non-unitised traffic (e.g. liquid gas). Many port developments have been consented, are underway or have been completed recently, most of which have been funded through the private sector:

- £26m has been invested in the Grimsby River Terminal making the port the UK's leading automotive handling facility[2].
- £100m is being invested in ports along the Humber to handle biomass shipments to Selby power station[3].
- £630m is being invested in Belfast to reclaim 120 acres and install 6km of new quays, this included dedicated investments by Belfast Harbour into coal and freight[4].
- £40m was invested in Aberdeen by 2012 to accommodate extra traffic (UKTI 2008).
- £90m is being invested in Liverpool for a second container port (UKTI 2008).
- £1.5bn is being invested in the London Gateway, a new deep water container port with 3km of quay space (UKTI 2008).

---

[2] http://www.gardiner.com/projects/?sc=28&proj=371
[3] http://www.shippingandmarine.co.uk/article-page.php?contentid=18601&issueid=520
[4] https://www.offshorewind.biz/2014/01/31/offshore-wind-sparks-belfast-harbours-trade-rise/

3.5 The electricity transmission network

The development of offshore wind farms in UK waters has led to the extension of the electricity transmission network through the installation of cables, seabed substations and upgrades to the grid to accept the variable input of electricity generated from wind turbines. The network, however, requires further reinforcement and extension if additional offshore wind farms are to deliver the energy they are anticipated to generate. This investment is expected to cost in the region of £15 billion (Ofgem, cited in O'Keefe and Haggett 2012). It includes reinforcement of the power transmission capacity between Scotland and England, a major bottleneck in the UK (O'Keeffe and Haggett 2012), and additional connections with other countries (see for example, SKM, 2010). The North Seas Countries' Offshore Grid Initiative[5] has been formed to evaluate and facilitate coordinated development of an offshore grid in the North Sea specifically to support the attainment of renewables targets up to 2020. Investments in the grid system will help ensure that not only offshore wind farms can supply electricity to the UK population, but also other renewable energy sources such as wave and tidal power. Modernisation to both onshore and offshore grid infrastructure is considered critical for maintaining energy security and ensuring the country meets wider energy objectives (DECC 2014b).

4. Human capital impacts

Human capital is the stock of knowledge, skill, health and motivation that can contribute to human welfare and economic productivity (Forum for the Future 2007). It draws on the ability of people to develop intellectually and work in environments which support individual wealth creation (Forum of the Future 1990). In turn it is expected that improvement in human capital will contribute directly to well-being through the domains of: what we do, education and skills, personal finance and health, and indirectly in relationships.

Human capital → **Well-being domains potentially impacted:** what we do; education and skills; personal finance; health.

4.1 Skills

Jobs linked directly with offshore wind farms are considered high skill jobs (Cambridge Econometrics 2012) drawing on expertise within the marine construction sector, operation and maintenance. The work is conducted in sometimes risky conditions while dealing with high end technology. To support these skills, a number of programmes are currently available for this still developing sector.

[5] http://www.benelux.int/nl/kernthemas/energie/nscogi-2012-report/

Apprenticeships: are available to anyone over the age of 16 who is not in full time education. These are funded by the Skills Funding Agency and its National Apprenticeship Service (NAS) (HM Government 2014). There is also the Employer Ownership of Skills Pilot, a £340m competitive fund, supported by the Department for Business, Innovation & Skills (BIS) and the Department for Education (DfE) and administered by the UK Commission for Employment & Skills (UKCES) and the Skills Funding Agency (HM Government 2014). To be the recipient of these funds companies need to show that the use of public funds in training staff would grow the UK economy. Some of the companies currently benefiting from apprenticeships are Siemens (total of 500 apprentices), E.ON (100 apprentices), Seacat Services (12 apprentices), Offshore Structures (Britain) Ltd, Belay Rope Access Ltd, DONG and Centrica.

College networks and research council training: The Offshore Renewable Energy (ORE) Catapult has developed a training course at their Blyth site offering RenewableUK accredited training which includes working on the turbine tower, blade inspection and repair, and health and safety (ORE Catapult 2015b). There are also other bespoke centres of excellence (see also section 4.3) such as the Advanced Manufacturing Research Centre (AMRC) and The Deep in the Humber which simulates ocean conditions to test offshore wind turbine foundation designs (HM Government 2012). The EPSRC (Engineering and Physical Sciences Research Council) offers doctoral training programmes in offshore wind to provide PhD level wind energy researchers. In Scotland, Northern Ireland and Wales additional critical mass in relevant education and training efforts has been made by pooling expertise and resources to ensure flexibility in responding to offshore wind industry demands (HM Government 2014). In 2010-2011 there were approximately 160,900 students studying engineering subjects in the UK related to offshore wind (HM Government 2012). It is not known what proportion of these students subsequently enter the offshore wind industry, however, it is likely to be small, given the size of the offshore wind sector. Nevertheless, the employment and career opportunities the offshore wind industry presents could be influencing some students' choices of higher and further education courses.

Industry led initiatives: National skills academies have been set up by industry to tailor training to the needs of employers. They comprise a network of colleges, training providers and centres of excellence. The National Skills Academy for Power covers offshore wind training while the Renewables Training Network (RTN) is an industry led training initiative aimed at filling the gap in skilled workers in the wind and marine renewables industry and has become a division of RenewableUK (RenewableUK 2015b; HM Government 2014). The Crown Estate sponsored portals on the ORE Catapult site showcases careers in the offshore industry to secondary school and older students as well as parents. There are a number of business networks including Carbon Trust, the Energy Technologies Institute and the Offshore Wind Developers Forum that can support skills development (HM Government 2012). The See Inside Manufacturing (SIM) government initiative also promotes the engineering and manufacturing sectors to young people by enabling visits to exemplar plants.

Talent Bank and Talent Retention Solution: Efforts are being made to ensure that appropriately skilled personnel are hired and retained within the different sectors. The Energy & Utility Skills, an employer-led membership organisation, assist employers to attract new talent, develop their workforces, and assure a high level of competence in engineering (EUSkills 2015). Talent Bank removes the barriers to organisations, especially small and medium enterprises, in selecting and training employees. The Talent Retention Solution (TRS) is an industry led initiative supported by BIS to facilitate the redeployment and retention of people with advanced manufacturing and engineering skills along the supply-chain (TRS 2013). Engineering and STEM-based (Science, Technology and Mathematics) skills are advertised with application to all sectors including offshore wind and ancillary industries.

4.2 Employment

Direct employment in the offshore wind industry is that generated by people working in the manufacture of turbines, and the construction, operation and maintenance of offshore wind farms. Indirect employment is created in ancillary supporting industries but which is still fundamental to the offshore wind industry. Indirect employment includes jobs in the transportation, mining of raw materials and service sectors, such as banking. There is also induced employment that occurs due to direct and indirect employees spending their wages on every day goods and services such as food, clothing and furniture. This has further employment effects within the wider economy.

Direct employment: generated within offshore wind has shown an upward trend from 2008 when employment figures were first sourced (RenewableUK 2013). In 2010, direct employment was 3,151 but had doubled to 6,830 in 2013 – as a comparison, the UK coal industry declined from 6,000 directly employed in 2010 to 5,005 people in 2013 (RenewableUK 2013, UKTI 2014, Pettinger 2012). These increases in direct employment are occurring both in large as well as small and medium enterprises (i.e. enterprises which have fewer than 250 people) (RenewableUK 2013). The split of jobs is in general 30% in construction and installation, 25% in planning and development, 18% in support services, 16% in operations and maintenances and 10% in manufacturing. Additionally the split of direct employment between the four nations is England with 62%, Scotland 21%, Wales and Northern Ireland 4%, with the remainder made up of a mobile UK workforce responding to demand needs. Development in areas that have high unemployment and low GDP per capita (Assisted Areas) could also benefit from offshore wind (see Box 3).

Box 3: North-East employment from offshore wind

An ESD and Greenpeace report published in 2004 highlighted how the potential positive benefits offshore wind could contribute to job generation in the North-East of England (ESD 2004). At the time of writing of the report, ESD and Greenpeace noted that unemployment was high (6.5% in the North-East) and that almost 18,000 of the region's science and engineering professionals, skilled workers in construction, engineering and other trades, and plant and machine operators were unemployed. It was concluded that the provision of these skill sets in the region, partly from higher education, could support a rapidly growing offshore wind sector. Recently, unemployment in the North-East has reached a 7-year low dropping from 9.9% to 8%, although this is still high compared to the UK as a whole, which is currently at 5.7% (ONS 2015). Unemployment for women in the North-East has dropped from 9.8% to 8% due to an increase in women taking manufacturing jobs, while for men the drop was from 8.7% to 8%. With 10% of offshore wind being associated with manufacturing (RenewableUK 2013), it could be a possibility that some of these manufacturing jobs are supporting offshore wind within the North-East.

Indirect employment: Along the offshore wind supply-chain a further 7,000 people are employed indirectly (UKTI 2014). These jobs are in the supply of goods and services, such as transportation, computers, banking. Different studies (such as ORE Catapult, 2014 and CEBR, 2012) use a range of multipliers to infer indirect jobs. The more conservative range of multipliers range between 1 to 2 indirect jobs for every 1 direct job. This range could change in the future depending on whether UK sectors become more interdependent and/or specialist in offshore wind related activities (RenewableUK 2013).

Induced employment: A report by BVG calculated that out of the 187 full time equivalent jobs supported by the offshore wind farm of Robin Rigg (Solway Firth, Scotland), 37 were direct jobs and the remaining were indirect and induced. The report also noted that even though the direct jobs were in Cumbria, where the wind farm's operational base and grid connection are located, most of the indirect and induced jobs were located in Dumfries and Galloway and other parts of the UK (BVG 2012). A report by Regenris for the proposed Triton Knoll Offshore Wind Farm provides potential direct, indirect and induced employment impacts as well as regional distribution of these employment benefits (Box 4). Data on actual employment associated with different offshore wind by region could be used as a useful comparative analysis and offer further insight into regional development.

Box 4: Triton Knoll Offshore Wind Farm – anticipated employment and regional benefits

The proposed Triton Knoll wind farm will be located off the coast of Lincolnshire. The impact assessment carried out by Regeneris (2014) for the 900 MW capacity offshore wind farm identified the electrical system as the major part of the overall capital investment. Using bespoke regional and national input-output tables the direct, indirect and induced employment figures for the construction of the electrical system were estimated on three spatial scales including: Lincolnshire (local scale), the East Midlands (regional scale) and the whole of the UK (national scale). Table B4 shows how employment may change in relative terms between directly generated employment and indirectly and induced employment over the different spatial scales if the Triton Knoll farm was to be developed.

Table B4: Employment impacts of electrical system in the construction phase (Regeneris 2014)

	Annual FTE Employment		
	Lincolnshire	**East Midlands**	**UK**
Direct	25	80	135
Indirect	15	135	175
Induced	10	95	185
Total	**50**	**310**	**495**

Wages: in addition to the job creation, wages contribute to individual well-being, particularly in terms of personal finances. The types of jobs generated by the offshore wind sector vary in their skill set and managerial position (Tables 4.1, 4.2). The current wage of a person occupying positions within the offshore wind industry with the relevant skills ranges from £19,706 to £102,837 (HM Government 2012). Information on the median gross annual wage of the offshore wind industry was not found which makes comparison with other sector wages difficult. However, this information is presented for illustrative purposes.

Table 4.1: Wages within offshore wind

Type of offshore wind job	Wage level (£, 2012)
Head of manufacturing	102,837
Production manager	58,898
Production operative (highly skilled)	23,286
Production operative (skilled)	19,706
Quality control manager	55,546
Quality control specialist	28,829
Engineer	32,596
Senior engineer	41,308

Source of data: HM Government 2012, ONS 2015

Table 4.2: Median gross annual earnings of non-electricity generating industries

Other Industries	**Wage level* (£, 2012)**
Agriculture	20,453
Mining	38,219
Manufacturing	26,989
Construction	28,394
Wholesale & retail	20,731
Information & communication	35,685
Finance & insurance	35,210

Source of data: HM Government 2012, ONS 2015

Other employment impacts: it is not clear whether the development of offshore wind will lead to lost or displaced jobs in other sectors such as fisheries and tourism. A recent MMO report noted that the social impacts of offshore wind on fisheries, aquaculture, tourism and recreation where mixed. In some instances there were opportunities for co-location, but others led to conflict (Papathanasopoulou et al. 2013). The following subsections for tourism, fisheries/aquaculture and other marine sectors explore where communities could gain or lose from the development of offshore wind – particularly in terms of employment.

Tourism: Little work has explored the impacts of offshore wind farms on tourism. A study from the southern Baltic indicates very few negative effects (Albrecht et al. 2013). Studies from the UK focusing on onshore wind impacts on tourism may provide additional insight. A 2011 survey for VisitScotland noted that the vast majority of UK respondents (86%) and Scottish respondents (91%) stated that scenery is important when taking holidays or short breaks in the UK (VisitScotland 2012). Only approximately 19% of UK respondents and 20% of Scottish respondents, however, considered that wind farms spoil the look of the UK (Scottish) countryside. Elsewhere, many tourists (80%) have been reported to be in favour of wind-generated energy and some studies have shown that some tourists (40%) have positive feelings when wind turbines are seen in the landscape (Fialte 2008, Glasgow Calendonian University 2008). A previous review of studies for Scotland, Wales and Ireland, found that tourists (96%, 77% and 75%) would not be negatively impacted the wind farms (Star Consultants and Leeds Metropolitan University 2003). Nevertheless, in the same study some tourists (22%) claimed that they would visit less due to windfarm development. There are also tourists (21 – 38%) who believe that windfarms have a negative impact (NFO 2002, 2003). Evidence from a survey of mountaineers in Scotland suggests that the majority of respondents are avoiding areas with wind farms (The Mountaineering Council for Scotland, 2014). Based on negative impacts found by studies, loss in tourist number and expenditure can be estimated using models. In a study for Scotland, based on responses from tourists indicating that they would not return to an area because of wind farms, such changes were estimated to result in a loss of 211 full time equivalent jobs (0.1% of tourism in Scotland) (Glasgow Calendonian University 2008). The study also cautioned though that these losses might be less for Scotland as a whole as tourists switch to other destinations but still within Scotland. Although this study is a little dated, these findings are still likely to hold true. A more recent survey suggests a similar proportion of respondents (18% from the UK and 17% from Scotland) would avoid an area of countryside if they knew there was a wind farm there (VisitScotland 2012).

Fisheries and aquaculture: There are concerns that OWFs may negatively impact fisheries (due to, for example, the exclusion of certain gear types from within the OWF footprint). Research in this area has primarily focused on perceived implications and possible mitigation measures (de Groot et al., 2014; Blythe-Skyrme, 2010; Mackinson et al., 2006), as opposed to documenting actual evidence of changes in fishing behaviour or fish catches. Gray and Stromberg (in prep) state, however, that fishers report a reduction or cessation of effort on grounds now within OWF areas in the Irish Sea, although not all of this change could be attributed to the presence of an OWF. Vessel Monitoring System data (where this exists at a sufficiently high resolution) also suggests a spatial shift in fishing effort for *Nephrops* in response to the presence of the Walney 2 OWF (Gray and Stromberg, in prep). The main reason for this change in behaviour appears to be concerns over gear entrapment and vessel collision, as opposed to changes in fish stocks. Some fishing (including the use of towed gear) has also been reported within operational OWFs (Gray and Stromberg, in prep; Hooper et al., 2015). A review of statutory monitoring suggests that major or moderate impacts on fish populations are unlikely from the smaller Round 1 and 2 OWFs, although there are concerns over the adequacy of the monitoring, and the occurrence of minor effects is unknown (MMO, 2014a).

Fishers have been supported by financial compensation for loss of fishing during construction, through work opportunities from guard ship duty and survey work, and benefits from investments from the offshore wind. Kilkeel trawlers recently managed to secure multi-million pound contracts from offshore wind developers to supply boats and crew to assist in the development and environmental impact assessments for planning applications (News Letter 2014).

Detailed assessment of any changes in overall effort and landings, or wider implications for fisheries (such as the effect of any increased fuel expenditure on profitability) appears to be lacking (see section 6.2). Such evidence is required if the scale of impact can be understood and placed in the context of other pressures on fisheries, not least the likely implications of climate change on fish stocks and fishing practices.

The potential co-location of OWFs and aquaculture has also been considered, primarily for mussels and other shellfish, but also as a location for finfish cages (Buck et al., 2004; Buck et al., 2008; Buck et al., 2010; Krausse et al., 2011; Linley et al., 2007; Mee, 2006; Michler-Cieluch and Kodeih, 2008; Michler-Cieluch and Krausse, 2008; Michler-Cieluch et al., 2009a,b). However, development of such schemes has not yet progressed in practice beyond some initial trials (Syvret et al., 2013).

Other marine sectors: a recent report commissioned by the MMO explored how a potential co-existence assessment approach could be developed to consider the range of marine activities included in the Marine Policy Statement. The approach was to include the physical, environmental, social and economic impacts of synergies and conflicts of the marine sectors. Offshore wind was one of the sectors included in the report (MMO 2014b).

4.3 Knowledge generation

The offshore wind industry has made substantial investment in research and development, an important component of human capital. This has focused on technology development as well as research into the supply chain and environmental impacts. It therefore has the potential to impact on well-being in a number of ways. This may be directly through employment and skills, but also indirectly through what we do, personal finance, where we live and the natural environment.

4.3.1 Investment in OWF research and development

Industry-university partnerships: A number of institutes across the UK are involved in research and development for the offshore wind industry. Many of these are partnerships between industry and universities. They include, for example:

- Renewables Energy Engineering Centre at Siemens Energy Transmission in Manchester[6]. This houses the Global Centre of Competence for High Voltage Grid Connections (HVGC) and focuses on the design of HVGC transmission systems for the UK and North West Europe.
- Sheffield-Siemens Wind Power Research Centre[2], based at Sheffield University. Research focuses on the reliability and efficiency of wind turbine generators.
- Siemens Research Centre[2], based at Keel University, specialises in developing power converter technology, turning electricity from turbine generators into a form compatible with the electricity grid.
- The European Offshore Wind Deployment Centre (EOWDC)[7] is being developed by a joint venture company Aberdeen Offshore Wind Farm Ltd, comprising Vattenfall, Technip and the Aberdeen Renewable Energy Group (AREG). The £230m project consists of a commercial offshore windfarm with associated research, test and training facilities.

[6] http://www.google.com/url?q=http%3A%2F%2Fwww.siemens.co.uk%2Fen%2Fwind%2Fresearch-development.htm&sa=D&sntz=1&usg=AFQjCNEuJP-jMcH5D5FZnCLW9NVBojT0Ag
[7] http://www.power-technology.com/projects/european-offshore-wind-deployment-centre-aberdeen/

- Gamesa Offshore Wind Technology Centre[8], Glasgow. The £12.5m centre will focus on developing next-generation offshore wind technology.
- SUPERGEN Wind Consortium[9] is led by Strathclyde and Durham Universities and includes seven research partners and 18 industrial partners. Established by the EPSRC (Engineering and Physical Sciences Research Council), it aims to "undertake research to achieve an integrated, cost-effective, reliable and available offshore wind power station". Since 2006, this group has received approximately £10m in funding from the EPSRC.

University centres: A number of universities also have centres that contribute to research and development relevant to the offshore wind industry. For example Strathclyde University has the largest university electrical power engineering and energy research group in Europe and this includes the Wind Energy Centre for Doctoral Training Centre and SSE's Centre of Engineering Excellence for Renewable Energy. Newcastle University has an Electrical Power Research Group which, amongst other topics, undertakes research into wind turbine generator technology and low carbon grids. One of the specialisms of Manchester University's School of Mechanical, Aerospace and Civil Engineering is in offshore wind energy focusing on, for example, turbine blade composites, structures for deep water deployment, and turbine performance. The Universities of Dundee, Aberdeen and Robert Gordon University have recently created a partnership to form the Offshore Renewables Institute (ORI). The ORI aims to develop and deliver solutions to the offshore wind industry, offering support at all stages of wind farm development.

Bespoke centres of excellence: In addition bespoke centres of excellence have been established across the UK. These include the ORE catapult (see section 2.2. and 3.3) and the Advanced Manufacturing Research Centre. The Advanced Manufacturing Research Centre[10] was established in 2001 as a £15m collaboration between the University of Sheffield and Boeing. It now forms part of the new High Value Manufacturing Catapult and is expanding its activities to explore the challenges of the offshore wind power sector.

Other public-private partnerships: Other public-private partnerships, such as the Energy Technologies Institute (ETI) and the Carbon Trust's Offshore Wind Accelerator (OWA), are also supporting the offshore wind industry. ETI was established in 2007 and is a partnership between global energy and engineering companies and the UK Government. It acts as a link between industry, academia and government with the aim of accelerating developments across low carbon technologies (ETI 2014). To date it has committed £58.5m to developments in offshore wind energy generation (ETI 2015). Similarly the OWA is a

---

[8] http://www.gamesacorp.com/es/cargarAplicacionNoticia.do?idCategoria=70&identificador=777&urlAmigable=offshore-wind-technology-centre-opens-in-scotland.html
[9] http://www.supergen-wind.org.uk/
[10] https://hvm.catapult.org.uk/advanced-manufacturing-research-centre

collaborative RD&D programme involving nine offshore wind developers. It is two thirds funded by industry with the remainder coming from DECC and the Scottish Government. Through innovation it aims to reduce the cost of offshore wind by 10% in preparation for the Round 3 offshore wind farm developments.

Additional public support: In addition to the OWA, DECC also supports:

- the DECC/TSB Offshore Wind Components Technologies Scheme. The £15m scheme funds projects that aim to develop and demonstrate technology components that can reduce costs.
- Offshore Wind Structural Lifecycle Industry Collaboration project (SLIC), a collaboration with industry to research the behaviour of turbine structures in the offshore environment.
- EUROGIA-UK, a collaboration with Eurogia+ and the Technology Strategy Board that encourages UK companies to participate in transnational collaborations focusing on low carbon technologies.

Over the four financial years from 2011, DECC expected to invest £30m in offshore wind innovation, from a total of approximately £160m for low carbon technologies (HM Government 2014).

The UK's research councils (EPSRC, NERC, and the RCUK Energy Programme) are funding research and development in offshore wind with an investment of approximately £2.5m being assigned in total per year.

4.3.2 Knowledge transfer

Lessons learnt from oil and gas: The offshore wind industry has itself benefited from lessons learnt from other industries including offshore oil and gas, aerospace and automotive industries. For example, technologies developed for the offshore oil and gas industry, such as construction vessels, dynamic positioning systems, heave compensated winches and cranes are also useful for the offshore wind industry. The offshore oil and gas operation supply chain could also be directly transferrable to the offshore wind industry if permanently manned offshore installations become operational. In addition, lessons can be learnt from the pan industry initiatives that were developed by the offshore oil and gas industry to drive down costs in the supply chain (Edwards 2011).

From aerospace: The aerospace industry has experience in lightweight materials which is relevant to the offshore wind sector. It has also contributed to turbine blade design (Collier 2010). Turbine blades behave in similar ways to aircraft wings and computer software developed to support design optimisation of high-speed aircraft is now being used to support turbine blade design. Turbine blades, however, are now much larger than aeroplane wings, meaning the wind industry has entered new territory.

From the automotive industry: The offshore wind industry is also learning lessons from the automotive industry. The automotive industry is known for the competitive structure of its supply chain. Best practice in automation and standardisation could be transferred to the offshore wind sector generating significant cost savings (HM Government 2013). Furthermore, there is considerable accumulated knowledge from the onshore wind industry. This includes computational model and measurements of structural dynamics, allowing the wind industry to have 'virtual turbines' (Garrard 2012).

From offshore wind to other sectors: Knowledge is not only being transferred to the offshore wind sector. Technology developed in the offshore sector is relevant to other industries. For example, direct drive wind turbines have features in common with electric and hybrid cars. Both use permanent magnets, the former to convert mechanical force into electric force and the latter vice versa. Many permanent magnets use neodymium, a rare earth metal, which is dirty to produce and 95% of production comes from China. This situation is considered unsustainable, so manufacturers across industries are looking for alternatives (Ashby 2015).

Many of the experiences of the wind industry (both on- and offshore) are pertinent to other marine renewable sectors. Grid development, cabling technologies and cable seals that are being developed for the offshore wind industry can support all offshore energy development. For example, Rotex UK has recently developed a cable seal specifically for underground power cables serving wind turbines and electricity substations, but which could also be used for other marine renewable installations (Sharpley 2015). The substantial investment in research into converters and grid connections for offshore wind turbines is also relevant to other marine renewable energy devices (Perveen et al. 2014). The more general experiences of the industry create lessons for other marine renewable energy sectors as well. For example, the EIA experience of other marine renewable energy installations is largely based on offshore wind (Leeney et al. 2014). There are also lessons to be learnt from engineering mistakes as well as from commercial and political ones across the offshore wind industry.

Export of services: Of particular interest is the accumulation of skills in the UK in the planning, construction, operation and maintenance of offshore wind farms. Many countries around the world are seeking to learn from the experiences in the UK (e.g. the US, Canada, South Korea, Japan, India, China and Taiwan). The UK may be able to capitalise on this by selling services relating to offshore wind farm development, design, financing and procurement, construction, operation and maintenance (UKTI 2014). Three recent reports from the Carbon Trust (2014 a, b and c) indicate how the UK can support Chinese offshore wind development through learning from the UK policy experience and existing technology solutions.

4.4 Health impacts

In a review conducted by Ison and Pearce-Smith (2009) of the health impacts of onshore and offshore wind (the results of which are reproduced here), they conclude that compared to fossil fuels and nuclear, wind energy is less environmentally polluting and has relatively low emissions particularly in generating electricity in terms of CO_2 emissions. This latter point contributes to the reduction of the effects of climate change, and consequently the health impacts associated with rising atmospheric temperature, rising sea levels, intensity and frequency of extreme weather events, shifts in species distribution particularly disease vectors (e.g. mosquitoes) and loss of agricultural production (which could in some cases lead to malnutrition). Additional benefits of wind technologies are better air quality with reduced respiratory illnesses (3,800 people died in 2005 from associated air pollution, Markandya and Wilkinson 2007) and reduction of local impacts such as acid rain (Ison and Pearce-Smith 2009).

On an occupational basis, accidents and deaths could occur in the transportation, installation and operation of the offshore wind turbines if safety procedures are not followed. In 2005, there was a total of 6 accidental and 13 occupational deaths over all electricity generating technologies (Markandya and Wilkinson 2007). Use of helicopters to manage installation and maintenance of the offshore wind farm over its life-time (on average 20 years), can also potentially impact residents in adjacent coastal communities through noise effects and air traffic. In addition to these physical impacts, there may be mental impacts. A negative impact might be the distress caused by falling property values due to proximity to offshore wind farms. Positive effects could also be gained if people associate their buying green electricity with a personal contribution to mitigating greenhouse gas emissions and a subsequent feel-good factor. Conflicts of interest in marine use however may further contribute to health impacts, particularly where there are direct conflicts between offshore wind and fishing, shipping, defence, aggregate extraction, marine archaeology, recreation and tourism. These negative impacts need to be balanced with the benefits gained from knowing that electricity is being domestically produced and supporting energy security.

In addition to the individual health impacts (both physical and mental noted above), there are also potentially social well-being impacts. Increased transient workers during the installation of wind farms could: increase the demand for housing and public health putting added stress on these services; impact on homelessness services; cause issues of integration with the local communities, introduce alcohol, illicit drugs use and sexual health problems (Ison and Pearce-Smith 2009). Inclusive and proper management of these possible problem areas can reduce negative impacts and capitalise on potential benefits.

5. Social capital impacts

The concept of social capital encompasses notions of community spirit, networks, and social resources i.e. it is an attribute of communities as opposed to individuals. The Organisation for Economic Co-operation and Development has adopted the definition of social capital as "networks together with shared norms, values and understandings that facilitate cooperation within or among groups" (Cote and Healy 2001).

Social capital	→	**Well-being domains potentially impacted:** personal well-being; where we live what we do; our relationships; health.

The implications of OWFs for social capital have been considered in two ways: the impact on particular cultural ecosystem services, and broader community issues, linking to the ONS indicators of where we live and what we do. Cultural ecosystem services directly influence human well-being in many ways, but in particular through personal well-being in terms of happiness, mental and physical health, sense of place and belonging, and creating opportunities for social interaction.

5.1 Recreation

The well-being benefits of recreation are increasing well documented, in terms of the mental and physical health benefits of activity and access to outdoor and natural spaces (Lee and Maheswaran 2011) as well as the creation of jobs and income in leisure and tourism industries.

Studies of the impacts of OWFs on recreation appear to be rare, and restricted to guidance on how the Environmental Impact Assessment process should address implications for recreation (particular surfing) (Surfers Against Sewage 2009), the possible benefits of artificial reefs (Westerberg et al. 2013) and objections raised during the planning process regarding perceived impacts on tourism (Rudolph 2014). Evidence of actual impacts (or lack thereof) is anecdotal. It points to the continued existence of a tourism industry close to an OWF site (Keuhn 2005) and the 35,000 people visiting an OWF visitor centre in one summer season (BWEA 2006).

Literature on the impacts of onshore wind on recreation seems similarly limited, although 90%-95% of tourists interviewed at two sites in the Czech Republic reported that the presence of wind turbines would have no impact on their intended future visits to the area (Frantal and Kunc 2011).

5.2 Visual impact

It has long been established that appealing natural landscapes contribute to well-being through reducing stress and evoking positive emotions (Ulrich 1979; Abraham et al. 2010), and that landscape is linked to many components of well-being including identity, attachment and belonging (Abraham et al. 2010).

There is strong consensus that the effect of an OWF on the seascape is viewed by most people as the primary negative impact (Devine-Wright and Howes 2010; Gee and Burkhard 2010; Waldo 2012). The perception of how a development will degrade visual amenity is a predictor of general attitude to OWFs (Teisl et al. 2015). There is evidence that people perceive OWFs to be less intrusive than their onshore counterparts (Busch et al. 2011; Ladenburg 2010), although locations 3 to 4 miles off the coast are not regarded any more favourably than onshore wind farms (Waldo 2012). Attitudes to visual impact vary with demographic factors: older people value loss of visual amenity more highly (Westerberg et al. 2013), while respondents under 30 years of age are indifferent to the proposed distance from shore at which an OWF will be sited (Ladenburg and Dubgaard 2007, 2009). Despite this apparent strength of feeling, when residents, second home owners, tourists, and non-resident workers in a coastal area close to an existing OWF were asked what currently disturbed their view, only six people (out of 1000) mentioned a windfarm onshore on the seafront and only three mentioned existing OWFs (Vanhulle et al. 2010). However, even those with a favourable attitude to OWFs have a saturation point for the number of turbines in a particular area (Vanhulle et al. 2010; Waldo 2012).

5.3 Wider attitudes

There is generally strong support for OWFs (Karlstrøm and Ryghaug 2014; Ladenburg 2008, 2010), motivated by beliefs that it is an environmentally sound energy source which does not harm wildlife, creates jobs and leads to local economic growth (Gee and Burkhard 2010; Vanhulle et al. 2010; Waldo 2012). Negative opinions include a belief that OWFs are unprofitable and inefficient (Waldo 2012), may decrease property values (Teisl et al. 2015) and some concern for wildlife impacts (Busch et al. 2011). In addition, survey respondents generally do not support the notion that OWFs have the potential to actively attract tourists (Vanhulle et al. 2010).

Again demographic variation is apparent: older people are generally more sceptical about OWFs (Ladenburg 2008; Karlstrøm and Ryghaug 2014), and men and those on higher incomes also seem to be less positive (Ladenburg 2010). Prior experience of OWFs has an effect on how proposed developments are viewed, with those familiar with distant OWFs (14km from shore) more likely to respond positively than those who have experiences closer sites (Ladenburg 2009). Recreational use of the coast (Ladenburg 2010; Ladenburg and Dungaard 2009) can also influence attitudes, although the scale and direction of this effect varies depending on how and when the area is used recreationally.

Overall, immaterial values (such perception of the sea as a wilderness and a feeling of responsibility for protecting marine life) are more important than material factors such as economic growth (Busch et al. 2011). Negative attitudes (in terms of perceived project outcomes, emotional responses and oppositional behaviours) are often linked to the strength of respondents' place attachment (Devine-Wright and Howes 2010). People can feel strongly that a greater value inherent in the area will be spoilt by OWF development (Waldo 2012).

5.4 Community Funds

Perception of personal impacts and benefits is the most significant variable in explaining public support for renewables projects, and people generally feel that benefits should be accrued locally, not just by distant corporations and shareholders (Cass et al. 2010). Support for a hypothetical OWF increased when respondents were provided with information detailing the expected community benefits of the project (Walker et al. 2014). However, offers of support from developers are not always met with enthusiasm. Support in terms of local jobs and contracting is generally unproblematic and uncontroversial, but the provision of direct financial contributions to communities may be perceived as bribery (see also section 7.3), and the more prevalent this opinion, the lower the support for the project (Cass et al. 2010). When such critical viewpoints were presented alongside information about community benefits, additional support for a hypothetical OWF was negated (Walker et al. 2014). However, actual experience of positive community benefits increases the level of support expressed for a proposed OWF development (Cass et al. 2010).

Whatever the perception of financial contributions from developers, investments in community projects do support the development of social capital. Some developers have established dedicated funds for this purpose, while others have instead taken a more *ad hoc* approach to investing in local communities. Other developers consider their role in providing community benefits in terms of the direct and indirect economic impact of the development on employment and the supply chain (Cowell et al. 2012). The economic value of these contributions has been discussed in Section 2.2. In terms of the social capital generated, the projects supported by community funds have been wide ranging. They include:

- environmental projects such as habitat restoration, community gardens and monitoring programmes (RWE 2013; E.ON 2015b, Sheringham Shoal 2014);
- training, particularly related to beach lifeguarding and lifeboats (Sheringham Shoal 2014; London Array 2015);
- educational activities in science, sport, environment and sustainability as well as student bursaries (London Array 2015; Cowell et al. 2012);
- renewable energy schemes (Sheringham Shoal 2014);
- support for disabled, homeless and vulnerable people (RWE 2014b).

Three additional funds, for communities near the Humber Gateway, Burbo Bank and Gwynt y Mor are due be open for applications in 2015 (E.ON 2015a; Grantscape 2015; RWE 2014a) and a fund connected to the Dudgeon OWF will come on stream from 2017 when the development becomes operational (Dudgeon offshore wind farm 2012).

5.5 Connecting people

OWF industry groups and networks may be established with an ultimate economic or political goal, but there is also significant social capital generated through the connections created between the people involved. At a national level, examples include the Offshore Wind Energy Council, a forum for representatives from industry and Government, and RenewableUK, the renewable industry's umbrella body. Regional groups, such as Energi Coast in the North East of England, also exist, supporting north east England's renewables supply chain. Formed of a steering group of companies involved in the offshore wind industry, they have already invested £400 million in offshore renewables. Together with NOF energy, Energi Coast has a supply chain database identifying regional capabilities within the North East Region. NOF energy also has a supply chain directory of members (businesses involved in oil and gas, nuclear and offshore renewables). Other directories also exist, such as the WindPower Directory by Wind Power Monthly, which contains entries for 367 companies focusing on offshore wind and based in the UK.

Offshore wind farms have also created social capital through the formation of groups that oppose the developments. The Atlantic Array, proposed for the Bristol Channel, generated particularly strong opposition, with the formation of groups including "No Atlantic Array", "Atlantic Disarray", "Slay the Array" and "Atlantic Array – No Way". These groups created web-pages, encouraged coordinated lobbying of MPs, generated at least two e-petitions and organised local protests. The proposed Navitus Bay OWF has also seen the creation of the "Challenge Navitus" opposition group, although in this case there is also evidence of coordinated support for the development. Of the 400 people who gathered to protest in Swanage in January 2013, 100 were in favour of the wind farm (The Guardian 2013). Stakeholder engagement has been a learning process for both communities and developers. Lessons learned from the developer perspective are that early involvement of stakeholders from the pre-planning stage minimises conflict, maintains a more objective dialogue and increases public acceptance (Gerdes et al. 2006).

6. Natural capital impacts

The term 'Natural capital' refers to "the elements of nature that produce value or benefits to people (directly and indirectly), such as the stock of forests, rivers, land, minerals and oceans, as well as the natural processes and functions that underpin their operation" (Natural Capital Committee 2013). As the Natural Environment White Paper states, "Natural resources and functioning natural systems are vital support services for our wellbeing and security, and are themselves sustained by biodiversity" (HM Government 2011b). The ways in which we benefit from natural capital include the availability of food and raw materials (provisioning services), protection from hazards such as flooding, erosion and pollution (regulating services), recreational opportunities (cultural services), all of which are underpinned by complex webs of species and habitat interactions (supporting services).

Natural capital	→	**Well-being domains potentially impacted:** the natural environment via provisioning, regulating, cultural and supporting ecosystem services

There is the potential for the construction and operation of OWFs to affect marine life, and hence natural capital, in different ways, with possible negative implications expected due to seabed disturbance during construction, loss of habitat and changes in sediment, water turbidity and current flows (Wilson et al. 2010). Impacts may also be positive, not least the global environmental effects of generating energy from wind power, and hence reducing carbon emissions. However, there is no meaningful way to attribute climate change mitigation at the scale of individual OWFs, and hence the focus of this review is on local impacts.

Many existing reviews (e.g. Bailey et al. 2014; Tabassum-Abbasi et al. 2014; Inger et al. 2009) as well as individual studies consider the potential environmental impacts of OWFs based on comparisons with similar offshore structures and processes, but do not provide evidence from actual experience of OWFs. However, there is a growing volume of literature (particularly since 2010) that does report the outcomes of empirical research, and it is this evidence that has been considered. It should be noted that existing research tends to focus on seeking evidence to substantiate perceived negative impacts. Therefore, in reporting the literature this study generally takes the format of introducing the perceived threat before reviewing the available evidence that supports or refutes the expected impact.

Some of the literature identified relates to the statutory monitoring carried out on behalf of developers as part of their consent obligations. Care must be taken in using the outputs from this monitoring, as the suitability of the approaches, methods and data analysis (and hence the reliability of the data) has been questioned (Walker et al. 2009; Walker and Judd, 2010; MacLean et al. 2013). That is not to say that all peer-reviewed research is without methodological flaw. The quality of any evidence is therefore a key component of any review. The evidence base considered was drawn almost exclusively from within Europe, although less than 25% of the studies originated from the UK.

6.1 Provisioning services

The key focus of research on provisioning services has been in relation to food species, with some consideration of raw materials in terms of possible seaweed aquaculture (Buck et al.

2008; Michler-Cieluch and Kodeih, 2008). Activities to extract other raw materials (such as aggregates) are unlikely to be located in the immediate vicinity of OWFs, and any implications of changes to seabed characteristics have not been discussed in these terms.

Electromagnetic Fields and Noise: There is concern that the electromagnetic fields (EMF) generated by OWF cables could impact commercial species. EMF may affect the ability of certain animals to navigate or detect prey. Commercial species that are both sensitive to EMF and relatively common in areas where UK OWFs have been, or will be, constructed include rays, eels, cod and plaice (Gill et al. 2005). Minor effects on eels have been documented (Westerberg 1994, reported in Öhman et al. 2007), which suggested that migratory patterns were unaltered beyond 500m from the turbine. Changes in eel catches were observed, but it was not possible to attribute these changes to EMF or acoustic effects. One field-based experiment (Gill et al. 2009) suggested behavioural responses from both dogfish and rays to cables with similar EMF properties to those used in OWFs, but the responses were not predictable and did not always occur. EMF did not appear to affect the survival rates of mussels or prawns (Fisher and Slater 2010). Evidence of EMF effects is predominantly derived from laboratory experiments. Studies of the *in situ* effects on marine life of OWF cables appear to be limited, and this issue has been identified as a continuing data gap (Gill et al. 2012).

Fish species can also be affected by noise, and the possible implications of pile driving during OWF construction have also caused some concern. Again, empirical evidence in this area is lacking, but one laboratory experiment has suggested that noise levels equivalent to pile driving have no effect on the mortality of sole larvae (Bolle et al. 2012). Significant behavioural responses have, however, been detected in both cod and sole when pile driving noise was played back to caged animals in shallow coastal waters (Mueller-Blenkle et al. 2010). The responses were highly variable, but indicate that the animals move away from the source of the noise, although they may also become habituated to it.

Species abundance: OWFs may have positive effects on commercial fish and shellfish stocks through artificial reef effects: the hard surface of the turbine foundations (when introduced into areas otherwise characterised by soft sediments) provides a new habitat for sessile species such as barnacles and mussels, and these prey sources, as well as the shelter provided by the foundations, attract mobile species such as fish. There is evidence that the abundance of mussels, brown crab, cod, pouting, eel and sole increase in proximity to OWF turbines (Hooper and Austen 2014; Reubens et al. 2013a; Vandendriessche et al. 2014; Bergström et al. 2013; Wilhelmsson and Malm 2008). Tagging individual fish has also demonstrated that juvenile cod spend long periods within OWFs (Winter et al. 2010; Reubens et al. 2013b) and remain very close to the turbines (Reubens et al. 2013b), using the benthic communities on them as a food source (Reubens et al. 2014). The fish are in good condition, so there is no evidence that OWFs are an ecological trap in which fish are caught in a suboptimal habitat (Reubens et al. 2013c).

However, the evidence of positive effects is not universal. Sole have been shown to use OWF sites, but there is no evidence of a particular attraction such as that emerging for cod (Winter et al. 2010). No change in the abundance of flounder has been detected (Bergström et al. 2013) and the abundance of dab has been shown to decline (Vandendriessche et al. 2014). Also, while increases in the abundance or biomass of certain fish and benthic species have been reported from certain OWFs, the evidence is not universal across all sites (Ashley et al. 2014).

Implications for fisheries: Any increase in the population of commercial species around OWF foundations does not automatically lead to an increase in catch rates within the fishery, for a number of reasons. The individuals found in proximity to the turbines may simply have moved from elsewhere, and even in cases where the OWF is contributing to fishery production, it may not be possible for fishers to exploit enhanced stocks. The willingness of developers and fishers to support crab fisheries within OWFs has been explored, and suggests considerable variability in opportunities and attitudes (Hooper et al., 2015). The issue of employment implications for fisheries has been discussed in the human capital section under the subsection employment.

6.2 Supporting and regulating services

In many cases, empirical research has considered marine species and habitats more broadly, not just those important for food and raw materials. This research is rarely conducted within an ecosystem services framework, and instead approaches the assessment of ecological change from a standard natural science perspective. Although ecosystem services are not directly evaluated in these cases, any changes in fundamental biophysical parameters within the environment may have implications for a range of supporting and regulating services. For example, the observed increase in mussel abundance at OWF foundations (Wilhelmson and Malm 2008; Bunker 2004) is likely to increase the capacity of the system to remediate waste (regulating service), and will also increase food availability for other species (supporting service).

Benthic communities

Changes in species presence, diversity, abundance and biomass are key to potential changes in supporting and regulating services. Significant changes to the existing soft sediment communities following the construction of OWFs have rarely been detected (Daan et al. 2006; Degraer and Brabant 2009; Leonhard and Pedersen 2006) but the high natural variability of the OWF sites may mask any effects that have resulted from the construction or operation of the OWF (Coates et al. 2014; Vandendriessche et al. 2014; Degraer and Brabant 2009). The inadequacy of current monitoring programmes in this respect has been reported (Walker et al. 2009). There is some evidence that the construction phase has greatest impact, but that communities are resilient and characteristic biotopes become re-established during OWF operation (Walls et al. 2013). A potential benefit to the reef-building ross worm has also been detected, which showed an increase in extent following OWF construction although, again, with natural variability (Pearce et al. 2014).

The communities on the turbines differ from those in the surrounding soft sediments (Andersson and Öhman 2010; Leonhard and Pedersen 2006). There is consensus that the turbine foundations become dominated by mussels, barnacles and small mobile crustaceans, with worms, starfish and anemones also common (Birklund 2005; Bunker 2004; Degraer and Brabant 2009; Kerckhof et al. 2010; Lengeek and Bouma 2009; Wilhelmsson and Malm 2008). The turbine communities have also been shown to differ from those in rocky areas in their vicinity, particularly in terms of a reduced presence of algae, herbivorous gastropods and sand-dwelling species and an increased abundance of mussels and barnacles (Wilhelmsson and Malm 2008; Birklund 2005).

Fish assemblages

Implications for commercial fish species have been discussed above, and higher abundance of non-commercial fish at the turbines has been reported, particularly for two-spotted goby but also for wrasse and sculpin (Andersson and Öhman 2010; Bergström et al. 2013; Wilhelmsson and Malm 2008). However, species diversity and richness have been found to be lower at the turbines than on the surrounding seabed (Wilhelmsson and Malm 2008). There may be temporal differences in how species are affected by turbine presence: both a short-term benefit and a long-term negative impact have been detected for sandeels (van Deurs et al. 2012). As with studies of the benthic community, high natural variability may mask the effects of OWFs on fish communities (Degraer and Brabant 2009; Andersson and Öhman 2010).

Non-native species

The presence of OWFs tends to increase the number of species present in the area, but changes in species abundance or composition are not always viewed positively: the introduction of new habitat and associated biodiversity where it did not previously exist can be a cause for concern due to the potential for disrupting the endemic biodiversity structure and function, and changing the behaviour of endemic species (Russell et al. 2014).

Concern has also been raised about OWFs acting as stepping stones and facilitating the spread of non-native species, an issue that has a demonstrable negative effect on wellbeing (Börger et al. 2014). Non-native species have been detected on turbine foundations, indicating an extension of range (Degraer and Brabant 2009; de Mesel et al. 2015). Modelling studies have also demonstrated that OWFs in the Irish Sea could allow the transport of larvae from species present in Northern Ireland to the Scottish coast (Adams et al. 2014), while those in the Baltic may provide a vector for the transport of moon jellyfish larvae (Janßen et al. 2013), a species that is native but which causes problems in high densities for fishing, tourism and coastal power stations.

Physical processes

OWFs have the potential to impact the physical processes within the water column and on the seabed, affecting sediment composition and transport mechanisms. This area is not well studied, although the development of scour pits around OWF foundations, particularly in sandy sediments, is a known phenomenon (Christie et al. 2012; Whitehouse et al. 2011). Fishers have also reported changes in local sedimentation patterns following OWF development (Hooper et al., 2015). Satellite imagery has demonstrated the presence of large, turbid wakes extending for over a kilometre downstream of individual turbines (Christie et al. 2012; Li et al. 2014; Vanhellemont and Ruddick 2014), suggesting their presence has an effect on the transport of suspended sediment. OWFs also decrease the downstream wind speed (Christiansen and Hasager 2005), and large downstream wakes may have a direct impacts on water circulation around the installation (Broström 2008).

6.3 Cultural services: Charismatic species

Charismatic species such as marine mammals and seabirds are highly valued (Richardson and Loomis 2000), which prompts particular concern about potential impacts upon them. There is some recreational use of these species, particularly through bird watching, but most people rarely interact directly with marine mammals. There is also a non-use component to the value of these species, with significant value placed on knowing that the animals exist and will continue to do so for future generations (Loomis and White 1996). Any changes to the population or health of marine mammals and seabirds is linked mostly to the less tangible cultural services (such as spiritual wellbeing and inspiration) rather than through direct use, with associated impacts on personal wellbeing and happiness. This concern for the impacts on charismatic species reflects that shown for onshore windfarms, where the effects on birds are again a particular focus of impact assessment (Powesland 2009).

Marine mammals

Responses to construction noise: One key area of field research has been the impacts on marine mammals of the noise created during pile driving. The existing evidence for effects on populations of grey and harbour seals is inconclusive. Some studies suggest haul out rates may decline (Edrén et al. 2010; Teilmann et al. 2006) and that seals avoid OWF areas during construction (Brasseur et al. 2012; Teilmann et al. 2006). However, overall changes in population size have not been observed (Teilmann et al. 2006), and the techniques used often lack the statistical power to detect OWF effects (Brasseur et al. 2012; Tougaard et al. 2006). Effects may be species specific, as declines in harbour seals attributed (although not conclusively) to an OWF were not observed in grey seals (Skeate et al. 2012).

Conversely, a growing body of research has shown that the activity and abundance of harbour porpoise within the area declines during OWF construction (Brandt et al. 2011; Carstensen et al. 2006; Dähne et al. 2013; Jakob et al. 2006). The spatial extent of the disturbance may be considerable, as effects have been detected 20km from the OWF site (Dähne et al. 2013; Tougaard et al. 2009). However, acoustic deterrents are typically deployed during pile driving as are techniques such as "ramping up" in which the noise levels are gradually increased. These practices are designed to reduce the presence of mammals in the area and hence minimise any harm to them. It is not clear whether the changes in mammal behaviour are in response to these deterrents or to the noise of pile driving (Brandt et al. 2011; Dähne et al. 2013). Other factors related to construction (boat activity, changes in prey behaviour) may also contribute to the observed changes in abundance (Teilmann and Carsten 2012).

Whatever the exact cause, it remains the case that changes in mammal behaviour as a result of construction activities have been observed, although it is not known whether these have wider consequences in terms of animal health. In a single study of a captive porpoise within an aquarium, the playback of noise resembling that of OWF pile driving increased breathing rate and the frequency with which the animal jumped from the water (Kastelein et al. 2013), although caution should be attached to the results of captive animal experiments.

There is some evidence that any disturbance created by construction noise is relatively short-term. Activity levels for porpoise have been reported to return to normal within six to eight hours (Jakob et al. 2006), although other research suggests it may take 72 hours (Brandt et al. 2011) or as long as six days (Dähne et al. 2013) for normal activity levels to resume. Porpoise may also become habituated to the noise levels, as in one instance the second construction phase did not result in the same significant decline in activity as had been recorded for the initial period of pile driving (Thompson et al. 2010). A second study also drew conclusions of a reduction in effect over time (Teilmann and Carsten 2012). The noise created by the installation of gravity base turbines (which do not require pile driving) did not appear to have a significant effect on porpoise abundance (Tougaard and Carstensen 2011).

Mitigation measures: As mentioned previously, where responses to construction noise (typically displacement) have been detected, it is often unclear whether the cause of these effects is the pile driving itself, as measures designed to reduce the exposure of marine mammals to potentially damaging noise levels have usually also been implemented. Actions to minimise the potential harm to marine mammals during construction are required by OWF licences. Since 2007, detailed mitigation measures have been prescribed including soft-starts (i.e. gradually increasing noise levels) and monitoring by observers and passive acoustic devices such that activities can be suspended when marine mammals approach

(MMO, 2014a). The use of acoustic deterrents designed to discourage mammals from entering the construction area has not previously been a common licence condition, although the measure has been implemented at individual OWFs (MMO, 2014a).

Effects during OWF operation: There is no evidence of negative impacts on harbour porpoise from OWF operation. Playback of recorded sounds had no effect on porpoise behaviour, except an indication that the animals were investigating the source (Koschinski et al. 2003). Activity levels have been shown to return to normal during operation following disturbance during the construction phase (Jakob et al. 2006) and no evidence was found of any decline in abundance (Walls et al. 2013). One instance of increased activity within an OWF during operation has also been reported. Increasing activity was also observed within reference areas, but the change was greatest within the OWF (Scheidat et al. 2011). While normal operation appears to have no detrimental effect, periods of high maintenance activity may create a significant disturbance (Jakob et al. 2006).

Again, no significant negative effects of OWFs on seals have been reported (Brasseur et al. 2012; McConnell et al. 2012; Teilmann et al. 2006; Walls et al. 2013). Where temporal population effects have been observed (a poor breeding season coincident with construction and reduced numbers hauling out during operation) these cannot be conclusively attributed to the OWF (Skeate et al. 2012). Recovery of affected populations may take a period of two years or more (Skeate et al. 2012). The implications of boat traffic as a source of disturbance have again been highlighted for seals (Skeate et al. 2012).

A potential benefit to seals of OWF structures has also been observed. A small number of individual seals have been recorded travelling in striking grid-like patterns within OWF sites, with activity concentrated at the turbines (Russell et al. 2014). The repeated use of the structures in this way suggests that successful foraging was occurring at the turbine foundations.

Population level effects: The studies reported above concerning effects on marine mammals tend to be limited to assessments of the behaviour of individual animals. Only one study considered population level effects, and this did not contain evidence of causal links between OWF construction and population change (Skeate et al., 2012). Population effects are challenging to study but are key to understanding any long-term and larger-scale implications of disturbance, which will be of greatest relevance in determining impacts on cultural services and wellbeing. In December 2014, a consortia of OWF developers launched a two year research programme to investigate Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) (Forewind, 2014), the results of which may help to better understand this issue.

Birds

Migration patterns: Assessment of the implications of OWFs for birds focuses overwhelmingly on the interaction between turbines and the flight paths of seabirds and waterfowl, and how these inform potential collision risks and likely mortality. There is a growing evidence base that most birds avoid the turbines, with the orientation and height of flight paths being altered in response to turbine presence and only a minority of individuals in a flock flying within the OWF area (Masden et al. 2009; Petersen et al. 2006; Pettersson 2005; Pettersson and Fågelvind 2011; Plonczkier and Simms 2012). Avoidance behaviour may be learned: with each year post-construction the proportion of pink-footed geese flying within the OWF footprint continued to decline (Plonczkier and Simms 2012). Birds continue to exhibit avoidance behaviour even at night, when collision risk is greater due to increased flight altitude. Waterfowl were shown to alter their flight path later at night compared with behaviour in the day, but the birds still veered off about 500m from the turbines even in poor visibility (Pettersson and Fågelvind 2011).

The extra flying distance resulting from OWF avoidance is unlikely to have a detectable energy cost for species such as eider, given the large total distance of their migration, although energy costs for other species moving daily between roosting and feeding grounds would be greater (Masden et al. 2009).

Collision risk and mortality: The interaction between birds and OWFs has been interpreted in terms of collision risk. Risk varies with species due to differences in local abundance and flying height (Skov et al. 2012), and so findings for particular species cannot be extrapolated universally. Modelling studies have suggested a strike rate for common eider of approximately 45 individuals per autumn season across an OWF (Petersen et al. 2006), while gull strikes are predicted at less than 3 per turbine per year (Vanermen et al. 2013). Passerines and waterbirds have a predicted rate of about 10 to 15 strikes per year (Pettersson and Fågelvind 2011; Pettersson 2005) although this is based on crude extrapolation from single observed collisions during the study periods. A study examining bird corpses on a beach close to an OWF suggested that turbine strikes were responsible for 3% of bird deaths (approximately 11 per year), the vast majority of which were seabirds (Newton and Little 2009). The design of an OWF can have implications for collision risk. Modelling of two OWFs suggested that higher bird mortality was likely at the site in which turbine height was 10m closer to sea level (Skov et al. 2012).

Changes in bird populations: In terms of observed effects on bird populations and health, there is growing evidence of a decline in gannet populations at OWF sites (Degraer and Brabant 2009; Petersen et al. 2006; Vanermen et al. 2013). Common guillemot, razorbill and long-tailed ducks have also been reported to avoid OWF areas (Petersen et al. 2006; Vanermen et al. 2013), while no significant change in abundance has been observed for eider (Guillemette et al. 1998; Rothery et al. 2009). In some cases, an increase in abundance of particular species has been reported following the construction of OWFs. There have been reported increases in common terns (Degraer and Brabant 2009) and sandwich terns (Rothery et al. 2009), although the foraging success of little terns has been shown to decline during OWF construction (Perrow et al. 2011). Large gulls and cormorants appear to show little avoidance of OWFs, and increases in their abundance have been recorded (Petersen et al. 2006; Rothery et al. 2009; Vanermen et al. 2013; Walls et al. 2013).

However, there is insufficient evidence to draw general conclusions from these changes in abundance, and hence infer potential impacts on well-being, as the evidence base does not show unequivocal trends. For example, Rothery et al. (2009) report a decrease in cormorants, in contrast to the findings of other studies. Also, while divers remained absent from the area of one OWF for the entire three year period of post-construction observation, despite having been present in average densities prior (Petersen et al. 2006), other studies have reported no change in abundance (Walls et al. 2013). Results for common scoter are similarly variable (Petersen et al. 2006; Rothery et al. 2009; Walls et al. 2013). Individuals of the same species may also exhibit variation in their interactions with OWF areas both within and between years (Thaxter et al. 2015).

Finally, existing studies tend not to consider the wider context of changes in bird populations as a result of other pressures such as altered prey availability and climate change. As is the case for benthic communities and fish populations, longer term monitoring is required to really understand the effect of OWFs on birds (Degraer and Brabant 2009).

7. Governance impacts

The term governance is used in many ways, but broadly speaking refers to the process of governing, as undertaken by a variety of social actors including governments, private companies, non-governmental organisations and service providers (Bevir 2012). In the present case, governance is explored in the context of decision-making for offshore wind farm development and the role that the state and other influential actors have taken in this decision-making process. Governance is an ONS domain for well-being, a component of which is trust in national government (and therefore also related to social capital). While the UK Government plays a role in the development of the offshore wind industry, decisions affecting the industry’s future are also taken at regional and local scales. This section therefore explores decisions-making with respect to the development of the offshore wind industry from local to national levels. It focuses on both trust and uncertainty. Governance can play a key role in reducing uncertainty, which may in turn influence the level of investment in offshore wind and offshore wind’s subsequent impact on well-being. Three governance relationships are examined: Government and industry, communities and Government/local authorities, and communities and industry (both energy suppliers and offshore wind farm developers).

7.1 Government-industry relationships

Planning uncertainty and governance shift: There has been a shift in governance with respect to offshore wind farms since 2007. Prior to 2007, the UK Government only supported offshore wind farms to a limited extent. The complexity of the planning and consent process is often cited as reason for slow development of offshore wind farms in the UK (Markard and Petersen 2009; Gibson and Howsam 2010). This slow development has made investment in the industry difficult and economically unattractive (Ochieng et al. 2014). Following the Climate Change Act 2008 and the introduction of renewable energy targets via the Renewable Energy Directive (2009/28/EC) there has been rapid deployment and changes to the licensing and consenting processes (Kern et al. 2014). This resulted from changes in UK law and marine planning to support the decision that offshore wind energy generation would play a significant contribution towards meeting the UK's renewable energy targets (Scarff et al. 2015). Jay (2010) notes that such changes are not unique to the UK. Countries with the greatest interest in offshore wind energy appear to be pursuing marine spatial planning most enthusiastically. This suggests that the offshore wind industry was in a strong political position (Toke 2011), and this was furthered by the backing afforded it by well-known environmental NGOs (such as Greenpeace, the RSPB and WWF). More recent changes in the UK, however, arising from the UK Energy Act (2013) and Electricity Market Reform, implies that this may no longer be the case (see section on financial uncertainty below).

Changes to the consenting process: Changes in UK law have benefited Round Three wind farms as well as developments in Scotland and extension applications for Rounds One and Two sites. Round Three windfarms have been subject to a different consenting process from Rounds One and Two, according to the Planning Act of 2008, the Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and the Localism Act 2011. This has seen the introduction of a Major Infrastructure Planning Unit through the Planning Inspectorate (which replaced the Infrastructure Planning Commission)[11]. In England (and potentially in Wales and Scotland), applications for offshore wind farms with capacity over 100MW fall into the remit of a Nationally Significant Infrastructure Project (NSIP) and consent takes the form of a development consent order, rather than planning permission. A development consent order combines planning permission with other consents that would have had to have been applied for separately (e.g. licences for navigation, coastal protection and for an electricity power plant), it can also include rights to compulsorily purchase land. The decision to award a development consent order is taken by the relevant Minister (e.g. Secretary of State for Energy and Climate Change or Secretary of State for transport in the case of port development). Smaller projects will be considered by the Marine Management

[11] In Wales, consent can be given via the Transport and Works Act 1992, if applicants apply to Welsh Ministers. The Planning Inspectorate will not examine applications in Scotland, but energy policy is largely a matter for UK Ministers, so the National Policy Statement for Renewable Energy Infrastructure may apply. In Northern Ireland, planning consents for all energy infrastructure is devolved to the Northern Ireland Executive (DECC, 2011).

Organisation under the Marine and Coastal Access Bill. This new process aims to reduce the average time to consent from two years to less than one (Gibson and Howsam 2010).

Changing role of The Crown Estate: The Crown Estate, the body charged by Parliament with the responsibility for managing the Marine Estate and development of the seabed, has also changed its role in the offshore wind farm consenting process. In Rounds One and Two, offshore wind farm developers bid for self-proposed sites. In Round Three, The Crown Estate became more strategically involved, identifying zones with the greatest economic potential. The Crown Estate co-invested with developers to implement a Zone Appraisal and Planning process, which extends the environmental and consenting site selection process to a larger zone, allowing for the potential for multi-site developments (The Crown Estate 2010). This approach offered developers greater control over how a zone could be developed and was designed to reduce risk to project delivery and accelerate the programme (Kern et al. 2014).

Financial uncertainty: The changes in the planning and consenting process were (in part) developed to provide greater certainty to the offshore wind industry, in line with the Blue Economy agenda in Europe (Scarff et al. 2015). The removal of planning uncertainty means that financial uncertainty is considered the main barrier to development of the offshore wind industry (Toke 2011). The UK government attempted to reduce financial uncertainty by offering incentives in the form of Renewables Obligation Certificates. ROCs, however, have not had the desired effect on the offshore wind industry, offering little long-term financial security or sufficiently large incentives to stimulate investment. Following the Electricity Market Reform initiative legislated for in the UK Energy Act (2013), ROCs are being replaced by a feed-in tariff through Contracts for Difference (Higgins and Foley 2014) (see section 2.3).

The slow progress of the UK Energy Act (2013) through parliament is reported to have resulted in increased policy uncertainty and led to a slow-down in investment (Shankleman, 2013). This is coupled with uncertainty around the Contracts for Difference (CfD) scheme. The second auction for subsidy contracts due in October 2015 has been postponed. Given the importance of the subsidy in supporting cost reduction efforts, there are concerns that any withdrawal of subsidies will actually raise the cost of capital and consequently slow down the cost reduction pathway the offshore wind industry is currently following (Nicholls, 2015). Without subsidy support many investors may freeze their investment suggesting that currently consented offshore wind farms may remain unbuilt, at least in the short-term. For example, the First Flight Wind consortium (B9 Energy, DONG Energy and RES) has dropped plans to develop the only offshore wind farm Northern Irish waters. The consortium blames the decision on delays to new market and incentive arrangements and an inability to build the wind farm in the timeframes required under the new rules (BusinessGreen 2014). There are calls by the industry for the government to follow through with its promises to maintain the UK as the world leader in offshore wind (Shankleman 2013).

7.2 Government/Local Authority-community relationships

Public acceptability: Despite apparent widespread support for renewable energy installations, public acceptability of local implementation is not guaranteed (see section 5.1). Many onshore wind farms have been controversial and it is often assumed that by placing them offshore, that acceptability is improved (Haggett 2011 and references therein). This has not always been the case (e.g. Devine-Wright and Howes 2010; Ellis et al. 2007), although more recent evidence for the UK is lacking. Analysis of opposition to wind farms has primarily focused on onshore installations, but many of the findings are common to both on and offshore wind farms. Hagget (2011) identifies five key reasons for support or opposition: impacts on the aesthetic value of the land/seascape; the social, political and historical context of a site; a disjuncture between the local impacts of wind farms and global issues such as climate change; the level of ownership of a development and the relationship communities have with the developers; and trust in decision-makers and the decision-making process as well as the ability to engage with the process.

Local communities and lack of trust: In the context of trust Barry et al. (2008) show how opposition groups position themselves not as fighting against wind farms *per se*, but as fighting on the side of the democratic process. Distrust in government and local authorities arises from a sense that the Government is supporting wind energy developments through subsidies, or is being forced to support wind energy as a result of EU policy. Big business is seen to be favoured over the wishes of local communities and the environment. The environment, a public good, is seen as being commercialised for private profit. The integrity of official procedures such as consultations, regulatory and planning measures used to govern wind farm development is therefore questioned.

Concerns about the process by which offshore wind farms are agreed are perhaps a more significant issue for the offshore wind industry as planning decisions are more centralised. Planning inquiries for offshore wind farms cannot be called for by local authorities as offshore wind farms are not within local authority boundaries (Toke 2011). While consultations are undertaken with local communities, Haggett (2008) found that many considered these to be cosmetic and were more about information distribution than dialogue. There are many calls within the literature for improvements to the level of public involvement in the offshore wind planning process (from assessment to decommissioning) as a way to improve trust between communities and decision-makers (e.g. Aitken 2010a; Haggett 2008, 2011). In attempt to overcome issues of community concern in Scotland, an initiative has been underway to explore the impact of offshore renewables in general on issues of importance and value to the Scottish public. Through extensive dialogue, the impacts of renewables on aspects of social capital (e.g. community networks, shared norms, values and understanding, and sense of place) are being examined (Collingwood Environmental Planning 2015).

Relationships with the fishing industry: It is not only coastal communities that raise concerns over the siting of offshore windfarms and the decision process. Although evidence indicates that offshore wind farms have limited impacts on the fishing industry (see section 4.2), the fishing industry is often reported to be distrusting of both developers and regulators. This distrust results from previous bad experiences with the planning process that have led to increased restrictions on their activities (Mackinson et al. 2006). The concerns of the fishing industry over the consultation process are not dissimilar to those of local communities, with consultation often viewed as tokenism on the part of the developer (de Groot et al. 2014; Gray et al. 2005). De Groot et al. (2014) reports a number of ways in which members of the fishing industry feel that the consultation process can be improved including demonstrating the degree of influence the consultation may have, ensuring consultation is inclusive and improving communication in consultation and engagement processes. Much of this relates to the creation of social capital between the fishing industry, offshore wind farm developers and other relevant decision-makers, and efforts are being made in this direction.

7.3 Industry-community relationships

Lack of trust: Distrust is also a problem in industry-community relationships. To overcome this it has often been assumed that providing the public with more information is the solution (e.g. Ellis et al. 2007; Aitken 2010b). There is no clear relationship, however, between knowledge and acceptance of wind farms. Furthermore, there is a perception within communities that developers only engage with them as an attempt to manage or overcome opposition (Aitken 2010b). If trust is to be established between developers and communities, Aitken (2010b) suggests that it should not be seen as a means to an end (i.e. that more trust will lead to less opposition).

Developers and community benefits: Toke (2005) indicates that it is the outcomes of the developments that are important to communities and a feeling that benefits should accrue to the community rather than to private corporations and their stakeholders. In Denmark and Germany, local ownership is commonplace and is reported as one reason behind local acceptance (Toke 2005; Cass et al. 2010). In an attempt to emulate this success, community benefit packages are often associated with wind developments in the UK, although this is less well established for offshore than onshore wind (Allan 2013) (see section 2.4). These are voluntary contributions that are independent of benefits gained from the supply chain and in addition to Section 106 Agreements[12]. While the motives behind these packages may

[12] Section 106 Agreements are private agreements made between local authorities and developers to make developments that would be unacceptable in planning terms acceptable, e.g. through compensation or mitigation for loss or damage.

be social corporate responsibility, in some instances they have been construed by local communities as bribes and a way of buying consent (Cass et al. 2010). This creates tension over how and when to administer these funds and potentially leads to a loss of well-being within the communities that the developers want to support.

A number of other mechanisms are therefore suggested as ways to demonstrate a developer's commitment to a local community. These include cheaper community electricity tariffs, ring-fenced business rates and community ownership shares (Cass et al. 2010; Allan 2013). Each of these presents difficulties, however. For example, cheaper community electricity tariffs face regulatory obstacles linked to the current electricity market (Cass et al. 2010) and community ownership shares would require some upfront investment by the community which may be beyond their capacity (Allan 2013).

Trust between developers and the fishing industry: There is limited evidence documenting the relationship between fishermen and offshore wind farm developers. Anecdotal sources suggest that the relationship can be strained, as has been the case, for example, between Norfolk crab fishermen and DONG Energy. DONG Energy sought a court injunction to remove the crab fishermen from the area under consideration for the Race Bank project in The Wash (Gosden 2014). Elsewhere, relationships are better, with members of the fishing industry diversifying to support the construction of offshore wind farms (see section 2.2).

8. Discussion and conclusions

The offshore wind industry impacts on each of the five capital stocks and the governance context in a variety of ways. Given documented links between the capital stocks and well-being (e.g. Cote and Healy 2001; Costanza 2003; Walker and Pearson 2007), it can therefore be assumed that the offshore wind industry impacts upon human well-being. The impacts evidenced by this review cover all the well-being domains identified by the Office for National Statistics (ONS). A summary of these impacts is presented in Table 8.1. The overall picture emerging from this review is that the offshore wind industry appears to have positive impacts on well-being indicators associated with financial, manufactured and human capital (with some reservation over local health effects). The impacts on well-being indicators associated with social and natural capital, however, are more mixed or are still to be determined. Governance impacts are also somewhat mixed.

Table 8.1 Impacts of the offshore wind industry on the five capitals and ONS well-being domains. *Ecosystem services are not an ONS well-being domain, but changes in these are considered to influence human well-being (Millennium Ecosystem Assessment, 2003).

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
Financial capital (e.g. investments)	The economy	**Positive impact** • Investments in the region of £4bn to date in innovation support, supply chain programmes and financing but could be higher if all on-going investments and unpublished investments were included. • £2bn paid in price support and subsidies per year. • Regional investments in areas which have been identified as Assisted Areas • Stability in market providing an environment for further investment and long term operation
Manufactured capital (e.g. infrastructure)	The economy	**Positive impact, although currently limited** • Many turbine components are imported but supply chain support is seeing investment in turbine component manufacture. • Investment is being made in port facilities to support the offshore wind industry, but in line with port investments made by other industries. • Development of the electricity transmission network will support future energy security.
	What we do	**Positive impact** • Investments in turbine manufacturing and port facilities are bringing new jobs to areas where these investments are made.
	Where we live	**Impact unclear** • The construction onshore of infrastructure relating to the offshore wind industry has implications for the communities where construction occurs. Whether this is positive or negative is not reported. • Associated community projects can be assumed to have a positive impact on where we live.
Human capital (e.g. skills and education)	What we do	**Positive impact** • 3,151 direct jobs created in the manufacture, construction, operation and maintenance of offshore wind turbines. • An estimated 7,000 indirect jobs created along the offshore wind supply chain. • Induced employment effects reported. • Considerable investment in knowledge generation through R&D.
	Education and skills	**Positive impact** • Jobs created in the offshore wind industry are reported to be high skilled. These skills are in demand outside the UK, allowing the export of skills and knowledge transfer. • A number of dedicated training courses have been developed to meet the rising demand to appropriate skills.
	Personal finance	**Positive impact** • Wage levels for jobs associated with the offshore wind industry range by skill with scope for career development.

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
	Health	**Impact unclear** • There are concerns over the safety of offshore workers but protocols for offshore working are well established in the oil and gas industry and can be adopted. • There are potential health gains resulting from the mitigation of CO_2 emissions and future climate change. • Mental health impacts related to offshore wind are uncertain but could be influenced by falling house prices, transient work force, and buying energy from green sources.
Social capital (e.g. social networks)	Personal well-being	**Mixed impacts** • Generally strong support for offshore wind farms (OWFs) motivated by beliefs about environmental impact, job creation and local economic growth. • Opposition exists, motivated by concerns over profitability, decreases in property values and impacts on wildlife.
	Where we live	**Mixed impacts** • Community funds can have positive impacts, but some view such funds as bribes.
	What we do	**Impact unclear** • Evidence is anecdotal and suggests tourism continues to exist alongside the offshore wind industry with some new recreation opportunities (e.g. boat trips to OWFs). • Effects on the view and the restorative nature of environment could affect engagement with the coastal environments and ultimately health.
	Our relationships	**Positive impact** • Industry groups and networks developed to support supply chain and national and regional capabilities. • Formation of opposition and supporter groups builds relationships and social capital within communities.
Natural capital (e.g. natural resources)	The natural environment: provisioning ecosystem services	**Impacts unclear** • Data are limited but evidence suggests some commercial species negatively affected by EMF and noise. • Artificial reef effects may have a positive effect on commercial species.
	Supporting and regulating ecosystem services	**Mixed impacts** • Benthic communities appear to be resilient to impacts during the construction phase. • Turbine communities and associated fish assemblages are different to those in surrounding area. • Concerns over role of OWF in the spread of invasive species.
	Cultural ecosystem services	**Impacts unclear, but mixed effects emerging** • Research on impacts of marine mammals is inconclusive as population level effects have been little studied. • Birds demonstrate avoidance behaviour and collision risk is low. • Impacts on bird populations around OWF vary with some showing increases and others decreases.

Capital stock	Relevant ONS Well-being domains	Summary and direction of change
Governance (e.g. participatory decision making)	Governance	**Mixed impacts** • Government policy is reducing planning and financial uncertainty, but policy is still creating uncertainty leading to a slow-down in investment by industry. • Opposition to offshore wind farms stems from distrust in government/local authorities and concern about erosion of the democratic process. • Community funds have been viewed as bribes. • The fishing industry is unhappy with the consultation processes and relationships can be strained with both developers and regulators.
	Where we live	**Mixed impacts** • Community funds can have a positive impact on local communities, but extent to which they compensate for visual impacts is unknown.

8.1 Linking the offshore wind industry to changes in well-being

Identifying the links between the offshore wind industry and well-being is challenging. Well-being domains identified by the ONS are general in nature and need to be interpreted broadly to capture possible effects resulting from the offshore wind industry. It is likely, however, that the impacts of the offshore wind industry are wider reaching than those identified in Table 8.1. Additional direct links include, for example, health changes arising from impacts on natural capital, financial capital impacts on personal finance, or employment and income impacts on the fishing industry arising from changes in natural capital. Given the interconnected nature of the well-being domains many indirect effects are also possible, for example, health impacts resulting from changes in personal well-being or changes in personal finance affecting where we live. Evidence for these many potential additional linkages is currently lacking, making it difficult to relate impacts on these well-being domains to specific effects resulting from the offshore wind industry. The findings presented here are consequently descriptive in nature, presenting a best estimate given the evidence available.

As Busch et al. (2011) state, well-being indicators can lack sensitivity. They highlight how it is difficult to distinguish the role of the offshore wind industry on well-being domains and their indicators from the impacts of other factors. Issues such as wider economic conditions or demographic change could mask the impacts of the offshore wind industry or, conversely, amplify their effects. For many domains of well-being, especially those relating to aspects of personal well-being, the absence of a baseline against which to measure impacts is also problematic. To overcome this, monitoring of all the capital stocks and their associated well-being domains is needed (see section 8.2). Such monitoring would need to be tailored to the offshore wind industry. How the offshore wind industry impacts on many of the existing well-being indicators used by the ONS in the Measuring National Well-being Programme (e.g. crime against the person or satisfaction with accommodation, indicators of the domain Where We Live) will always be hard to establish. Also, the ONS Programme does not contain an exhaustive list of well-being indicators, with those currently in The Environment domain being particularly unrepresentative of the possible well-being effects.

Whose well-being needs to be assessed is also questionable. As demonstrated by this review, it may be easier to establish well-being impacts at the community, regional or national level than at the individual level. This has different policy implications. For example, the total impact on jobs in a community or region arising from the offshore wind industry may suggest an improvement in economic conditions and therefore enhanced community, local or regional well-being. It could, however, disguise the fact that some jobs may be lost elsewhere (e.g. from the fishing industry or from other energy installations) with considerable well-being impacts for the individuals concerned. The well-being impacts may also accrue outside the communities or regions adjacent to the offshore wind farms. In many cases the impacts may be international, given the current state of the UK offshore wind farm supply-chain, and the global nature of climate change implications. This spatial disconnect between offshore wind farm sites and the well-being impacts presents an additional challenge for well-being assessments of the offshore wind industry.

The selection of appropriate well-being indicators is another important issue in a well-being assessment, and care is need in their interpretation. An increase in a well-being indicator does not necessarily mean a positive change in well-being for all. For example, additional jobs in the offshore wind industry may be considered a positive impact by some. Others may view them differently, especially if those additional jobs go to people from outside the local community or the increase in jobs means more people within a community resulting in additional strains on public services. When planning for interventions that will impact upon well-being, trade-offs between different well-being domains will inevitably be made. The desirability of the different well-being domains to individuals and society, however, is unknown.

8.2 Key gaps in knowledge

A significant challenge in undertaking this review has been the lack of appropriate data for assessing well-being impacts. In addition, the following gaps in knowledge have been identified:

Financial capital: It has been assumed that investment in the offshore wind industry has provided a stable environment for the sector and its supply-chain industries. However, it is unclear what return these investments are providing and how they are actually contributing to local and regional economies. A time series analysis of the public and private investments by geographic area, return on investment in terms of contribution to local, regional and national economies and impacts viewed from long- and short-term perspectives would clarify the magnitude of the support being provided to communities. The benefits of carrying out such research would provide information that could indicate the role of the offshore wind industry to some of the indirect well-being elements identified, in particular personal finance and personal well-being.

Manufactured capital: Information about investments in manufactured capital is dispersed within the peer reviewed and grey literature as well as across numerous websites. This makes the creation of an inventory of offshore wind impacts on manufactured capital challenging. Impacts on the well-being domains related to manufactured capital have been assessed primarily at a UK level, although some regional and local effects have been identified. It was not possible to assess the impacts on individual well-being. As a result, it is likely that the impacts of the offshore wind industry on the well-being domains related to manufactured capital are underestimated.

Human capital: has been grouped according to skills, employment, knowledge generation and health. Each of these elements can be further investigated from a number of perspectives and linked to well-being. For instance, skill and knowledge generation could be explored in terms of productivity and contribution to more integrative management solutions in, for example, marine planning. Additionally, there are a number of impact assessments that have been produced to support proposed offshore wind developments. Many of these reports estimate expected employment numbers, however they have not been compared to actual numbers following construction. Research into the forecasted and actual impacts could provide insight into how the sector is developing and maturing and how forecasts can be brought in line to manage expectations and well-being impacts. Finally, information on the physical and mental impacts of offshore wind is sparse and would benefit from a structured programme of primary data collection and analysis.

Social capital: Social capital in relation to OWFs has rarely been explored directly, and much evidence remains anecdotal. Research into the implications for cultural services has tended to focus on impacts on the seascape and sense of place. It has not yet been determined whether recreation has been impacted, and whether the potential for new opportunities presented by OWFs has been realised. Data on tourism impacts is also lacking. Understanding these effects would provide further information on how financial capital is affected by OWFs.

Natural capital: There is a general lack of comprehensive long-term monitoring of OWF sites, and therefore any impacts resulting from OWF installation are difficult to identify equivocally above the inherent natural variability. Longer term datasets (before and after construction) are essential if the impacts (both positive and negative) are to be properly understood and placed in the context of other pressures on the marine environment. This need for longer term monitoring, better understanding of baseline conditions, and improved choice of and consistency between survey methods has been noted in reports to the MMO (Walker and Judd, 2010; MMO, 2014a) as well as in individual studies. Practical suggestions for increasing the efficacy of monitoring while minimising additional resource requirement have been made, such as maintaining the same number of benthic surveys but increasing the time interval between them (Walker and Judd, 2010). Opportunities may also exist for the development of monitoring standards to overcome any inadequacies in current monitoring practise and improve their efficiency.

Priority areas for additional research that are likely to have the most direct impact on well-being relate to provisioning and cultural services. More detailed assessments of changes in the populations of commercial fish and shellfish species, and changes in fishing practices, are required as data on these issues are particularly sparse. It is also important that follow-up assessments should be undertaken where disturbance effects have been documented (such as to marine mammals during construction and the avoidance behaviours demonstrated by some birds), to determine whether these result in any population level effects (survival, breeding success, etc.) and how these compare to other pressures. The potential for maximising positive impacts of OWFs (such as artificial reef effects) should be explored further, as this could bring additional benefits for financial, human and social capital. Evidence of fishery production from the artificial reef effects of OWFs has been shown locally but is lacking at a regional level (Vandendriessche et al., 2013), and so issues of scale and timeframe should be considered in any such assessment.

Governance: Evidence for the impact of the offshore wind industry on governance is limited, compared to that for the onshore wind industry. Although evidence is emerging, there is little understanding of the trust relationships between the offshore wind industry, regulators and impacted communities (e.g. fishing, tourism and coastal communities). An exploration of how to build trust between these different parties is needed and may benefit future offshore wind farm developments.

In addition to the above, other gaps are evident:

- There is little evidence of the impacts of offshore wind farms on subjective well-being, captured by the ONS through personal well-being. This is important because the coastal and marine environment has frequently been found to be an especially beneficial environment in terms of subjective well-being. Compared to other environments, the sea and coastline have been demonstrated to promote greater stress reduction, happiness and overall well-being (White et al. 2010).
- Little is known about the relative importance to the public of the different domains of well-being and their indicators. It may be that the public or other affected stakeholders would prefer a greater emphasis to be placed by the offshore wind

industry on one capital at the expense of others. Identifying this may improve the acceptability of the offshore wind industry to the public.
- Given the absence of an established baseline from which to measure change, all of the impacts of the offshore wind industry need to be placed in the context of other changes that may also be affecting well-being.

8.3 Conclusions

This review identifies that, when considered primarily at the regional/national level, the offshore wind industry appears to have positive impacts on financial, manufactured and human capital (although this is not unequivocal, especially in the context of health). The messages are more mixed for social and natural capital, and for governance, with both positive and negative impacts emerging. The paucity of data relevant to well-being limits the extent to which these impacts can be assessed, although further analysis of existing data could provide additional insights. This suggests that messages may become clearer with more in-depth study into each of the capitals. Attention also needs to be given to individual well-being effects and the well-being trade-offs individuals are willing to make to ensure a clean, secure supply of energy in the future. On balance, however, emerging evidence indicates the offshore wind industry has a largely positive impact on well-being.

References

ABLE (2015) ABLE Humber Port – ABLE Marine Energy Park http://www.ableuk.com/sites/port-sites/humber-port/amep/ (accessed 31/03/15).

Abraham, A., Sommerhalder, K. and Abel, T. (2010). Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. *International Journal of Public Health*, *55*(1): 59-69.

Adams, T., Miller, R., Aleynik, D. and Burrows, M. (2014). Offshore marine renewable energy devices as stepping stones across biogeographical boundaries. *Journal of Applied Ecology*, 51: 330-338.

Aitken, M. (2010a). Wind power and community benefits: Challenges and opportunities. *Energy Policy* 38: 6066-6075.

Aitken, M. (2010b). Why we still don't understand the social aspects of wind power: a critique of key assumptions within the literature. *Energy Policy* 38: 1834-1841.

Albrecht, C., Wagner, A., Wesselmann, K. and Korb, M. (2013) The Impact of Offshore Wind Energy on Tourism. Good Practices and Perspectives for the South Baltic Region. http://www.offshore-stiftung.com/60005/Uploaded/Offshore_Stiftung%7C2013_04SBO_SOW_tourism_study_final_web.pdf (accessed 02/09/15).

Allan, G. (2013). Community benefits from offshore renewable developments. http://www.climatexchange.org.uk/files/2513/7339/1262/Community_benefits_from_offshore_renewable_developments.pdf (accessed 21/05/15).

Andersson, M. and Öhman, M. (2010). Fish and sessile assemblages associated with wind-turbine constructions in the Baltic Sea. *Marine and Freshwater Research*, 61(6): 642-650.

Ashby, M. (2015) Materials and Sustainable Development. Elsevier, Oxford.

Ashley M.C., Mangi S.C. and Rodwell L.D. (2014). The potential of offshore windfarms to act as marine protected areas – A systematic review of current evidence. *Marine Policy*, 45: 301-309.

Bailey, H., Brookes, K. L., and Thompson, P.M. (2014). Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future. *Aquatic Biosystems*, 10(1): 8.

Barry, J., Ellis, G., Robinson, C. (2008). Cool rationalities and hot air: a rhetorical approach to understanding debated on renewable energy. *Global Environmental Politics* 8(2):67-98.

Bartley, M. (1994). Unemployment and ill health: understanding the relationship *J Epidemiol Community Health* 48:333-337.

BBC (2015). Isle of Wight wind turbine firm Vestas creates 200 jobs http://www.bbc.co.uk/news/uk-england-hampshire-31145066 (accessed 31/03/15).

Belfast Harbour (undated) Renewables offshore report https://www.belfast-harbour.co.uk/port/renewables/ (accessed 21/05/15).

Bergström, L., Sundqvist, F., and Bergström, U. (2013). Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. *Marine Ecology Progress Series*, 485: 199-210.

Bevir, M. (2012). Governance: A very Short Introduction. Oxford University Press, Oxford.

Bilgili, M., Yasar, A. and Simsek, E. (2011). Offshore wind power development in Europe and its comparison with onshore counterpart. *Renewable and Sustainable Energy Reviews,* 15: 905-915

Birklund, J. (2005). Surveys of Hard Bottom Communities on Foundations in Nysted Offshore Wind Farm and Schönheiders Pulle in 2004. Report by DHI and ENERGI E2. pp 46.

Blyth-Skyrme, R. (2010). Options and Opportunities for Marine Fisheries Mitigation Associated with Windfarms. Report by Ichthys Marine Ecological Consulting. pp 70.

Bolle, L. J., De Jong, C. A., Bierman, S. M., Van Beek, P. J., Van Keeken, O. A., Wessels, P. W., van Damme C.J.G, Winter, H.V., de Haan, D. & Dekeling, R. P. (2012). Common sole larvae survive high levels of pile-driving sound in controlled exposure experiments. *PLoS One*, *7*(3), e33052-e33052.

Börger, T., Hattam, C., Burdon, D., Atkins, J. P. and Austen, M. C. (2014). Valuing conservation benefits of an offshore marine protected area. *Ecological Economics*, 108: 229-241.

Brandt, M. J., Diederichs, A., Betke, K., & Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series*, *421*, 205-216.

Brasseur, S., Aarts, G., Meesters, E., Petel, T., Dijkman, E., Cremer, J. and Reijnders, P. (2012). Habitat Preferences of Harbour Seals in the Dutch Coastal Area: Analysis and Estimate of Effects of Offshore Wind Farms. Report by IMARES - Wageningen UR and Noordzeewind. pp 58.

Broström, G. (2008). On the influence of large wind farms on the upper ocean circulation. *Journal of Marine Systems*, 74(1): 585-591.

Buck, B. H., Ebeling, M. W., and Michler-Cieluch, T. (2010). Mussel cultivation as a co-use in offshore wind farms: potential and economic feasibility. *Aquaculture Economics and Management*, 14(4): 255-281.

Buck, B. H., Krause, G. and Rosenthal, H. (2004). Extensive open ocean aquaculture development within wind farms in Germany: the prospect of offshore co-management and legal constraints. *Ocean and Coastal Management*, 47(3): 95-122.

Buck, B. H., Krause, G., Michler-Cieluch, T., Brenner, M., Buchholz, C. M., Busch, J. A., Fisch R., Geisen M. and Zielinski, O. (2008). Meeting the quest for spatial efficiency: progress and prospects of extensive aquaculture within offshore wind farms. *Helgoland Marine Research*, 62(3): 269-281.

Bunker, F. (2004). Biology and Video Surveys of North Hoyle Wind Turbines 11th-13th August 2004. Report by Centre for Marine and Coastal Studies Ltd (CMACS). pp 32.

Busch, M., Gee, K., Burkhard, B., Lange, M. and Stelljes, N. (2011). Conceptualizing the link between marine ecosystem services and human well-being: the case of offshore wind farming. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 7(3): 190-203.

BusinessGreen (2014). Northern Ireland's only offshore wind project scrapped http://www.businessgreen.com/bg/news/2384460/northern-irelands-only-offshore-wind-project-scrapped (accessed 13/05/15).

BVG (2012). UK content analysis of Robin Rigg offshore wind farm operations and maintenance. https://www.eonenergy.com/~/media/PDFs/Generation/wind/offshore/Eon_Robin_Rigg_OM_report.pdf (accessed 21/05/15)

BVG (2014) UK offshore wind supply chain: capabilities and opportunities https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277798/bis-14-578-offshore-wind-supply-chain-capabilities-and-opportunities.pdf (accessed 20/07/15).

BWEA (2006). The impact of wind farms on the tourist industry in the UK. Prepared by the British Wind Energy Association (BWEA) For the All-Party Parliamentary Group on Tourism. May 2006.

Cambridge Econometrics (2012). A study into the Economics of gas and offshore wind. http://www.camecon.com/libraries/downloadable_files/a_study_into_the_economics_of_gas_and_offshore_wind.sflb.ashx (accessed 24/03/15).

Carbon Trust (2014a). Offshore Wind in China – Sharing the UK's policy experience http://www.carbontrust.com/media/510538/carbon-trust-offfshore-wind-policy-report.pdf (accessed 30/05/15).

Carbon Trust (2014b). Mapping existing technology solutions to barriers identified in China's Offshore Wind Industry http://www.carbontrust.com/media/510534/offshore-wind-china-mapping-existing-technology-solutions.pdf (accessed 30/05/15).

Carbon Trust (2014c). Detailed appraisal of the offshore wind industry in China http://www.carbontrust.com/media/510530/detailed-appraisal-of-the-offshore-wind-industry-in-china.pdf (accessed 30/05/15).

Carstensen, J., Henriksen, O. and Teilmann, J. (2006). Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). *Marine Ecology Progress Series*, 321: 295-308.

Castro-Sitiriche, M.J. and Ndoye M. (2013). On the links between sustainable wellbeing and electric energy consumption. *Africa Journal of Science, Technology, Innovation and Development* 5(4):327-335.

Cass, N., Walker, G. and Devine-Wright, P. (2010). Good neighbours, public relations and bribes: the politics and perceptions of community benefit provision in renewable energy development in the UK. *Journal of Environmental Policy and Planning*, 12(3): 255-275.

CEBR (2012). The macroeconomic benefits of investment in offshore wind. http://mainstreamrp.com/content/reports/benefits-of-offshore-wind.pdf (accessed 19/06/15).

CCF (2014). Coastal Communities Fund Annual progress report 2014 https://www.gov.uk/government/publications/coastal-communities-fund-annual-progress-report-2014 (accessed 31/03/15).

Chinn, M. (2014). The UK Offshore Wind Supply Chain: A review of opportunities and barriers. http://www.thecrownestate.co.uk/media/389763/owic-uk-offshore-wind-supply-chain-review-opportunities-barriers.pdf (accessed 30/03/15).

Christiansen, M. B. and Hasager, C. B. (2005). Wake effects of large offshore wind farms identified from satellite SAR. *Remote Sensing of Environment*, 98(2): 251-268.

Christie, E., Li, M. and Moulinec, C. (2012). Comparison of 2d and 3d large scale morphological modeling of offshore wind farms using HPC. *Coastal Engineering Proceedings*, 1(33), sediment-42.

Coates, D. A., Deschutter, Y. et al. (2014). Enrichment and shifts in macrobenthic assemblages in an offshore wind farm area in the Belgian part of the North Sea. *Marine Environmental Research* 95: 1-12.

Collier, C. (2010). From aircraft wings to wind turbine blades: NASA software comes back to Earth with green energy applications. http://www.techbriefs.com/legal-footer-127/23-ntb/features/feature-articles/8602-28058-121?limitstart=0 (accessed 30/03/15)

Collingwood Environmental Planning (2015) CORR/5536 A two way Conversation with the people of Scotland on the Social Impact of Offshore Renewables. Draft Dialogue Report. Prepared for Marine Scotland.

Commission of the European Communities (2009). GDP and Beyond: Measuring Progress in a Changing World.

Cost Reduction Task Force (2012). Offshore Wind Cost Reduction Task Force Report. pp44. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66776/5584-offshore-wind-cost-reduction-task-force-report.pdf (accessed 31/03/15).

Costanza, R. (2003). Social goals and the valuation of natural capital. *Environmental Monitoring and Assessment* 86: 19–28.

Cote, S. and Healy, T. (2001). *The Well-being of Nations. The role of human and social capital.* Organisation for Economic Co-operation and Development, Paris.

Cowell R., Bristow G. and Munday M. (2012) Wind Energy and Justice for Disadvantaged Communities. Joseph Rowntree Foundation. http://www.jrf.org.uk/publications/wind-energy-disadvantaged-communities (accessed 31/03/15)

Daan, R., Mulder, M. and Bergman, M. (2006). Impact of Windfarm OWEZ on the Local Macrobenthos Community. Report by IMARES - Wageningen UR and Noordzeewind. pp 79.

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., Sundermeyer, J. and Siebert, U. (2013). Effects of pile-driving on harbour porpoises (Phocoena phocoena) at the first offshore wind farm in Germany. *Environmental Research Letters*, 8: 1-16.

DCLG (2014). The Growing Places Fund: Investing in Infrastructure. Department for Communities and Local Government. pp22. https://www.gov.uk/government/publications/the-growing-places-fund-investing-in-infrastructure (accessed 31/03/15).

de Groot, J., Campbell, M., Ashley, M. and Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management*, 102**:** 7-18.

De Mesel, I., F. Kerckhof, Norro, A., Rimes, B. and Degraer, S. (2015). Succession and seasonal dynamics of the epifauna community on offshore wind farm foundations and their role as stepping stones for non-indigenous species. Hydrobiologia.

DECC (2009). UK Offshore Energy Strategic Environmental Assessment. Future Leasing for Offshore Wind Farms and Licensing for Offshore Oil and Gas and Gas Storage. Environmental Report. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/194328/OES_Environmental_Report.pdf (accessed 31/03/15).

DECC (2010). Offshore manufacturing sets sail for UK ports. https://www.gov.uk/government/news/offshore-manufacturing-sets-sail-for-uk-ports (accessed 19/06/15).

DECC (2013). UK renewable energy roadmap—update 2013. https://www.gov.uk/government/publications/uk-renewable-energy-roadmap-second-update (accessed 31/03/15).

DECC (2014a). UK Energy in Brief 2014. www.gov.uk/government/collections/uk-energy-in-brief (accessed 30/05/15).

DECC (2014b). Delivering UK Energy Investment. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/331071/DECC_Energy_Investment_Report.pdf (accessed 30/05/2015).

Degraer, S. and Brabant, R. (2009). Offshore Wind Farms in the Belgian Part of the North Sea: State of the Art After Two Years of Environmental Monitoring. Report by Ghent University, Institute for Agricultural and Fisheries Research (ILVO), Management Unit of the North Sea Mathematical Models (MUMM), Royal Belgian Institute of Natural Sciences (RBINS), and The Research Institute for Nature and Forest (INBO). pp 327.

Department for Transport (2012). National Policy Statement for Ports https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/3931/national-policy-statement-ports.pdf (accessed 28/05/15)

Devine-Wright, P. and Howes, Y. (2010). Disruption to place attachment and the protection of restorative environments: A wind energy case study. *Journal of Environmental Psychology*, 30(3): 271-280.

Dodge, R., Daly, A. P., Huyton, J. and Sanders, L. D. (2012). The challenge of defining wellbeing. International. *Journal of Wellbeing* 2:222-235.

Dolan, P. and Metcalfe, R. (2012). Measuring subjective wellbeing: recommendations on measures for use by national governments. *Journal of Social Policy* 41(2): 409-427.

Dolan, P., Peasgood, T. and White, M. (2008). Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being. *Journal of Economic Psychology* 29:94-122.
Dudgeon Offshore Wind Farm (2012). Community Fund. http://dudgeonoffshorewind.co.uk/community/community.php (accessed 30/03/15).
E.ON (2015a). E.ON launches £2m Community Benefit Fund as the Humber Gateway Wind Farm generates electricity for the first time. http://pressreleases.eon-uk.com/blogs/eonukpressreleases/archive/2015/02/24/2413.aspx (accessed 30/03/15).
E.ON. (2015b). Robin Rigg. https://www.eonenergy.com/About-eon/our-company/generation/our-current-portfolio/wind/offshore/robin-rigg (accessed 30/03/15).
Edrén, S., Andersen, S., Teilmann, J., Carstensen, J., Harders, P., Dietz, R. and Miller, L. (2010). The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. *Marine Mammal Science*, 26(3): 614-634.
Edwards, I. (2011). Overcoming Challenges for the offshore Wind Industry and Learning from the Oil and Gas Industry http://www.power-cluster.net/Portals/6/Offshore%20wind%20report%20Overcoming%20Challenges%20for%20the%20Offshore%20Wind%20Industry.pdf (accessed 28/05/15).
Ellis, G., Barry, J., Robinson, C., (2007). Many ways to say 'no', different ways to say 'yes': applying Q-methodology to understand public acceptance of wind farm proposals. *Journal of Environmental Planning and Management* 50 (4), 517–551.
Environmental Audit Committee (2014). Energy subsidies. http://www.parliament.uk/business/committees/committees-a-z/commons-select/environmental-audit-committee/inquiries/parliament-2010/energy-subsidies-in-the-uk/ (accessed 22/05/15)
ESD (2004). Offshore wind onshore jobs – a new industry. http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/6702.pdf (accessed 21/05/15.)
ETI (2014). Offshore Wind http://www.eti.co.uk/wp-content/uploads/2014/03/Offshore-Wind-Brochure1.pdf (accessed 31/03/15).
ETI (2015). Offshore Wind. Technology innovation to improve reliability and reduce through-life costs http://www.eti.co.uk/programme/offshore-wind/ (accessed 31/03/15).
EUSkills (2015). Energy & Utility Skills: Attract, Develop and Assure. http://www.euskills.co.uk/about-us (accessed 26/03/15).
EWEA (2015). The European offshore wind industry - key trends and statistics 2014 http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2014.pdf (accessed 31/03/15).
Fialte Ireland (2008). Wind Farms. Visitor Attitudes on the Environment, 2008/No.3

Fisher C. and Slater M. (2010) *Effects of electromagnetic fields on marine species: A literature review.* Report prepared for the Oregon Wave Trust. September 2010.

Forum for the Future (1990). The Five Capitals http://www.forumforthefuture.org/project/five-capitals/overview (accessed 31/03/15).

Forum for the Future (2007). The Five Capitals Model – a framework for sustainability. https://www.forumforthefuture.org/sites/default/files/project/downloads/five-capitals-model.pdf (accessed 28/05/15).

Forewind. 2014. Forewind partners harbour porpoise research programme. http://www.forewind.co.uk/news/117/34/Forewind-partners-harbour-porpoise-research-programme.html Accessed 24 August 2015.

Frantal, B. and Kunc, J. (2011). Wind turbines in tourism landscapes: Czech experience. *Annals of tourism research*, 38(2): 499-519.

Garrard, A. (2012). Lessons learned from the development of the wind energy industry that might be applied to marine industry renewables. *Philosophical Transactions of the Royal Society A* 370: 451-471.

Gee, K. and Burkhard, B. (2010). Cultural ecosystem services in the context of offshore wind farming: a case study from the west coast of Schleswig-Holstein. *Ecological Complexity*, 7(3): 349-358.

Gerdes, G., Tiedemannm, A. and Zeelenberg, S. (2006). Case Study: European Offshore Wind Farms-A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms. http://tethys.pnl.gov/publications/case-study-european-offshore-wind-farms (accessed 31/03/15).

Gibson, E and Howsam, P. (2010). The legal framework for offshore wind farms: a critical analysis of the consent process. *Energy Policy* 38: 4692-4702.

Gill A.B., Gloyne-Phillips I., Neal, K.J. and Kimber, J.A. (2005). *The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review*. COWRIE 1.5 Electromagnetic Fields Review. COWRIE-EM FIELD 2-06-2004. July 2005.

Gill, A. B., Bartlett, M. and Thomsen, F. (2012). Potential interactions between diadromous fishes of UK conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. *Journal of Fish Biology*, 81(2): 664-695.

Gill, A., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. and Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF Sensitive Fish Response to EM Emissions from Sub-sea Electricity Cables of the Type used by the Offshore Renewable Energy Industry. Report by Centre for Environment Fisheries and Aquaculture Science (CEFAS), Centre for Intelligent Monitoring Systems (CIMS), Centre for Marine and Coastal Studies Ltd (CMACS), Cranfield University, and University of Liverpool. pp 128.

Glasgow Calendonian University (2008). The economic impacts of wind farms on Scottish tourism: a report for the Scottish Government http://www.gov.scot/resource/doc/214910/0057316.pdf (accessed 30/03/2015).

Gosden (2014). Norfolk crab fishermen forced out to make way for offshore wind farm works http://www.telegraph.co.uk/news/earth/energy/11031591/Norfolk-crab-fishermen-forced-out-to-make-way-for-offshore-wind-farm-works.html (accessed 21/05/15).

Grantscape (2015). Burbo Bank Extension Community Fund. http://grantscape.org.uk/bbecbf/ (accessed 30/03/15).

Gray, M. and Stromberg, P-L. In prep. Changes to fishing practices around the UK as a result of the development of offshore windfarms – Phase I. Report for The Crown Estate. Draft November 2014. 148pp

Gray, T., Haggett, C. and Bell, D. (2005) Offshore wind farms and commercial fisheries in the UK: A study in stakeholder consultation. *Ethics, Place and Environment* 8(2):127-140,

Greenacre, P., Gross, R. and Heptonstall, P. (2010). Great Expectations: The cost of offshore wind in UK waters - understanding the past and projecting the future. A report produced by the Technology and Policy Assessment Function of the UK Energy Research Centre.

GreenPortHull (2015). Project Update http://greenporthull.co.uk//uploads/files/Green_Port_Project_Update_Brochure.pdf (accessed 30/03/15).

Grimsby Telegraph (2013a). Wind firm harbours a grand plan for Grimsby's Royal Dock http://www.grimsbytelegraph.co.uk/Wind-firm-harbours-grand-plan-Grimsby-s-Royal/story-18256778-detail/story.html (accessed 30/03/15).

Grimsby Telegraph (2013b). 100 jobs as Danish energy giant DONG commits to Grimsby for offshore wind operations and maintenance http://www.grimsbytelegraph.co.uk/s-pound-11m-Dong-deal/story-20306885-detail/story.html (accessed 30/03/15).

Guillemette, M., Larsen, J. and Clausager, I. (1998). Impact Assessment of an Off-shore Wind Park on Sea Ducks. Report by National Environmental Research Institute (NERI). pp 63.

GWEC (2012). Global Wind Report 2012 http://www.gwec.net/wp-content/uploads/2013/07/Global-Offshore-2012.pdf (accessed 30/03/15).

Haggett, C. (2008) Over the sea and far away? A consideration of the planning, politics and public perceptions of offshore wind farms. *Journal of Environmental Policy and Planning* 10 (3), 289-306.

Haggett, C. (2011). Understanding public responses to offshore wind power. *Energy Policy*, 39(2), 503-510.

Higgins, P. and Foley, A. (2014). The evolution of offshore wind power in the United Kingdom. *Renewable and Sustainable Energy Reviews* 37: 599-612.

HM Government (2011a). Centre for Offshore Renewable Engineering. Department for Business, Innovation and Skills. pp18.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31730/11-1393-centres-for-offshore-renewable-engineering.pdf (accessed 31/03/15).
HM Government (2011b). *The Natural Choice: securing the value of nature*. Natural Environment White Paper. June 2011.
HM Government (2012). Building offshore wind in England: CORE – Centres for offshore renewable engineering. http://www.liverpoollep.org/pdf/CORE%20Brochure-FINAL.pdf (accessed 26/03/15).
HM Government (2013). Offshore Wind Industrial Strategy. Business and Government Action https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243987/bis-13-1092-offshore-wind-industrial-strategy.pdf (accessed 30/03/15).
HM Government (2014). Overview of support for the offshore wind industry. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319026/bis-14-880-support-for-the-offshore-wind-industry-overview.pdf (accessed 25/03/15).
HM Government/British Embassy Seoul (2015). https://www.gov.uk/government/world-location-news/south-korean-wind-tower-manufacturer-plans-to-set-up-production-facilities-in-the-uk (accessed 30/03/15).
Hooper T. and Austen M. (2014). The co-location of offshore windfarms and decapod fisheries in the UK: Constraints and opportunities. *Marine Policy*, 43: 295-300.
Hooper, T., Ashley, M. and Austen, M. 2015. Perceptions of fishers and developers on the co-location of offshore wind farms and decapod fisheries in the UK. *Marine Policy* 61:16-22 doi:10.1016/j.marpol.2015.06.031
Humber LEP (2014). Humber LEP secures £14.9m EZ grant for Able Marine Energy Park http://www.humberlep.org/news108/ (accessed 30/03/15).
IISD 2008. The Natural Capital Approach: a concept paper. https://www.iisd.org/pdf/2008/natural_capital_approach.pdf (accessed 31/05/15).

Inger, R., Attrill, M. J., Bearhop, S., Broderick, A. C., James Grecian, W., Hodgson, D. J., Mills C., Sheehan E., Votier S.C., Witt M.J. & Godley, B. J. (2009). Marine renewable energy: potential benefits to biodiversity? An urgent call for research. *Journal of Applied Ecology*, 46(6): 1145-1153.
Ison, E. and Pearce-Smith, N. (2009) Rapid Review of Health Impacts of Wind Energy www.apho.org.uk/resource/view.aspx?RID=83200 (accessed 02/09/15).
Jakob, T., Carstensen, J., Wisz, M., Jespersen, M., Teilmann, J., Bech, N. and Skov, H. (2006). Harbour Porpoises on Horns Reef Effects of the Horns Reef Wind Farm. Report by DHI, National Environmental Research Institute (NERI), and Vattenfall A/S. pp 111.
Janßen, H., C. B. Augustin, et al. (2013). Impact of secondary hard substrate on the distribution and abundance of Aurelia aurita in the western Baltic Sea. *Marine Pollution Bulletin,* 75(1-2): 224-234.

Jay, S. (2010). Planners to the rescue: spatial planning facilitating the development of offshore wind energy. *Marine Pollution Bulletin* 60: 493-499.

Karlstrøm, H. and M. Ryghaug (2014). Public attitudes towards renewable energy technologies in Norway. The role of party preferences. *Energy Policy,* 67: 656-663.

Kastelein, R. A., D. van Heerden, et al. (2013). Behavioral responses of a harbor porpoise (Phocoena phocoena) to playbacks of broadband pile driving sounds. *Marine Environmental Research,* 92: 206-214.

Kerckhof, F., Rumes, B., Jacques, T., Degraer, S. and Norro, A. (2010). Early development of the subtidal marine biofouling on a concrete offshore windmill foundation on the Thornton Bank (Southern North Sea): first monitoring results. *International Journal of the Society for Underwater Technology*, 29(3), 137-149.

Kern, F., Smith, A., Shaw., C., Raven., R. and Verhees, B. (2014). From laggard to leader: explaining offshore wind developments in the UK. Energy Policy 69:635-646.

Keuhn, S. (2005). Sociological Investigation of the Reception of Horns Rev and Nysted Offshore Wind Farms in the Local Communities. Annual status report 2003 to Elsam Engineering.

Koschinski, S., Culik, B., Henriksen, O., Tregenza, N., Ellis, G., Jansen, C. and Kathe, G. (2003). Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator. *Marine Ecology Progress Series*, 265: 263-273.

Krause, G., Griffin, R. M. and Buck, B. H. (2011). Perceived Concerns and Advocated Organisational Structures of Ownership Supporting 'Offshore Wind Farm–Mariculture Integration' (pp. 203-218). INTECH.

La Placa, V., McNaught, A. and Knight, A. (2013). Discourse on wellbeing in research and practice. *International Journal of Wellbeing* 3:116-125.

Ladenburg, J. (2008). Attitudes towards on-land and offshore wind power development in Denmark; choice of development strategy. *Renewable Energy*, 33(1): 111-118.

Ladenburg, J. (2009). Visual impact assessment of offshore wind farms and prior experience. *Applied Energy*, 86(3): 380-387.

Ladenburg, J. (2010). Attitudes towards offshore wind farms: the role of beach visits on attitude and demographic and attitude relations. *Energy Policy,* 38(3): 1297-1304.

Ladenburg, J. and Dubgaard, A. (2007). Willingness to pay for reduced visual disamenities from offshore wind farms in Denmark. *Energy Policy*, 35(8): 4059-4071.

Ladenburg, J. and Dubgaard, A. (2009). Preferences of coastal zone user groups regarding the siting of offshore wind farms. *Ocean and Coastal Management*, 52(5): 233-242.

LCICG (2012). Technology Innovation Needs Assessment (TINA). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48279/4467-tina-offshore-wind-summary.pdf (accessed 27/03/15).

Lee, A. C. K. and Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health*, 33(2): 212-222.

Leeney, R. H., Greaves, D., Conley, D. and O'Hagan, A.M. (2014). Environmental Impact Assessments for wave energy developments - Learning from existing activities and informing future research priorities. *Ocean and Coastal Management* 99: 14-22.
Lengkeek, W and Bouma, S. (2009). Development of Underwater Flora and Fauna Communities on Hard Substrates of the Offshore Wind Farm Egmond aan Zee. Report by Bureau Waardenburg bv and Noordzeewind. pp 49
Leonhard S.B. and Pedersen J. (2006). Benthic Communities at Horns Rev Before, During and After Construction of Horns Rev Offshore Wind Farm: Final Report. Report by Bioconsult and Vattenfall A/S. pp 134.
Li, X., Chi, L., Chen, X., Ren, Y., and Lehner, S. (2014). SAR observation and numerical modeling of tidal current wakes at the East China Sea offshore wind farm. *Journal of Geophysical Research: Oceans*, 119(8): 4958-4971.
Linley, E. A. S., Wilding, T. A., Black, K., Hawkins, A. J. S. and Mangi, S. (2007). Review of the reef effects of offshore wind farm structures and their potential for enhancement and mitigation. *Report to the Department for Business, Enterprise and Regulatory Reform. RFCA*, *5*.
London Array. (2015). Community Facts at Your Fingertips. http://www.londonarray.com/community-2/key-facts/ (accessed 30/03/15).
Loomis, J. B. and White, D. S. (1996). Economic benefits of rare and endangered species: summary and meta-analysis. *Ecological Economics*, 18(3): 197-206.
Mackinson, S., Curtis, H., Brown, R., McTaggart, K., Taylor, N., Neville, S. and Rogers, S. (2006). A Report on the Perceptions of the Fishing Industry into the Potential Socio-Economic Impacts of Offshore Wind Energy Developments on their Work Patterns and Income. Report by Centre for Environment Fisheries and Aquaculture Science (CEFAS). pp 62.
Maclean, I., Rehfisch, M. M., Skov, H., & Thaxter, C. B. (2013). Evaluating the statistical power of detecting changes in the abundance of seabirds at sea. *Ibis*, *155*(1), 113-126.
Markandya, A. and Wilkinson, P. (2007) Electricity generation and health. Lancet 370; 979-990
Markard J., and Petersen, R. (2009). The offshore trend: structural changes in the wind power sector. *Energy Policy* 37(9): 3545–56.
Masden E.A., Haydon D.T., Fox A.D., Furness, R.W., Bullman R. and Desholm, M. (2009). Barriers to movement: Impacts of wind farms on migrating birds. *ICES Journal of Marine Science*, 66(4): 746-753.
McConnell, B., Lonergan, M., Dietz, R. 2012. 'Interactions between seals and offshore wind farms.' The Crown Estate, 41 pages.
Mee, L. (2006). Complementary benefits of alternative energy: suitability of offshore wind farms as aquaculture sites. Inshore Fisheries and Aquaculture Technology Innovation and Development SEAFISH - Project Ref: 10517.

http://www.seafish.org/media/Publications/10517_Seafish_aquaculture_windfarms.pdf (accessed 21/05/15).
Michler-Cieluch, T. and Kodeih, S. (2008). Mussel and seaweed cultivation in offshore wind farms: An opinion survey. *Coastal Management* 36(4): 392-411.
Michler-Cieluch, T., and Krause, G. (2008). Perceived concerns and possible management strategies for governing 'wind farm–mariculture integration'. *Marine Policy*, 32(6), 1013-1022.
Michler-Cieluch, T., Krause, G., and Buck, B. H. (2009a). Marine aquaculture within offshore wind farms: Social aspects of multiple-use planning. *GAIA-Ecological Perspectives for Science and Society*, 18(2): 158-162.
Michler-Cieluch, T., Krause, G., and Buck, B. H. (2009b). Reflections on integrating operation and maintenance activities of offshore wind farms and mariculture. *Ocean and Coastal Management*, *52*(1): 57-68.
Millennium Ecosystem Assessment (2003). Ecosystems and Human Well-Being: A Framework for Assessment. Island Press. Washington DC.
MMO (2014a). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, pp 194. MMO Project No: 1031. ISBN: 978-1-909452-24-4.
MMO (2014b). Scoping of a robust approach to the assessment of co-existence of activities in marine plan areas. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/317791/1049.pdf (accessed 22/05/15).
Moran, C.J., Franks, D.M. and Sonter, L.J. (2013). Using the multiple capitals framework to connect indicators of regional cumulative impacts of mining and pastoralism in the Murray Darling Basin, Australia. *Resources Policy* 38: 733-744.
Mueller-Blenkle, C., McGregor, P.K., Gill, A.B., Andersson, M.H., Metcalfe, J., Bendall, V., Sigray, P., Wood, D.T. and Thomsen, F. (2010). Effects of Pile-driving Noise on the Behaviour of Marine Fish. COWRIE Ref: Fish 06-08, Technical Report 31st March 2010
Natural Capital Committee. (2013). The State of Natural Capital: Towards a framework for measurement and valuation. April 2013.
News Letter (2014). Offshore wind farms blow new energy into Kilkeel fishing fleet's sails. http://www.newsletter.co.uk/news/business/offshore-wind-farms-blow-new-energy-into-kilkeel-fishing-fleet-s-sails-1-5806543 (accessed 21/05/15).
Newton, I. and Little, B. (2009). Assessment of wind-farm and other bird casualties from carcasses found on a Northumbrian beach over an 11-year period. *Bird Study*, 56(2): 158-167.
NFO (2003). *Investigation into the potential Impact of Wind Farms on Tourism in Wales*, prepared for Wales Tourist Board.
NFO System Three (2002). *Investigation into the Potential Impact of Wind Farms on Tourism in Scotland* Final Report, prepared for Visit Scotland

Nicholls, L. (2015) DECC postpones next Contracts for Difference auction http://www.edie.net/news/6/Contracts-for-Difference-CfD-2015-auction-postponed-by-DECC/ (accessed 06/09/15)

Ochieng, E.G., Melanie, Y., Potts, S.J., Zuofa, T., Egbu, C.O., Price, A.D.F. and Ruan, X. (2014). Future for offshore wind energy in the United Kingdom: the way forward. *Renewable and Sustainable Energy Reviews* 39: 655-666.

OECD. (2011). OECD Better Life Initiative Compendium of OECD Well-being Indicators. Organisation of Economic Cooperation and Development, Paris.

OffshoreWIND.biz (2014) Offshore Wind Sparks Belfast Harbour's Trade Rise https://www.offshorewind.biz/2014/01/31/offshore-wind-sparks-belfast-harbours-trade-rise/ (accessed 30/05/15).

Ofgem. (2010). Ofgem's role in offshore transmission

Öhman, M.C., Sigray P., and Westerberg H. (2007). Offshore windmills and the effects of electromagnetic fields on fish. *AMBIO: A journal of the Human Environment*, 36(8): 630-633.

O'Keefe, A. and Haggett, C. (2012) An investigation into the potential barriers facing the development of offshore wind energy in Scotland: Case study – Firth of Forth offshore wind farm. Renewable and Sustainable Energy Reviews 16: 3711-3721.

ONS (2015). Unemployment. http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Unemployment#tab-data-tables (accessed 21/05/15).

ORE Catapult (2014). Generating energy and prosperity: Economic impact study of the offshore renewable energy industry in the UK. https://ore.catapult.org.uk/documents/10619/116053/pdf/15b55f52-5a1f-4e5a-aa32-ee0dba297bce (accessed 30/03/15).

ORE Catapult (2015a). Who we are. https://ore.catapult.org.uk/who-we-are (accessed 22/05/15).

ORE Catapult (2015b). Offshore Renewable Energy Catapult. https://ore.catapult.org.uk/training (accessed 26/03/15).

Papathanasopoulou, E., Beaumont, N., Lear, D., Fisher, E., Walker, P., Midlen, A. and M. Austen. (2013). Social impacts of fisheries, aquaculture, recreation, tourism and marine protected areas (MPAs) in marine plan areas in England. MMO report 1035: http://webarchive.nationalarchives.gov.uk/20140108121958/http:/www.marinemanagement.org.uk/evidence/documents/1035.pdf

Pasternak, A.D. (2000). Global Energy Futures and Human Development: A Framework for Analysis http://www.geni.org/globalenergy/issues/global/qualityoflife/HDI-and-electricity-consumption.pdf (accessed 21/05/15).

Pearce, B., J. M. Fariñas-Franco, Wilson, C., Pitts J., deBurgh A. and Somerfield P.J. (2014). Repeated mapping of reefs constructed by Sabellaria spinulosa Leuckart 1849 at an offshore wind farm site. *Continental Shelf Research* 83: 3-13.

Perrow M.R., Gilroy J.J., Skeate E.R. and Tomlinson M.L. (2011). Effects of the construction of Scroby Sands offshore wind farm on the prey base of little tern *Sternula albifrons* at its most important UK colony. *Marine Pollution Bulletin*, 62(8): 1661-1670.

Perveen, R., Kishor, N. and Mohanty, S. (2014). Off-shore wind farm development: present status and challenges. *Renewable and Sustainable Energy Reviews* 29: 780-792.

Petersen, I., Christensen, T., Kahlert, J., Desholm, M. and Fox, A. (2006). Final Results of Bird Studies at the Offshore Wind Farms at Nysted and Horns Rev, Denmark. Report by DONG Energy, National Environmental Research Institute (NERI), and Vattenfall A/S. pp 166.

Pettersson, J. (2005). The Impact of Offshore Wind Farms on Bird Life in Southern Kalmar Sound, Sweden. Report by Lund University. pp 128.

Pettersson, J. and Fågelvind, J. (2011). Night migration of songbirds and waterfowl at the Utgrunden off-shore wind farm. Report by Swedish Environmental Protection Agency and Vindval. pp 59.

Pettinger, T. 2012. The Decline of the UK Coal Industry. Accessed 10/09/15. Available from http://www.economicshelp.org/blog/6498/uncategorized/the-decline-of-the-uk-coal-industry/

Plonczkier, P. and Simms, I. (2012). Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. *Journal of Applied Ecology*, 49(5): 1187-1194.

Powlesland, R. G. (2009). Impacts of wind farms on birds: a review. *Science for Conservation*, (289). Department of Conservation, Wellington, New Zealand. 51pp

Randall, C., Corp, A. and Self, A. (2014). Measuring National Well-being: Life in the UK, 2014. Office for National Statistics.

REA (2014). Renewable Energy View.http://www.r-e-a.net/resources/rea-publications (accessed 30/05/15).

Regeneris (2014). Triton Knoll Offshore Wind Farm – Impacts Study. http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCYQFjAA&url=http%3A%2F%2Fwww.rwe.com%2Fweb%2Fcms%2Fmediablob%2Fen%2F2576320%2Fdata%2F1576882%2F4%2Frwe-innogy%2Fsites%2Fwind-offshore%2Fdeveloping-sites%2Ftriton-knoll%2Fworking-with-businesses%2FTriton-Knoll-Offshore-Wind-Farm-Impacts.pdf&ei=tfBrVcLSJaas7Ab9l4PIDQ&usg=AFQjCNF-0KgjYH2CmSWk8q7DJ5WriTIaMQ&bvm=bv.94455598,d.bGg (accessed 21/05/15).

RegenSW (2015). Falling costs underpin CfD auction success, but the UK offshore wind sector needs greater certainty to fuel future growth. http://www.regensw.co.uk/blog/2015/03/march-2015-offshore-wind-update/ (accessed 18/06/15).

RenewableUK (2012). Onshore Wind: Direct and Wider Economic Impacts https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48359/5229-onshore-wind-direct--wider-economic-impacts.pdf (accessed 21/05/15).

RenewableUK (2013). Working for a Green Britain & Northern Ireland 2013-23. http://www.renewableuk.com/en/publications/index.cfm/working-green-britain (accessed 21/05/15).

RenewableUK (2015a) Offshore wind regenerates British coastal communities. http://www.renewableuk.com/en/news/press-releases.cfm/2015-01-26-offshore-wind-regenerates-british-coastal-communities (accessed 27/03/15).

RenewableUK (2015b) The voice of wind & marine energy. http://www.renewableuk.com/en/our-work/skills-and-employment/renewables-training-network.cfm (accessed 26/03/15).

Reubens, J., Braeckman, U., Vanaverbeke, J., van Colen, C., Degraer, S. and Vincx, M. (2013a). Aggregation at windmill artificial reefs: CPUE of Atlantic cod (Gadus morhua) and pouting (Trisopterus luscus) at different habitats in the Belgian part of the North Sea. *Fisheries Research*, 139: 28-34.

Reubens, J., Pasotti, F., Degraer, S. and Vincx, M. (2013b). Residency, site fidelity and habitat use of Atlantic cod (Gadus morhua) at an offshore wind farm using acoustic telemetry. *Marine Environmental Research*, 90: 128-135.

Reubens, J., Rijcke, M., Degraer, S. and Vincx, M. (2014). Diel variation in feeding and movement patterns of juvenile Atlantic cod at offshore wind farms. *Journal of Sea Research*, 85: 214-221.

Reubens, J., Vandendriessche, S., Zenner, A., Degraer, S. and Vincx, M. (2013c). Offshore wind farms as productive sites or ecological traps for gadoid fishes? Impact on growth, condition index and diet composition. *Marine Environmental Research*, 90: 66-74.

Richardson, L. and Loomis, J. (2009). The total economic value of threatened, endangered and rare species: an updated meta-analysis. *Ecological Economics*, 68(5): 1535-1548.

Ross, C.E. and Wu, C-L. (1995). The links between education and health. *American Sociological Review* 60(5) 719-745.

Rothery, P., Newton, I. and Little, B. (2009). Observations of seabirds at offshore wind turbines near Blyth in northeast England. *Bird Study*, 56(1): 1-14.

Rudolph, D. (2014). The resurgent conflict between offshore wind farms and tourism: underlying storylines. *Scottish Geographical Journal* 130(3): 168-187.

Russell D.J.F., Brasseur S.M.J.M., Thompson D., Hastie G.D., Janik V.M., Aarts G., McClintock B.T., Matthiopoulos J., Moss S.E.W. and McConnell B. (2014). Marine mammals trace anthropogenic structures at sea. *Current Biology*, 24: R638-R639.

RWE (2013). North Hoyle Wind Farm fund. http://www.rwe.com/web/cms/en/311624/rwe-innogy/sites/wind-offshore/in-operation/north-hoyle/local-community (accessed 30/03/15).

RWE (2014a). Investing in Communities http://www.rwe.com/web/cms/en/1252462/rwe-innogy/sites/wind-offshore/under-construction/gwynt-y-mr/investing-in-communities/ (accessed 31/03/15).

RWE (2014b). Local Community http://www.rwe.com/web/cms/en/478728/rwe-innogy/sites/wind-offshore/in-operation/rhyl-flats/local-community/ (accessed 31/03/15).
Scarff, G., Fitzsimmons, C. and Gray, T. (2015). The new mode of marine planning in the UK: aspirations and challenges. *Marine Policy* 51: 96-102.
Scheidat, M., Tougaard, J., Brasseur, S., Carstensen, J., Petel, T., Teilmann, J. and Reijnders, P. (2011). Harbor porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea. *Environmental Research Letters*, 6(6): 1-10.
Schultz, T.W. (1961). Investment in human-capital. *American Economic Review* 51: 1-17.
Shankleman, J. (2013). Are Britain's ports ready to reap the benefits of offshore wind power? http://www.businessgreen.com/bg/feature/2269247/are-britain-s-ports-ready-to-reap-the-benefits-of-offshore-wind-power (accessed 13/05/15).
Sharpley, N. (2015). UK-based Roxtec targets wind-farm sector with innovative new cable seal. Windpower Engineering and Development. February 26, 2015. http://www.windpowerengineering.com/design/mechanical/uk-based-roxtec-targets-wind-farm-sector-with-innovative-new-cable-seal/ (accessed 30/03/15).
Sheringham Shoal. (2014). Community Fund. http://scira.co.uk/community/content.php?ln=Community%20Fund (accessed 30/03/15).
Skeate E.R., Perrow M.R. and Gilroy J.J. (2012). Likely effects of construction of Scroby Sands offshore wind farm on a mixed population of harbour *Phoca vitulina* and grey *Halichoerus grypus* seals. *Marine Pollution Bulletin*, 64(4): 872-881.
SKM (2010). Offshore Grid Development For a Secure Renewable Future – a UK Perspective https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/39309/800-offshore-grid-development-secure-renewable.pdf (accessed 30/03/15).
Skov, H., Leonhard, S., Heinänen, S., Zydelis, R., Jensen, N., Durinck, J., Johansen, T., Jensen, B., Hansen, B., Piper, W. and Grøn, P. (2012). Horns Rev 2 Offshore Wind Farm Bird Monitoring Program 2010-2012. Report by DHI, DONG Energy, Marine Observers, and Orbicon. pp 134.
Smith, J.P. (1999) Healthy bodies and thick wallets: the dual relationship between health and economic status *Journal of Economic Perspectives* 13(2): 144-166.
SSE (2015). Construction is underway at the UK's first offshore wind turbine test facility at Hunterston in North Ayrshire. http://sse.com/whatwedo/ourprojectsandassets/renewables/Hunterston/ (accessed 30/03/15).
Star Consultants and Leeds Metropolitan University (2003). A Study into the Attitudes of Visitors, Tourists and Tourism Organisations towards Wind Farms on the Boundaries of the Lake District National Park, for Friends of the Lake District (FLD).
Stiglitz, J. E., Sen A and Fitoussi, J. P. (2009). Report by the Commission on the Measurement of Economic Performance and Social Progress. Commission on the Measurement of Economic Performance and Social Progress, Paris.

Surfers Against Sewage. (2009). Guidance on Environmental Impact Assessment of Offshore Renewable Energy Development on Surfing Resources and Recreation. pp 63.

Syvret, M., FitzGerald, A., Gray, M., Wilson, J., Ashley, M. and Ellis Jones, C. (2013). *Aquaculture in Welsh Offshore Wind Farms: A feasibility study into potential cultivation in offshore wind farm sites*. Report for the Shellfish Association of Great Britain, 250p.

Tabassum-Abbasi, Premalatha M., Tasneem Abbasi & Abbasi, S. A. (2014). Wind energy: Increasing deployment, rising environmental concerns. *Renewable and Sustainable Energy Reviews*, 31: 270-288.

TEEB (2010). The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. London and Washington, Earthscan.

Teilmann, J. and Carstensen J. (2012). Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic-evidence of slow recovery. *Environmental Research Letters,* 7(4): 045101.

Teilmann, J., Tougaard, J., Carstensen, J., Dietz, R. and Tougaard, S. (2006). Summary on Seal Monitoring 1999-2005 around Nysted and Horns Rev Offshore Wind Farms. Report by ENERGI E2, National Environmental Research Institute (NERI), and Vattenfall A/S. pp 22.

Teisl, M., McCoy, S., Marrinan, S., Noblet, C., Johnson, T., Wibberly, M., Roper, R. and Klein, S. (2015). Will offshore energy face "fair winds and following seas"? Understanding the factors influencing offshore wind acceptance. *Estuaries and Coasts* 38 (Suppl 1):S279-S286.

Thaxter, C. B., Ross-Smith, V. H., Bouten, W., Clark, N. A., Conway, G. J., Rehfisch, M. M., and Burton, N. H. (2015). Seabird–wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull Larus fuscus in the UK. *Biological Conservation*, *186*, 347-358.

The Crown Estate (2010). Round 3 zone appraisal and planning. A strategic approach to zone design, project identification and consent. http://www.thecrownestate.co.uk/media/5702/ei-km-in-pc-method-052010-round-3-zone-appraisal-and-planning.pdf (accessed 13/05/2015).

The Crown Estate (2012). Offshore Wind Cost Reduction Pathways Study. pp88. http://www.thecrownestate.co.uk/media/5493/ei-offshore-wind-cost-reduction-pathways-study.pdf (accessed 30/3/15).

The Crown Estate (2015) Round 3 http://www.thecrownestate.co.uk/energy-and-infrastructure/offshore-wind-energy/working-with-us/leasing-rounds/round-3/ (accessed 02/09/15).

The Guardian (2013). Pro-wind protesters gather for offshore windfarm. http://www.theguardian.com/environment/2013/jan/14/pro-wind-protesters-offshore-windfarm (accessed 30/03/15).The Mountaineering Council of Scotland (2014) Wind Farms and Changing Mountineering Behaviour in Scotland. http://www.mcofs.org.uk/assets/pdfs/mcofs-wind-farm-survey-report_2014.pdf (accessed 02/09/15).

The Offshore Wind Cost Reduction Task Force (2012) The Offshore Wind Cost Reduction Task Force Report June 2012. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66776/5584-offshore-wind-cost-reduction-task-force-report.pdf (accessed 24/08/15)

The Telegraph (2015). The proof we got a bad deal on offshore wind farms. Accessed 10/09/15. Available from http://www.telegraph.co.uk/news/earth/energy/windpower/11426763/The-proof-we-got-a-bad-deal-on-offshore-wind-farms.html

Thompson, P., Lusseau, D., Barton, T., Simmons, D., Rusin, J. and Bailey, H. (2010). Assessing the responses of coastal cetaceans to the construction of offshore wind turbines. *Marine Pollution Bulletin*, 60(8): 1200-1208.

Toke, D. (2005). Explaining wind power planning outcomes, some findings from a study in England and Wales. *Energy Policy* 33(12): 1527–1539.

Toke, D. (2011). The UK offshore wind programme: a sea-change in UK energy policy? *Energy Policy* 39: 526-534.

Tougaard J., Tougaard S., Jensen R.C., Jensen T., Teilmann J., Adelung D., Liebsch N. and Muller G. (2006). Harbour Seals at Horns Rev Before, During and After Construction of Horns Rev Offshore Wind Farm. Final report to Vattenfall A/S October 2006

Tougaard, J. and Carstensen, J. (2011). Porpoises North of Sprogø Before, During and After Construction of an Offshore Wind Farm. Report by Aarhus University and National Environmental Research Institute (NERI). pp 45.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H. and Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbour porpoises (Phocoena phocoena (L.)). *Journal of the Acoustical Society of America*, 26(1): 11-14.

TRS (2013). TRS for Advanced Manufacturing and Engineering Careers. https://talentretention.biz/page/about (accessed 26/03/15).

UKTI (2008) The UK Port Sector: Harbouring a World-Class Industry. Available from http://www.businessopportunities.ukti.gov.uk/uktihome

UKTI (2014). UK Offshore Wind: Opportunities for trade and investment. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/383687/UK_Offshore_Wind_-_Opportunities_for_trade_and_investment_update.pdf (accessed 30/03/15).

Ulrich, R. S. (1979). Visual landscapes and psychological well-being. *Landscape research*, *4*(1): 17-23.

van Deurs, M., Grome, T., Kaspersen, M., Jensen, H., Stenberg, C., Sørensen, J., Støttrup, J., Warnar, T. and Mosegaard, H. (2012). Short- and long-term effects of an offshore wind farm on three species of sandeel and their sand habitat. *Marine Ecology Progress Series*, 458: 169-180.

Vandendriessche, S., Derweduwen, J. and Hostens, K. (2014). Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. *Hydrobiologia*, 1-17.

Vandendriessche, S., Reubens, J., Derweduwen, J., Degraer, S., & Vincx, M. (2013). Offshore wind farms as productive sites for fishes? In: Degraer, S., Brabant, R., & Rumes, B. (2013). Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Learning From the Past to Optimise Future Monitoring Programs. *Royal Belgian Institute of Natural Sciences, Brussels*, p 153-161

Vanermen, N., Stienen, E., Courtens, W., Onkelinx, T., Van de walle, M. and Verstraete, H. (2013). Bird Monitoring at Offshore Wind Farms in the Belgian Part of the North Sea - Assessing Seabird Displacement Effects. Report by The Research Institute for Nature and Forest (INBO). pp 131.

Vanhellemont, Q. and Ruddick, K. (2014). Turbid wakes associated with offshore wind turbines observed with Landsat 8. *Remote Sensing of Environment*, 145**:** 105-115.

Vanhulle, A., Houthave R.and Di Marcantonio, M. (2010). Seascape and socio-economic study: final results. In: Degraer, S.; Brabant, R.; Rumes, B. (Ed.) (2010). Offshore wind farms in the Belgian part of the North Sea: Early environmental impact assessment and spatio-temporal variability. Royal Belgian Institute of Natural Sciences. Management Unit of the North Sea Mathematical Models. Marine Ecosystem Management Unit: Brussel. pp. 165-186.

VisitScotland (2012) Wind Farm Consumer Research http://www.visitscotland.org/pdf/Windfarm%20Consumer%20Research%20final_docUpdatedx.pdf (accessed 02/09/15).

Waldo, Å. (2012). Offshore wind power in Sweden-A qualitative analysis of attitudes with particular focus on opponents. *Energy Policy*, 41: 692-702.

Walker, R. and Judd, A. (2010). Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions. *Centre for Environment, Fisheries, and Aquaculture Science (CEFAS)*.

Walker, B. H. and Pearson, L. (2007). A resilience perspective of the SEEA. *Ecological Economics*, 61(4): 708-715.

Walker, B. J., Wiersma, B. and Bailey, E. (2014). Community benefits, framing and the social acceptance of offshore wind farms: an experimental study in England. *Energy Research & Social Science*, 3: 46-54.

Walker, R., Judd, A., Warr, K., Doria, L., Pacitto, S., Vince, S. and Howe, L. (2009). Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions. Report by Centre for Environment Fisheries and Aquaculture Science (CEFAS). pp 45

Walls, R., Canning, S., Lye, G., Givens, L., Garrett, C. and Lancaster, J. (2013). Analysis of Marine Environmental Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 1). Report by E.ON and Natural Power. pp 210.

Westerberg, H. (1994). Fiskenundersokningar vid havsbaserat vindkraftverk 1990-1993 Rapport, Fiskenverket, Utredningskontoret, Jonkoping, pp 1-4 (In Swedish).

Westerberg, V., Jacobsen, J. and Lifran, R. (2013). The case for offshore wind farms, artificial reefs and sustainable tourism in the French Mediterranean. *Tourism Management*, 34: 172-183.

White, M., Smith, A., Humphryes, K., Pahl, S., Cracknell, D., and Depledge, M. (2010). Blue space: The importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *Journal of Environmental Psychology*, 30 (4): 482-493.

Whitehouse, R. J., Harris, J. M., Sutherland, J. and Rees, J. (2011). The nature of scour development and scour protection at offshore windfarm foundations. *Marine Pollution Bulletin*, 62(1): 73-88.

Wilhelmsson, D. and Malm, T. (2008). Fouling Assemblages on Offshore Wind Power Plants and Adjacent Substrata. *Estuarine, Coastal and Shelf Science*, 79(3): 459-466.

Wilson J.C., Elliott M., Cutts N.D., Mander L., Mendão V., Perez-Dominguez R. and Phelps A. (2010) Coastal and offshore wind energy generation: Is it environmentally benign? *Energies*, 3**:** 1383-1422.

Winter, H., Aarts, G. and van Keeken, O. (2010). Residence Time and Behaviour of Sole and Cod in the Offfshore Wind Farm Egmond aan Zee. Report by IMARES - Wageningen UR and Noordzeewind. pp 50.

London
The Crown Estate
16 New Burlington Place
London
W1S 2HX
T 020 7851 5000

Edinburgh
The Crown Estate
6 Bell's Brae
Edinburgh
EH4 3BJ
T 0131 260 6070

Glenlivet
Main Street
Tomintoul
Banffshire
AB37 9EX
T 01479 870 070

Windsor
The Crown Estate
The Great Park
Windsor, Berkshire
SL4 2HT
T 01753 860 222

www.thecrownestate.co.uk
@TheCrownEstate
ISBN: 978-1-906410-65-0