# A Well-Being Framework for Impact Evaluation: the Case of the UK Offshore Wind Industry

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Highlights:
Framework developed to evaluate well-being impacts, applied to offshore wind industry
Links the five capital model, ecosystem services and well-being domains
Allows holistic evaluation of offshore wind industry impacts including sustainability
Acts a useful tool for organisation of evidence
Challenges remain, but framework transferrable to other industries and interventions

**Abstract**

Growing levels of energy consumption and concern over the environmental consequences of energy production are leading to an increased investment in renewable energy generation. Despite an important relationship between energy production, consumption and well-being, little attempt has been made to provide a holistic assessment of how renewable energy sectors can contribute to different aspects of human well-being. This paper develops an impact evaluation framework that can be used to capture societal-level impacts of change on primarily objective well-being and applies it to the case of the UK offshore wind industry. As such, the framework goes beyond the traditional view of economic, social and environmental impact assessment and evaluation capturing wider aspects of societal costs and benefits as well as sustainable development. The framework proves a useful tool for organising the available evidence and suggests a broadly positive impact of the UK offshore wind industry. While further testing and refinement of the framework is needed, it could be easily transferred for well-being assessment of other industries and interventions.

## 1. Introduction

The consumption and generation of energy, in particular electricity, is closely related to economic activity and other dimensions of human development (Ferguson et al., 2000; Kaygusuz, 2007; OECD/IEA 2015). Energy supports jobs and productivity, but also contributes to other human needs including food, shelter, health and education provision (OECD/IEA, 2004). This impact on multiple dimensions of human life indicates another important relationship: that between energy consumption and human well-being (Pasternak, 2000; Castro-Sitiriche and Ndoye 2013).

Globally energy consumption is growing and with it are concerns over the environmental consequences of energy production, especially its role in global climate change. Climate change has been associated with a multitude of negative impacts on well-being (e.g. forced relocations due to flooding; extreme weather disrupting road, rail and other services and isolating communities; disruption to the production and supply of food impacting livelihoods and food prices; Committee on Climate Change, 2011). To combat its effects, commitments are being made to reduce greenhouse gas emissions and in some countries, to increase the share of energy production from renewable sources. For example, the European Union's Renewable Energy Directive (2009/28/EC) commits the EU to increasing the share of energy consumption from renewable sources to 20% by 2020. Little has been done, however, to provide a holistic assessment of how renewable energy sectors can contribute to different aspects of human well-being.

Nationally recognised measures of well-being and societal progress have traditionally focused on the economic measure of Gross Domestic Product (GDP) (La Placa and Knight, 2014). For example, energy industries in the UK contributed 3.3% of GDP in 2013, 28% of which came from electricity including renewables (DECC, 2014a). GDP, however, is a measure of production. It fails to capture the full cost of economic activity as social and environmental costs are omitted (Stiglitz et al. 2009). An increase in GDP does not compensate for a lack of satisfaction of basic needs, it neglects changes in income distribution and ignores informal transactions that occur outside the market structure (van den Bergh, 2009). Consequently it is a poor measure of social welfare.

How to accurately measure well-being remains under dispute. 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, 2011a). Nevertheless, many governments, international and supranational bodies are now committed to measuring well-being more broadly (e.g. OCED, 2011a; Commission of the European Communities, 2009).

This paper develops an impact evaluation framework that can be used to capture societal-level impacts of change on primarily objective well-being. The framework emerged from a project undertaken for The Crown Estate (Hattam et al., 2015a), on which this paper builds by extending discussion of the theoretical concepts, merits and limitations of the approach. The framework links well-being domains with the five capitals model (Forum for the Future, 1990), which describes the assets from which the goods and services required to sustain well-being are derived. The framework also incorporates the concept of ecosystem services, to support understanding of the social and economic consequences of changes in natural resource provision. By combining these three elements, the impacts of interventions can be holistically assessed for the first time in terms of well-being.

The framework is applied to the case of the UK offshore wind industry, as an example of how it could be applied to any policy intervention or investment. The paper is structured as follows: section 2 introduces the well-being impacts framework; section 3 describes the offshore wind industry in the UK and the application of the framework to it; section 4 presents the results; section 5 discusses the merits and limitations of the approach and section 6 provides final concluding remarks.

## 2. Evaluating well-being impacts: a framework

The focus on well-being, as opposed to economic, social and environmental impacts, emphasises a holistic approach to impact evaluation. Sectoral divisions are rejected and the multiplicity of factors impacting upon the individual and society, and how they are interconnected, is recognised (White, 2010). The framework developed (Figure 1) uses a capital-based approach to understanding well-being and how it is changing. It builds on the framework developed by the OECD for its biannual study of "How's life? Measuring Well-Being" (OECD, 2011b; 2013; 2015) in which well-being is assessed across OECD member states. The "How's life?" framework arose from the recommendations of the Commission on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2009) and the Conference of European Statisticians on measuring sustainable development (UNECE, 2014). Well-being is not viewed as a fixed destination or outcome, but as a process, with conceptions of well-being changing over time (White, 2010).

**Figure 1 here**

### 2.1. Five capitals

The capital approach to well-being is based on the premise that well-being is generated from stocks of capital (or assets) and the ability of individuals and society to use these capitals (OECD, 2011a). This model emerged from debates on the steady-state economy and sustainable development during the latter part of the twentieth century, which focused on the maintenance of stocks of capitals, rather than the flows of goods and services (e.g. GDP) from them (e.g. Boulding, 1966; Schumacher, 1972; Ekins, 1992). It is assumed that capitals can be stored, transformed, exchanged or used to create a flow of goods and services that in turn lead to a change in well-being (Rakodi, 1999). The OECD (2011a) framework focuses on four types of capital: natural, economic, human and social capital. It recognises that the sustainability of well-being is dependent upon the preservation of these four capitals. These four capitals influence a broad range of well-being domains, persist to varying degrees over time and require investment and management if they are to be maintained (OECD, 2015). The four capitals model has a long history in the debate over sustainable development

To explore the well-being impacts of the offshore wind industry, a modified version of the OECD framework is applied. Five forms of capital are distinguished, with economic capital disaggregated into financial and manufactured capital, following Porritt (2007). This disaggregation allows a distinction to be made between the objects that humans create and that can themselves generate well-being (manufactured capital), and the representation of the value and productive power of the other forms of capital (i.e. financial capital). The five capitals are defined as:

- **Financial capital**: derived from revenues generated through sales and determined by production rates, market prices and costs of production (Moran et al., 2013).
- **Manufactured 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**: encompasses natural resources as well as the processes needed to sustain life and produce goods and services (Forum for the Future, 1990).

### 2.2. Assessing natural capital through ecosystem services

Considerable effort has been given to understanding the links between natural capital and human well-being through ecosystem services (e.g. via the Millennium Ecosystem Assessment (2003), The Economics of Ecosystems and Biodiversity initiative (2010) and many national ecosystem service assessments such as the UK National Ecosystem Assessment (2011) and the 2014 UK National Ecosystem Assessment – Follow On). Ecosystem services are considered to be “the direct and indirect contributions of ecosystems to human well-being” (TEEB, 2010). By assessing changes in ecosystem services the links between environmental change and human well-being are made more explicit (Millennium Ecosystem Assessment, 2003). The exact form of the relationship between ecosystem services and human well-being is unknown, but a loss of ecosystem services is assumed to have a negative impact on human well-being through a loss of the benefits that these services generate (Butler and Oluoch-Kosura, 2006). The natural capital component in the framework has therefore been augmented to include the four functional groups of ecosystem services defined by the Millennium Ecosystem Assessment (2003):

- **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.

### 2.3. Inclusion of governance

In a further modification of the OECD framework, the governance context is explicitly incorporated. 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). There is an argument that governance can be conceived of as a form of social capital (e.g. World Bank, 1997), but here it is considered as a distinct entity. The governance structure, or enabling environment, in which these capitals are located plays a role in well-being, determining how capital can be used (Kula et al., 2008). It influences the access of individuals and society to the different capitals, how they are exchanged and the level of return on investments made into each of these capitals. Governance also defines the roles, responsibilities, rights and relationships of the different organisation and institutions that affect the use of capitals (Kooiman, 2003).

Governance can play a key role in creating or reducing uncertainty. In the existing neo-liberal economic climate, the role of governance is to support the market in facilitating growth in sectors of interest (Porrit, 2007). The degree of support offered may influence the level of investment in an industry, thereby determining its growth. An increase or decrease in investment will change the extent to which an industry impacts on well-being via its effects on the five capital stocks.

### 2.4. Linking the five capitals to well-being

Following the OECD framework, stocks of capital are assumed to sustain various dimensions of well-being. Understanding how well-being changes requires an understanding of how the different capitals, which make up the systems in which individuals and households are a part, also change (Stiglitz et al., 2009; OECD, 2011). Changes in well-being are therefore closely linked to the sustainable use of the five capitals.

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 (Costanza et al., 2008; Stiglitz et al., 2009). The interlinkages are complex and more than one capital can affect the same well-being domains. It is often assumed that there is a positive relationship between changes in capital stocks 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 (use of natural capital) could lead to increases in employment (human capital), which could in turn improve economic well-being.

The OECD framework incorporates well-being indicators that focus on individual and household well-being, rather than aggregate conditions, recognising that the economy-wide situation may be a poor reflection of household or individual well-being. It also concentrates on well-being outcomes, rather than inputs, as there is an imperfect relationship between the two (e.g. health expenditure may be a poor predictor of individual health status; OECD, 2011). The indicators used comprise a mixture of objective and subjective aspects of well-being, reflecting individual capabilities as well as material outcomes.

Building on the OECD framework, many individual countries have also begun to develop their own well-being indicators. The UK's Office for National Statistics (ONS), through the Measuring National Well-being Programme (Randall et al., 2014), considers ten different well-being domains (the economy, what we do, where we live, personal well-being, education and skills, personal finance, health, our relationships, the natural environment, governance). For each of the domains, a series of individual or household level indicators have been developed (e.g. the health domain includes life expectancy, long term illness and satisfaction with personal health). To ensure a good fit to a UK case study, the OECD indicators are replaced by the ONS well-being domains.

Many of these well-being domains are closely linked, and change in one may feedback to another. For example, employment, education and economic status are known to have a relationship with health (Bartley, 1994; Ross and Wu, 1995; Smith, 1999) 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 (Smith, 1999; Dolan et al., 2008). The relative importance of the different domains to well-being may also change over time (Costanza et al., 2008).

## 3. Offshore wind case study

The adoption of the EU Renewable Energy Directive (2009/28/EC) commits the UK to a target of 15% of electricity consumption from renewable sources by 2020. Offshore wind energy is considered the main resource for the UK to meet this targets (DECC, 2013). By the end of 2015, the UK had 28 offshore wind farms projects containing 1,465 turbines with an installed capacity of 5.1 GW (RenewableUK, 2016a). It is expected to achieve over 10 GW by 2020 (UKTI 2014). In 2015, offshore wind farms provided 5.2 per cent of the UKs energy demand (RenewableUK, 2016b).

Application of the framework was undertaken using a two stage process. Stage one involved searching both peer reviewed and grey literature for available evidence on the actual impacts of the offshore wind industry on the five capitals. Anticipated future impacts were only noted where relevant. While the benefits arising from the use of renewable energy to future climate change are recognised, assessment of these impacts is beyond the scope of this review.

Stage two focused on assessing the evidence gathered in terms of well-being impacts and associating the evidence collected for each capital with the ONS well-being domains. No attempt was made to link changes in capitals to the specific well-being indicators defined by the ONS for each domain. The evidence available in the literature was considered insufficient to assess changes at this fine grained individual/household level. Identifying these linkages is challenging because well-being domains do not exist independent of each other. Furthermore, given the evidence available, unidirectional relationships between the offshore wind industry, capitals and well-being are difficult to describe. Also, the indicators provided by the ONS are not exhaustive. This association between the evidence, capitals and well-being domains was therefore based on expert judgment.

To avoid repetition, capitals were linked to the well-being domain(s) for which a change in the capital was expected to have the greatest impact or for which some evidence existed. For example, impacts on financial capital were only linked to the well-being domain of economy. While it is recognised that financial capital change is likely to impact upon other well-being domains, evidence for this was unavailable. The process of linking capitals to well-being domains was iterative with new links recognised as the literature review progressed.

## 4. Results

Table 1 presents the links identified between the five capitals, the ONS well-being domains and the evidence available for the offshore wind industry. Despite the recognition that well-being indicators need to focus on the individual or household level (OECD, 2011), limitations in the data available meant that the evidence identified focused more broadly on societal or community level effects. The review therefore evaluates UK-wide and regional effects, examining the meaning of this for individual and household well-being only where evidence permits.

Where possible, the impacts evaluated were linked to outcomes (i.e. the result of a capital change) as opposed to inputs (i.e. the cause of the capital change). Data limitations, however, meant that some inputs (e.g. investments in financial capital) have also been captured and well-being impacts assumed as a result. Data limitations and an absence of a baseline for both the capitals and well-being domains have meant that only qualitative assessments of change were made, identifying whether well-being changes could be considered positive or negative; where possible, quantitative accounts are given.

**Table 1 here**

### 4.1. Financial capital

Changes in financial capital were primarily linked to the well-being domain of the economy. Operating offshore wind farms were estimated to contribute approximately £1 billion to the UK economy in 2013, representing 0.2% of GDP (ORE Catapult, 2014). This is the result of both private and public investment. Between 2010 and 2013 an estimated £6.9 billion was invested in the offshore wind industry (REA, 2014). This is compared to an estimated £7.6 billion in onshore wind, £6.4 billion in solar, £6.3 billion in biomass and bioenergy, £0.2 billion in hydro, £0.1 billion in tidal and wave and £1.4 billion in other renewables for the same period (REA, 2014).

There is considerable support for the offshore wind industry, which in turn is generating economic activity, although the well-being impact of which cannot be assessed given available evidence. For example, supply chain programmes have been developed in attempt to capture the maximum gains for the UK economy. In 2013, only 43% of lifetime costs associated with UK offshore wind farms was maintained domestically (ORE Catapult, 2014), compared to 70% for North Sea oil and gas (HM Government, 2013). There are now a number of initiatives, organisations and advice networks that aim to grow the UK supply chain. These include the Advanced Manufacturing Supply Chain Initiative, GROW: Offshore Wind Fund and the Offshore Wind Investment Organisation, on top of substantial private investment (£300 million between 2012 and 2014; HM Government, 2014). In England, six Centres for Offshore Renewable Engineering (CORES) have also been strategically established (UKTI, 2014).

Technological innovation has received support on a UK-wide scale and with a regional focus. For example, the UK's Department of Energy and Climate Change (DECC) allocated £30million for technological innovation and The Green Investment Bank has invested £1bn in offshore wind during construction and operation phases. Public-private partnerships have been set up to accelerate knowledge building. Two UK government departments (DECC and Business, Industry and Skills), together with the UK research councils and organisations such as the Energy Technology Institute, the Technology Strategy Board and the Carbon Trust have spent in excess of £100 million (2011-2015) to support offshore wind through the Low Carbon Innovation Coordination Group (LCICG, 2012).

Financial support also takes the form of subsidies, which have been used to create certainty and incentivise investment in the offshore wind industry. In 2013, total UK energy subsidies were £3.6 billion for gas, £2.3 billion for nuclear and £3.1 billion for renewables (Environmental Audit Committee, 2014). There is currently uncertainty over the future of subsidies for the industry, with the October 2015 round of Contracts for Difference (a subsidy scheme which pays the renewable energy supplier the difference between the long-term strike price for electricity and the market price) being postponed (Nicholls, 2015).

**4.2. Manufactured capital**

Evidence from the literature indicates that changes in manufactured capital as a result of the offshore wind industry can be linked primarily to the well-being domains of economy (via manufacturing capacity), where we live (via infrastructure) and what we do (via jobs). Manufacturing related to the offshore wind industry, however, is limited within the UK, although investment in the region of £110 billion is expected by 2020 (HM Government, 2014). Impacts on well-being may therefore be relatively small via manufactured capital and can only be assumed to result from the inputs described below.

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 is only one tower production facility in the UK (Wind Towers Scotland) at Campeltown, Argyll; the majority of towers are imported primarily from Europe. This may change in the near future, for example an overseas subsidiary of South Korean CS Wind Corporation is being supported to build an offshore wind turbine tower manufacturing facility on Humberside. It is anticipated that this facility will create up to 200 direct jobs with others in the supply chain (HM Government/British Embassy Seoul, 2015). Other companies are also investing along the Humber. The Association of British Ports (ABP) is investing £310 million in dockside regeneration, which is hoped to create 100 jobs with more in the supply chain, and Siemens has committed to a new manufacturing facility on the Humber, producing blades and nacelles (UKTI, 2014).

It is not only investment in manufacturing facilities that is generating employment and income. There has also been investment in ports in support of the construction, operation and maintenance of OWFs (HM Government, 2012). For example, Barrow, Grimsby, Lowestoft, Mostyn, Ramsgate, Workington and Belfast have all attracted investments from the offshore wind industry. This investment, however, is in line with investments made by other industries such as the automotive, biomass, container transport industries.

An additional benefit arising from the offshore wind industry is 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. Further investments, such as offshore grids, reinforcement of the power transmission capacity between Scotland and England (O'Keeffe and Haggett, 2012), and additional connections with other countries (see for example, SKM, 2010) are also underway. This grid modernisation is considered critical for maintaining energy security and ensuring the country meets its wider energy objectives (DECC, 2014b).

### 4.3. Human capital

Human capital draws on the ability of people to develop intellectually and work in environments which support individual wealth creation (Forum of the Future, 1990). It is expected that improvement in human capital will contribute directly to well-being through the domains of what we do (through employment), education and skills, personal finance and health.

Generic apprenticeships, bespoke training courses and research at centres of excellence support skills development in the offshore wind industry. The offshore wind industry has made substantial investment into training, research and development. There are a number of industry-university partnerships (e.g. the £12.5 million Gamesa Offshore Wind Technology Centre in Glasgow), university centres (e.g. the Offshore Renewables Institute formed by the Universities of Dundee, Aberdeen and Robert Gordon University), bespoke centres of excellence (e.g. the Offshore Renewable Energy Catapult) and other public-private partnerships (e.g. the Energy Technologies Institute and the Carbon Trust's Offshore Wind Accelerator). These, together with experiences from OWF development, are leading to an accumulation of skills in the UK in the planning, construction, operation and maintenance of offshore wind farms. Many countries (e.g. the US, Canada, South Korea, Japan, India, China and Taiwan) are now seeking to learn from the experiences in the UK (UKTI, 2014).

In 2013, 6,830 people were directly employed by the offshore wind industry up from 3,151 in 2010 (RenewableUK, 2013). This compares to 5,005 in the UK coal industry in 2013 (Pettinger, 2012). Approximately 30% of jobs are in construction and installation, 25% in planning and development, 18% in support services, 16% in operations and maintenance and 10% in manufacturing. Estimates suggest that a further 7,000 people are employed indirectly along the offshore wind supply-chain (UKTI, 2014).

Jobs in the offshore wind industry are considered to be high skilled (Cambridge Econometrics, 2012). Wages reflect this, ranging from £19,706 for skilled production operatives to £102,837 for heads of manufacturing (HM Government, 2012). Unfortunately median gross annual wages for the offshore wind industry are unavailable making comparisons to other sectors difficult.

It is not clear whether the development of offshore wind is leading to lost or displaced jobs in other sectors such as fisheries and tourism. Little work has explored the effects of OWF on tourism. Anecdotal evidence indicates the continued existence of a tourism industry close to an OWF site (Keuhn, 2005). Impacts on fisheries also appear limited, with some displacement occurring because of concerns over gear entanglement (Gray et al., 2016). Detailed assessment of changes in overall effort and landings, or wider implications for fisheries (such as the effect of any increased fuel expenditure on profitability) is currently lacking.

Health is the final component of human capital considered. Evidence of health impacts is scant, but benefits may accrue in terms of air quality improvements and mitigation of the negative effects of climate change (Ison and Pearce-Smith, 2009). There are occupational health hazards but it is not possible to attribute these to the offshore wind industry specifically. For example, in 2005 there was a total of 6 accidental and 13 occupational deaths over all electricity generating technologies (Markandya and Wilkinson, 2007). Impacts on the seascape may also contribute to health impacts. Attractive landscapes have been shown to provide health and well-being (Abraham et al., 2010), but the primary negative effect of OWFs is considered to be the impact on the seascape (Devine-Wright and Howes, 2010; Gee and Burkhard, 2010; Waldo, 2012). This suggests that OWFs may cause a loss of human capital to some.

### 4.4. Social capital

The concept of social capital affects our relationships and encompasses notions of community spirit, networks, and social resources (i.e. it is an attribute of communities as opposed to individuals). Evidence available suggests that changes to social capital arising from the offshore wind industry can be linked to personal well-being, where we live and our relationships.

Generally there is strong support for OWFs (Ladenburg, 2008, 2010; Karlstrøm and Ryghaug, 2014; Hattam et al., 2015b). This is motivated by beliefs that may contribute to social capital including that the offshore wind industry creates jobs and leads to local economic growth (Gee and Burkhard, 2010; Vanhulle et al., 2010; Waldo, 2012). While negative opinions are also documented, they are not typically related to issues of social capital (Busch et al., 2011; Waldo, 2012; Teisl, 2015).

Perceptions of personal and community impacts and benefits are important for explaining public support for renewables projects. Offers of support from developers, commonly relating to community projects, are not always met with enthusiasm, however. 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. Nevertheless, experience of positive community benefits has been shown to increase the level of support expressed for a proposed OWF development (Cass et al., 2010).

Direct investments into communities from offshore wind activities are substantial. For example, the offshore wind industry, via The Crown Estate and HM Treasury, feeds into the Coastal Communities Fund, which has committed £45 million to 63 seaside towns in England

and Scotland (RenewableUK, 2015). The CORES have also raised between £5.7 million and £33 million for investment in projects, such as transport and housing, within their localities (HM Government, 2011; DCLG, 2014). In addition, individual developers have provided financial support to communities local to specific OWFs. These include the £19 million fund established by RWE to support Northern Welsh communities (RWE, 2014) and the £235,000 per annum pledged for communities within Liverpool Bay by Dong Energy (Grantscape, 2015). It has not been possible to identify the well-being outcomes arising from these investments, but community level changes are likely to impact on social capital.

The OWF industry is also developing social capital through the establishment of groups and networks. 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 regional renewables supply chains. Social capital is also built through the formation of groups that oppose, or support, the developments. The Atlantic Array, proposed for the Bristol Channel for example, led to the formation of several active opposition groups. Elsewhere (e.g. for the Navitus Bay OWF in Dorset, which did not gain consent), there is also anecdotal evidence of co-ordinated support (e.g. through campaign groups such as 38degrees) and of the 400 people who gathered to protest in Swanage in January 2013, 100 were in favour of the wind farm (The Guardian, 2013).

**4.5. Natural capital**

Natural capital links to the domain of the natural environment, and contributes to human well-being through, for example, the availability of food and raw materials (provisioning services), protection from hazards such as flooding, erosion and pollution (regulating services) and recreational opportunities (cultural services). All of these are underpinned by complex webs of species and habitat interactions (supporting services). While evidence exists on the localised impacts of OWF on components of natural capital, there are still gaps in the empirical evidence. It may not always be possible to attribute change in natural capital to the impacts of OWF and impacts are often species or location specific. Furthermore, the existing evidence is not sufficient to infer potential impacts on well-being, beyond the recognition that changes to ecosystem services can be assumed to result in changes in human well-being.

There is no unequivocal evidence that OWFs affect provisioning services through noise or electromagnetic field effects harming edible species. There is, however, a growing literature that suggests OWFs may have other effects, both positive and negative on the fisheries ecology of commercial species, although these are often mixed or uncertain (Bergström et al., 2013; Reubens et al., 2013; Vandendriessche et al., 2014; Ashley et al,. 2014).

The widely-reported colonisation of turbine foundations by mussels (e.g. Wilhelmsson and Malm, 2008) has the potential to influence regulating services. Mussels have an increased capacity to sequester carbon (at least in the short-term) and to remediate waste and toxins in the water column compared to the sediments surrounding OWFs. A further positive effect is the provision of nursery habitat (Leonhard and Pedersen, 2006; Reubens et al. 2013). Conversely, concern has been raised about OWFs acting as stepping stones and facilitating the spread of non-native species (Degraer and Brabant, 2009; de Mesel et al., 2015), an issue that has a demonstrable negative effect on wellbeing (Börger et al., 2014).

Charismatic species such as marine mammals and seabirds are highly valued by society (Richardson and Loomis, 2000), and are associated with the less tangible cultural services (such as spiritual wellbeing and inspiration). There is a relatively large volume of research on the effects of OWFs on marine mammals and seabirds, which shows short-term displacement of marine mammals during pile driving (e.g. Brandt et al., 2011; Brasseur et al., 2012; Dähne et al., 2013), although this may reflect the use of mandatory measures designed to discourage mammals from entering the construction zone. No evidence of harm to individual animals or of long-term or population level effects was found.

The interaction of OWFs and seabirds varies between species and between OWFs and so cannot be effectively generalised. Some modifications in seabird behaviour have been observed, particularly avoidance of turbines (e.g. Krijgsveld et al., 2011; Plonczkier and Simms, 2012), as have changes in abundance, with evidence of both increasing (Vanermen et al., 2013; Walls et al., 2013) and decreasing (Petersen et al., 2006; Degraer and Brabant, 2009) populations. Seabird strikes and mortality have also been reported, but at very low levels (Newton and Little, 2009).

Wider changes to species abundance, diversity and community composition have also been reported from OWF studies (e.g. Birklund, 2005; Wilhelmsson and Malm, 2008). These may alter the provision of supporting services, but the potential effect of any such changes on well-being is unknown.

### 4.6. Governance

Governance is explored here in the context of decision-making for OWF development and the role that the state and other influential actors have taken in this process. Having trust in this process and how this process affects our relationships are important contributors to well-being. Prior to 2007, the UK Government offered little support to the offshore wind industry. A complex planning and consenting process led to slow development (Markard and Petersen, 2009; Gibson and Howsam, 2010), making the industry economically unattractive (Ochieng et al., 2014). Following the UK 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). Planning has now been streamlined and, for applications for OWFs with capacity over 100MW, 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).

Planning inquiries for OWFs cannot be called for by local authorities as OWFs 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 to be more about information distribution than dialogue. This has led to distrust in government and local authorities arising 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. Barry et al. (2008) show how opposition groups often position themselves not as fighting against wind farms *per se*, but as fighting on the side of the democratic process.

To overcome this distrust it has often been assumed that providing the public with more information is the solution (e.g. Ellis et al., 2007; Aitken, 2010). There is no clear relationship, however, between knowledge and acceptance of wind farms and some consider the consultation process is ineffectual (Kerr et al., 2014). There is a perception within communities that developers only engage with them as an attempt to manage or overcome opposition (Aitken, 2010).

Although evidence indicates that offshore wind farms have limited impacts on the fishing industry, fishermen are often reported to distrust both developers and regulators. This largely arises from previous experiences with the planning process that have resulted in activity restrictions (Mackinson et al., 2006). Like local communities, fishermen often view consultation as tokenism on the part of the developer (Gray et al. 2005; de Groot et al. 2014). Nevertheless, the shape of the relationship between developers and the fishing industry varies with OWF and developer.

## 5. Discussion

The application of the framework developed for this review enables a holistic evaluation of the impacts of the offshore wind industry on human well-being in the UK. *Ex post* evaluation of the impacts resulting from investments, such as those made by the offshore wind industry, is essential for effective decision-making. Evaluations can assess how effective an investment is, not only in terms of achieving its desired outcomes, but also with respect to identifying wider and unintended outcomes (HM Treasury, 2011).

In contrast to *ex ante* impact assessments, which are enshrined in legislation (e.g. the European Union's Environmental Impact Assessment Directive 2011/92/EU) and are undertaken before a decision, investment or policy has been made, there is limited legal requirement for *ex post* impact evaluations. Often only post-construction environmental monitoring is required to validate assertions made in environmental statements, given the lack of peer-reviewed evidence on the impacts of offshore energy devices (Walker and Judd, 2010). There is no obligation, however, to monitor and evaluate the post construction social and economic impacts of offshore wind farm developments. This is despite the social and economics promises OWF developers make in their planning applications. The small number of economic evaluations that have been undertaken have been driven by industry and environmental NGOs (e.g. Cambridge Econometrics, 2012; ORE Catapult, 2014). The absence of wider evaluations is a missed opportunity for planners to understand the full extent of the impacts of their decisions (both positive and negative), as well as for developers to indicate the impacts of their industry beyond the delivery of renewable energy.

### 5.1. Merits of the framework

There is growing interest worldwide in the assessment of well-being change at the individual and societal level (e.g. the Bhutanese Gross National Happiness Index, the Canadian Index of Wellbeing). These evaluations are rarely undertaken for the impact of policies and other interventions, such as investments. This may in part be due to the difficulties in linking policies and interventions to well-being outcomes, but the framework presented here indicates how well-being evaluations could be made.

While this framework is only a first step towards evaluating well-being impacts, it goes beyond the traditional view of economic, social and environmental impact assessment and evaluation. These impacts are often evaluated independently, failing to capture the interlinkages between them or their links to capital assets and human well-being. For example, the Environmental Impact Assessment process is a crucial component of planning, but has been criticised for its emphasis on local, and predominantly negative, impacts (Smart et al., 2014). A framework that allows for a more holistic assessment of wider societal costs and benefits therefore represents an important step forward. While it has been used to evaluate impacts in this study after investment, it has potential for use prior to developments taking place. The importance of the framework is in highlighting the interplay between different types of capital and how the favouring of one capital may be at the expense of others. It may be particularly useful in situations where more common methods of evaluation (e.g. Cost Benefit Analysis or Multi-Criteria Analysis) are not applicable as impacts are not quantifiable and/or are incommensurate (Ekins et al., 2008).

Such a framework is also more aligned with changing approaches to management that reflect the two-way interaction between people and the environment, and seek to assess the trade-offs necessary to achieve societal goals (Loomis and Paterson, 2014). While it has not been possible in this study to identify and assess all well-being impacts, the framework does encourage the evaluation of impacts on multiple dimensions of well-being and provides a structure for this evaluation.

The emphasis on capitals also links to the concept of sustainable development (Stiglitz et al., 2009). Sustainable development necessitates the maintenance or improvement of the five capitals, upon which future well-being is dependent. Policies, programmes and investments that can demonstrate a positive impact on the five capitals will therefore likely benefit future well-being and intergenerational equity as well. There are numerous examples of the evaluation of sustainability of development using a capitals framework, for example, assessing urban sprawl in Prague (Balžek et al., 2008), regional development in Poland (Gorzalek et al., 2008), for mining and pastoralism in Australia (Moran et al., 2013) and rural livelihoods in developing countries (e.g. Bebbington, 1999). The framework's applicability at multiple scales is therefore possible, although the data needs at different scales will be distinct.

### 5.2. Limitations

The framework and its application to the offshore wind case study are not without their limitations. The framework itself is challenged by the underlying assumption that an increase (decrease) in a capital stock may lead to a corresponding increase (decrease) in well-being. The shape of the relationship (or more likely relationships) between capital assets and well-being is still to be determined. Despite the vast body of literature examining and documenting the determinants of well-being (see e.g. Cote and Healy, 2001; Dolan et al., 2008; Stiglitz et al., 2009), identifying the reasons behind changes in well-being indicators remains challenging.

Associated with this is a lack of understanding about how the different capitals can be traded-off against each other and what the implications of these trade-offs have for well-being. The extent to which gains in one capital can compensate for losses in another are unknown and has been subject to considerable debate (see e.g. Dobson, 1996). There has been a long history of assuming that manufactured capital can compensate for other capitals, at the expense, particularly, of natural and social capital, the consequences of which are now becoming apparent. In addition, the degree to which such trade-offs may be individual specific and temporally and spatially limited requires further investigation. The impacts of capital change on well-being may differ by person. For example, improvements in infrastructure and employment resulting from the construction of an OWF may benefit the well-being of some (e.g. those with engineering backgrounds), but result in well-being losses for others (e.g. individuals who consider their view has been spoilt). This raises equity questions over whose well-being should be measured and whether assessment should be undertaken at the individual or collective level.

An additional challenge for assessing well-being change is the lack of data on the outcomes of investments. Considerable investment by the offshore wind industry and the UK Government has been made in financial, manufactured and human capital. This is assumed to be linked to a well-being gain, but the outcomes of these investments remain to be seen. This is partly as a consequence of the recentness of the investments but also because of a lack of access to the appropriate data by this study. Improving upon this assessment would require additional data (primary and secondary) collection, potentially focused on specific case study locations.

The absence of a well-being baseline or capital accounts against which to measure change is also problematic. While the review has been able to show a general direction of change resulting from the development of the offshore wind industry, it has not been possible to quantify the magnitude of this change. In the absence of a counterfactual, it is also impossible to state what would have happened to both the capital stocks and well-being in the absence of the offshore wind industry. These issues could be overcome with more fine-scaled analysis and improvements in the evidence base that are tailored towards well-being assessments.

## 6. Conclusions

Drawing on peer-reviewed and grey literature, the framework developed in this study has been used to evaluate the high level impacts of the offshore wind industry. It has proved a useful tool for organising the evidence of the impacts on financial, manufactured, human, social and natural capital. As changes in capital assets can be associated with change in a number of human well-being domains, the framework allows for a more holistic evaluation than is typical in such assessments, which usually focus on single or more limited number of capitals and associated well-being outcomes. In general the impacts of the offshore wind industry appear to be positive in the context of financial, manufactured and human capital, if the current inputs can be assumed to result in well-being outcomes. They are more mixed and less clear for social and natural capital, however. While further testing and refinement of the framework is needed, especially at spatial scales where the evidence may be more fine-grained, the framework could be easily transferred for well-being assessment of other industries and interventions.


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Figure 1: Framework used to assess the well-being impacts of the offshore wind industry, combining a capitals approach, ecosystem services and the well-being domains identified by the UK's Office for National Statistics (Randall et al., 2014). Arrows are indicative only.

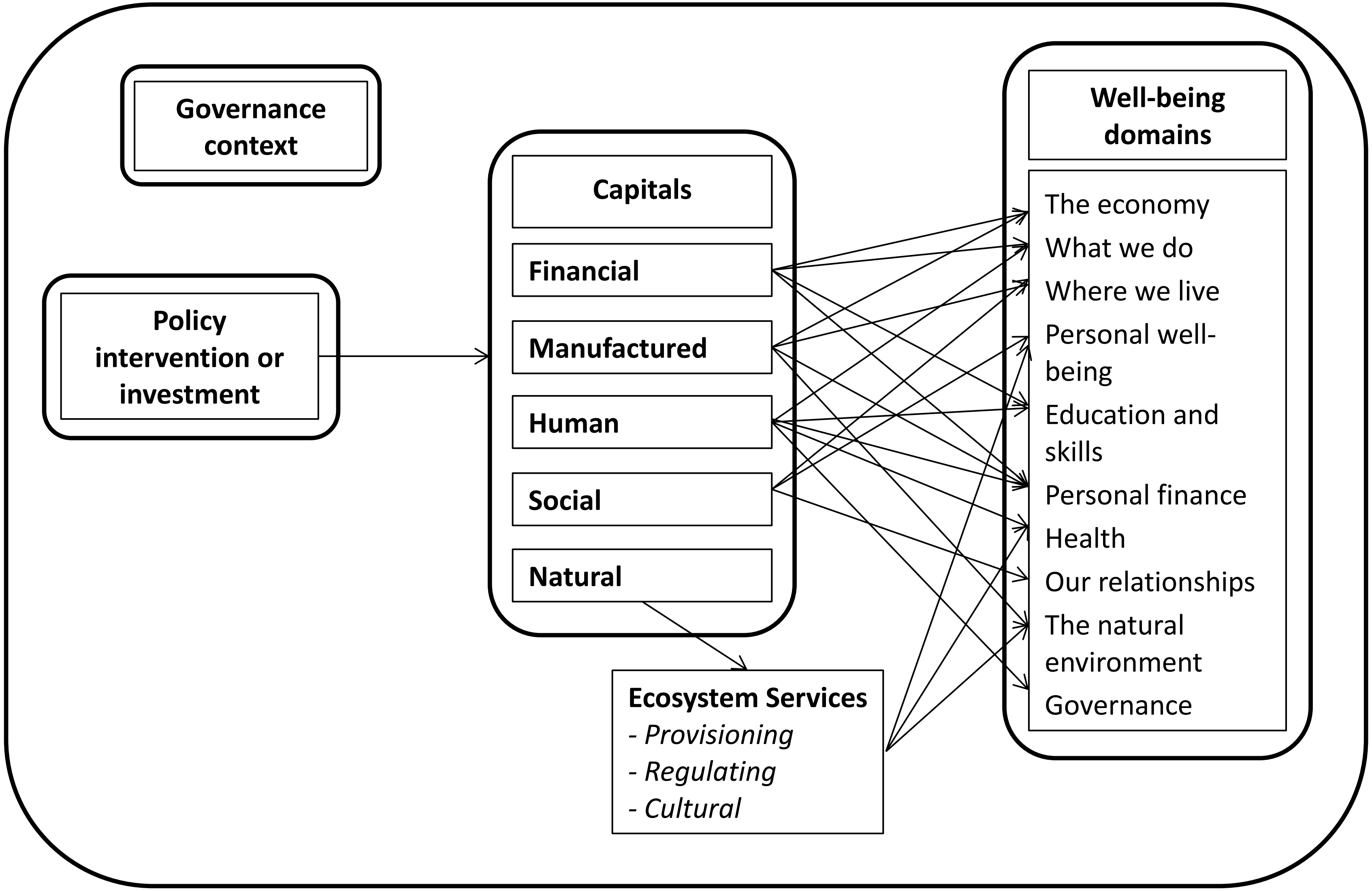

**Table 1: Links between capitals, ONS well-being domains and evidence used to evaluate the impact of the offshore wind industry.**

| Link to capital | ONS well-being domain | Evidence available for the offshore wind industry |
|---|---|---|
| Financial Capital | The economy | Contribution to GDP |
| | | Investments in supply chain and innovation support* |
| | | Investment via price support and subsidies* |
| | | Market stability* |
| Manufactured capital | The economy | Investment in manufacturing* |
| | What we do | Investment in manufacturing and infrastructure* |
| | Where we live | Infrastructure development |
| Human capital | What we do | Employment (direct, indirect and induced) |
| | | Investment in knowledge generation* |
| | Education and skills | Employment impacts on non-offshore wind industries |
| | | Skill level of employment |
| | | Dedicated training courses |
| | | Investment in research and development* |
| | Personal finance | Wage rates |
| | Health | Safety of workers |
| | | Mental health within the community |
| Social capital | Personal well-being | Level of support for offshore wind farms |
| | | Evidence of pro- and anti-offshore wind farm attitudes |
| | Where we live | Community funds and projects* |
| | Our relationships | Relationships within communities and with developers |
| | | Industrial relationships and networks |
| Natural Capital | The natural environment | Provisioning ecosystem services: impacts on commercial fish stocks* |
| | | Regulating and supporting ecosystem services: impacts on benthic communities* |
| | | Cultural ecosystem services: impacts on charismatic species* |
| Not linked to capital, but provides enabling environment | Governance | Government - industry relationships |
| | | Government/Local Authority - community relationships |
| | | Industry-community relationships |

* Not an outcome indicator