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LITERATURE REVIEW

Qualitative meta-analysis of the socioeconomic impacts of offshore wind farms

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Abstract. Climate change and an increased interest in renewable energy have resulted in a burgeoning wind energy sector. However, in the recent past, wind farms have faced resistance in acquiring permits due to concerns about their long-term effects on the local community. To understand the extent of these externalities, this study qualitatively meta-analyses four socio-economic impacts of interest, namely: house prices, tourism, catalytic effects of supply chain clustering, and social change. Geographically, the analysed reports include Europe, Canada and the US, and deductions are made for the EU. In order to bridge the gap of unavailability of primary data on the wind sector, relevant conclusions are drawn from other comparable sectors. Based on a rigorous review of primary qualitative research, this study concludes that offshore wind farms should be located more than 40 km away from the coast to eliminate risks of housing price devaluation and tourist activity reduction, which would directly affect the economic value of the region. In addition, the study found limited evidence to acknowledge the employment benefits in the local economy and social change in the community due to offshore wind farms. Monitoring mechanisms should be set up to prove or disprove the creation of local employment, crime and substance abuse. Furthermore, the study finds that adequate planning and management can ensure better socioeconomic outcomes in the community. Further research is recommended for the specific impact of overhead transmission lines and substations on property values and tourism.

Keywords: Offshore wind energy; renewable energy; socioeconomic impact; housing prices; tourism; supply chain impact

1. Introduction

Wind is increasingly becoming an important source of renewable energy in many parts of the world. Many wind energy projects have significant economic, environmental and social impacts. As a result, all European countries require a thorough Environmental Impact Assessment to be conducted. For example, in the UK, the construction of a generating station with a capacity of more than 100 MW is a National Significant Infrastructure Project (NSIP) and therefore requires an Environmental Impact Assessment (EIA) (UK Parliament, 2008). EIAs are necessary to bring economic construction activities in balance with the environment. Since the introduction of the Infrastructure Planning Regulations 2017, there is a special focus on socio-

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economic impacts required in EIAs (UK Government, 2017). Thereby, all three dimensions of sustainability are holistically considered in the construction of NSIP.

Wind farms take nature as a model by harvesting renewable energy and are proof of economic restructuring away from a fossil fuel-driven economy. The landmark decision of the precautionary principle from the 1992 Rio Declaration on Environment and Development states that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (The United Nations Conference on Environment and Development, 1992). Performing an EIA aims at identifying and mitigating serious damage, and it goes even further by considering the socio-economic threats.

This paper analyses the socio-economic effects of offshore wind farms. It is the product of a collaboration with a major European engineering consultancy leading numerous projects in the onshore and offshore wind industry. Figure 1 gives an overview of socio-economic effects that are assessed during EIAs. Out of these categories, four were chosen (highlighted in red in the figure below) for further investigation in this paper, as a result of EIA experts' opinions gathered through consultations. The following sections shed some light on the available evidence for these four categories of socio-economic effects and provide recommendations as to how to address these.

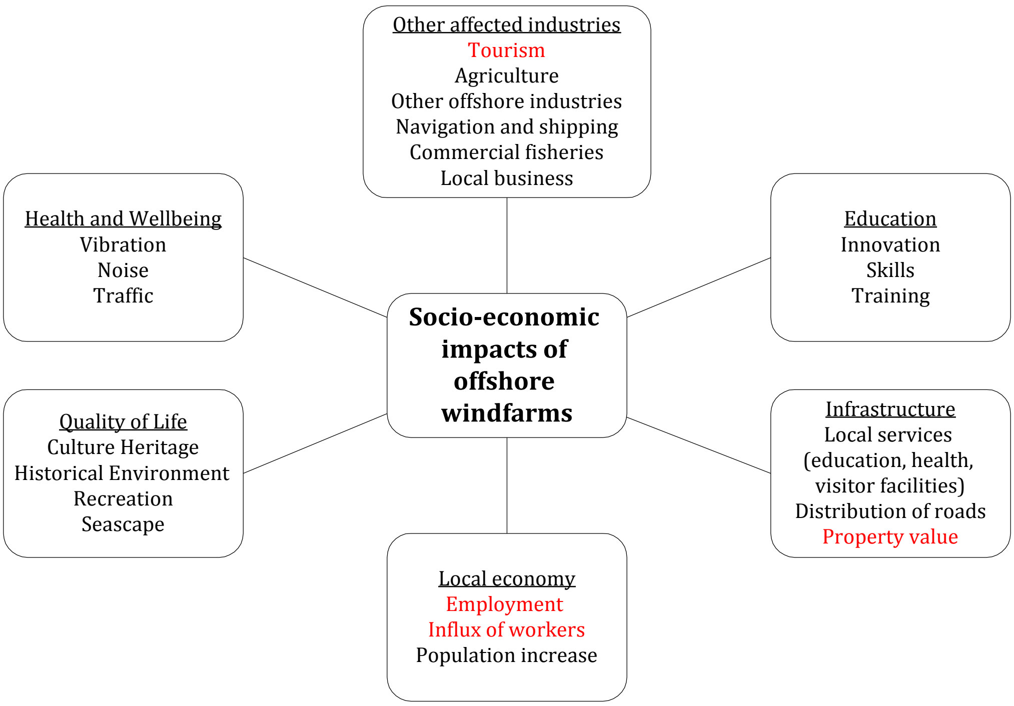

Figure 1. List of socio-economic determinants. Highlighted in red are the determinants addressed in this paper

2. Methodology

A qualitative meta-analysis was conducted as a rigorous secondary qualitative analysis, to identify the socioeconomic impacts of offshore wind farms across primary research. Preference was given to studies conducted within the last 20 years, to provide a more comprehensive analysis of the recent changes in the pattern of behaviour in the four areas of interest within the scope of this study. Studies with overlapping content and no clear conclusions drawn were excluded from the analysis. Studies were found through Google Scholar, Web of Science, iDiscover, and Scopus. Publications from Elsevier, ScienceDirect, Springer, JSTOR, and Wiley were used. Other informal sources such as reports, news articles and trade magazines were leveraged as well. Combinations of the terms "offshore wind energy" with "socioeconomic impacts", "housing prices", "tourism", "supply chains" and "social change" were used to conduct the search. Secondary exploration was also conducted using the reference lists of primary sources to complement the review.

Out of 124 studies that surfaced in the initial research, 91 were selected for final review. Studies selected include 45 peer-reviewed and 46 grey literature items (government documents, working papers, reports, white papers and evaluations) that look at the socioeconomic impacts of large infrastructure projects. From these sources, key impacts and insights of interest were extracted and tabled. Results were then analysed qualitatively through inductive coding, which facilitated grouping of the impacts into commonly observed categories, according to their relationship with the four areas of study. Where primary data on the wind sector was unavailable, studies from other comparable sectors were also considered; including nuclear, coal, offshore gas, and hydroelectric power plants.

3. Results and Discussion

This study identifies multiple variables associated with offshore wind farms that cause socio-economic impacts within the community. Within the scope of this particular study, four material aspects were researched in detail. The key findings from this study for the four variables are presented below.

3.1. House prices and changes to the quality of life around large electrical infrastructure

The impact of wind farms on property value is one of the major concerns for homeowners. In fact, the concern is so overwhelming that the "anticipatory stigma" resulted in self-fulfilling prophecies leading to lowered house prices. Some were even willing to pay to have wind farms located farther away (Dent & Sims, 2007; Ladenburg & Dubgaard, 2007; Walker et al., 2014). But are these concerns valid?

The overwhelming majority of research on the impact of onshore wind-farms on housing prices, conducted at various locations in Australia, Canada, Denmark, UK, and the USA; found no statistically significant evidence of wind-farms impacting property values in the vicinity (Canning & Simmons, 2010; Carter, 2011; Cox, 2017; Dupont & Etherington, 2009; Fonnesbech-Wulf et al., 2011; Heblich et al., 2016; Hinman, 2010; Hoen et al., 2011; Hoen et al., 2015; Hoen et al., 2010; Hoen & Atkinson-Palombo, 2016; Lang et al., 2014; Laposa & Mueller, 2010; Magnusson et al., 2012; Ostwald et al., 2016; Paterson, 2013; Renewable UK, 2014; Sims et al., 2008; Vyn & Mccullough, 2014). Nonetheless, there are also some cases where increased house prices were observed in the USA (Sterzinger et al., 2003), Crystal Rig Scotland (Barclay, 2012), and Melancthon Canada (Hinman, 2010).

Nevertheless, contrary evidence exists. A series of German studies found that properties with an "extreme to medium view due to the wind farm construction" depreciated by about 9–14%. Visual disamenity was the influencing factor till 1 km, while proximity explained the effect up to 3 km (Sunak & Madlener, 2012, 2016, 2017). Another report from Germany found 7.1% devaluation within a 1 km radius of a wind turbine. However, the effect faded to zero at a distance of 8 to 9 km (Frondel et al., 2019). A Dutch study found 1.4% price fall for houses within 2 km of a turbine and attributed the cause to "anticipation effect" (perceived threat) and distaste for visual disamenities and noise in rural areas (Dröes & Koster, 2016). Another study in Denmark stated that visual pollution reduces the neighbouring house prices by up to about 3%, while noise pollution reduces the price between 3% and 7% (Jensen et al., 2014). A study performed on three US counties produced mixed results with one county experiencing increased prices, while the other two experiencing depreciation (Heintzelman & Tuttle, 2012). The only study conducted in the UK to report depreciation concluded that "price reduction is around 5-6% on average for housing with a visible wind farm within 2 km, falling to under 2% between 2-4km, and to near-zero between 8-14km, which is at the limit of likely visibility" (Gibbons, 2015). Overall, from all these negative studies combined, the major pathways for onshore wind farms' devaluation effect appear to be visual disamenities, noise, and shadow flickers and the effect fades to obscurity between 8-14 km.

The literature body for offshore wind farm's effect on housing prices is quite thin. The sole research on the topic found that even though onshore wind farms negatively impact the housing prices up to 3 km, there was no "significant effect of having an offshore wind farm in the view from a property itself or from the nearest beach" (Jensen et al., 2018). This is consistent with the results from onshore wind farms. Offshore wind farms are usually located outside the 8-14 km sphere of influence and do not contribute to noise or shadow flickers. Any lingering concern regarding visual disamenity can also be mitigated by locating the wind farms at a distance greater than 40 km from the shore, which is the limit of visibility (New York State Energy Research and Development Authority Prepared, 2017; Sullivan et al., 2013).

One thing to note though is that none of these studies explicitly state the effect of substations or electrical infrastructures on the house prices separately. The sole study on substations, conducted by Korea Electric Power Corporation, found no notable effect on housing prices (Hwang et al., 2015). A large number of studies on the effect of High Voltage Transmission Lines on housing prices do not come to a consensus. About half the studies find a negative impact, while others find no significant difference.

Figure 1 shows the timeline of the papers on the topic of wind farm's effects on housing prices concisely arranged in three categories of impact - negative, no effect, and positive. Overall, the majority of the body of evidence appears to suggest that offshore wind farms do not impact housing prices. Any concerns (noise, visual disamenity, strobing) can be fully mitigated by locating the wind farms more than 40kms from the shore. However, the effect of substations on housing prices is still unclear.

3.2. Construction effects on recreational users and tourists

The impact of offshore wind farms on tourism and recreational activities is a concern for communities. In most cases, local residents are afraid of the agglomeration of big turbines having a negative effect on leisure zones (both land and sea) (German Offshore Wind Energy Foundation, 2013). However, a gap between tourists' and local residents' opinions exists, since the former has proven not to be impacted by the development and operation of offshore wind farms, while the latter continues to show concerns prior to construction about a decline in tourism (Rudolph, 2014; Westerberg et al., 2013).

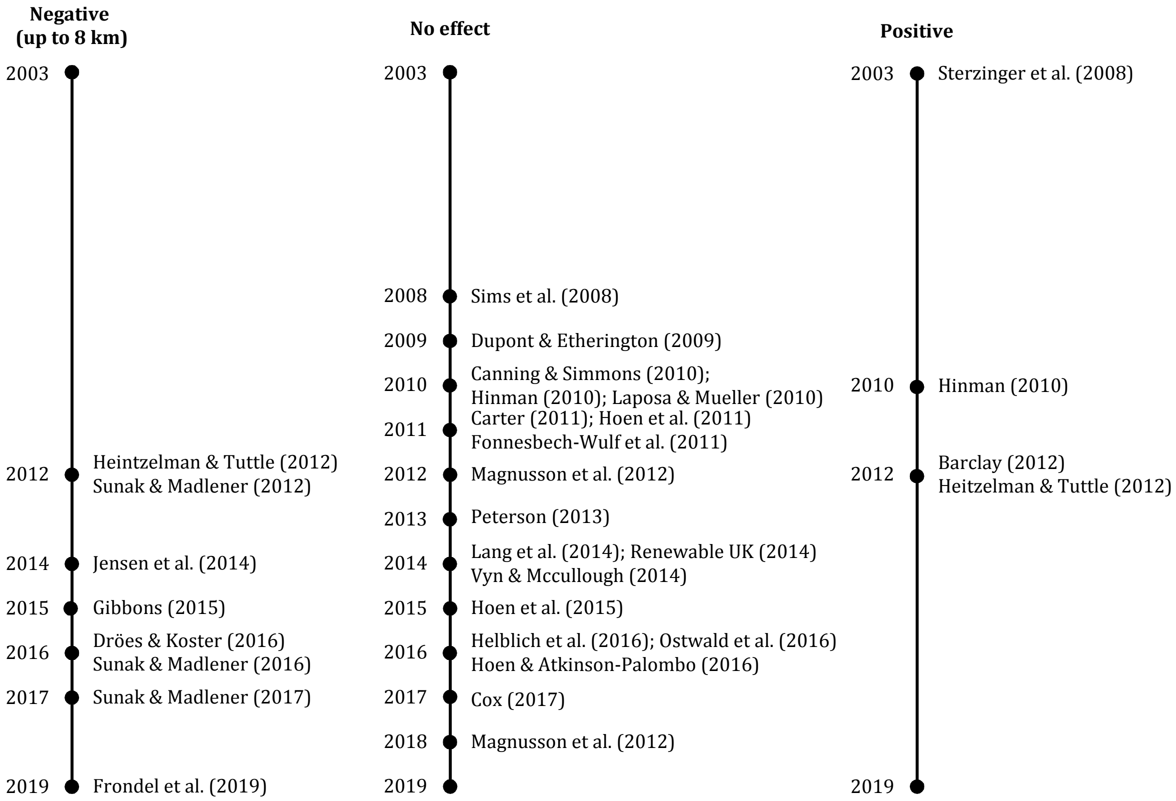

Figure 1. Timeline of papers on the topic of wind farm's effects on housing prices arranged in three categories of impact - negative, no effect, and positive

Prior to construction, communities believe that the area loses its recreational use and value, and therefore is in less demand (Pavlogeorgatos et al., 2015). Notwithstanding, the fears and the prejudices are mostly unjustified (German Offshore Wind Energy Foundation, 2013). Since there is no direct relationship between wind farm development and tourism sector decline, some studies argue that there is no substantial or empirical evidence to confirm that wind farms have a negative effect on the local tourist economy (BiGGAR Economics, 2016; Rudolph, 2014).

Other studies have proven through questionnaires, polls and interviews prior and after construction, that tourists perceive turbines neutrally or even positively, and that there is no effect on their decision to return to a given location or to go there for the first time. Studies confirm that there are few to no negative effects after construction in tourist numbers, experience, or expenditure in areas such as Europe, US, and Australia (Aitchison, 2004; British Wind Energy Association, 2006; Frantál & Kunc, 2011; Glasgow Caledonian University, 2008). Before the construction of Denmark's Horns Rev offshore wind farm, for example, local authorities and businesses opposed it, fearing declines in tourism. However, researchers found no decrease in the community's tourism levels (visits/expenditure), according to data on accommodations, food services, recreational activities, traffic volumes, and employment (Polecon Research, 2013). Also, in the Czech Republic and Scotland, according to the vast majority of tourists (over 90%), the presence of a wind farm does not influence their destination choice, and only a minimum (below 10%) offered a strict opinion against these locations (Aitchison, 2012; Frantál & Kunc, 2011).

Due to the rising importance of renewable energy, wind farms may attract a large number of tourists. Together with marketing promotion, these can contribute to the development of new forms of tourism in rural localities ("green tourism" or so-called "turbine bagging") (British Wind Energy Association, 2006; Frantál & Kunc, 2011; German Offshore Wind Energy Foundation, 2013). For example, after Nysted Offshore Wind Farm attracted tourists during the construction phase, the permanent exhibition called "The World of Wind", was opened (German Offshore Wind Energy Foundation, 2013; Weickmann, 2005).

Other studies confirm that impacts vary according to the distance of turbines from the shore. In the French Mediterranean for example, between 8 and 12 km, wind farms have no impact on tourism, while the opposite occurs for wind farms located within 8 km, if no coherent environmental policy or associated recreational activity exists (Cherry et al., 2012; Ladenburg & Lutzeyer, 2012; Ladenburg & Möller, 2011; Westerberg et al., 2013). Thus, locating turbines further out to sea would mitigate possible negative impacts on tourism (Lilley et al., 2010).

There is also contrary evidence. Studies argue that with more wind farms under construction, tourists start shifting to other places (Voltaire et al., 2017). Authors confirm that there is a strong correlation between lower housing value and drops in tourism (Etherington, 2014; Riddington et al., 2010). In addition, some studies have also found that negative relations exist between tourism and wind turbines construction, particularly with projects carried out in the near surroundings. However, the lack of empirical data on tourist flows and private holiday accommodations is one of the main research barriers (Broekel & Alfken, 2015).

As mentioned before, since studies do not explicitly confirm the effects during the construction of onshore electrical infrastructure, other large infrastructure projects have been analysed. Three studies on substations and onshore transmission works in Scotland explain that the developments were not expected to have any effects of significance on tourism (Arcus Renewable Energy Consulting Ltd, 2012; SSE Power Distribution, 2013). In addition, for a hydro-electric substation, a study which conducted surveys among tourists after construction shows that power plant infrastructure, with the exception of transmission lines, do not disturb the experience of the majority of tourists (Sæþórsdóttir & Hall, 2018). Transmission lines and pylons specifically have been proven to devalue natural amenities for recreational activities, tourism and local commerce (Cotton & Devine-wright, 2013). Studies which have focused on visitors' opinions have found that reactions are far more negative for pylons than for wind turbines. In questionnaires carried out in Ireland and Iceland, almost half of the visitors claimed that electricity pylons and wires affected their experience of visiting the countryside (EirGrid, 2015). Thus, transmission infrastructure is cited as the most negative type of development in the eyes of visitors (Stefánsson et al., 2017). Regarding nuclear power stations, negative impacts on tourism are related to construction traffic, accommodation, site noise, and environmental damage to the beach (Glasson, 2005; Gwynedd Council, 2018; Heywood, 2016).

Figure 2 shows the timeline of the papers on the topic of wind farm's effects on recreational users and tourists concisely arranged in three categories of impact - negative, no effect, and positive.

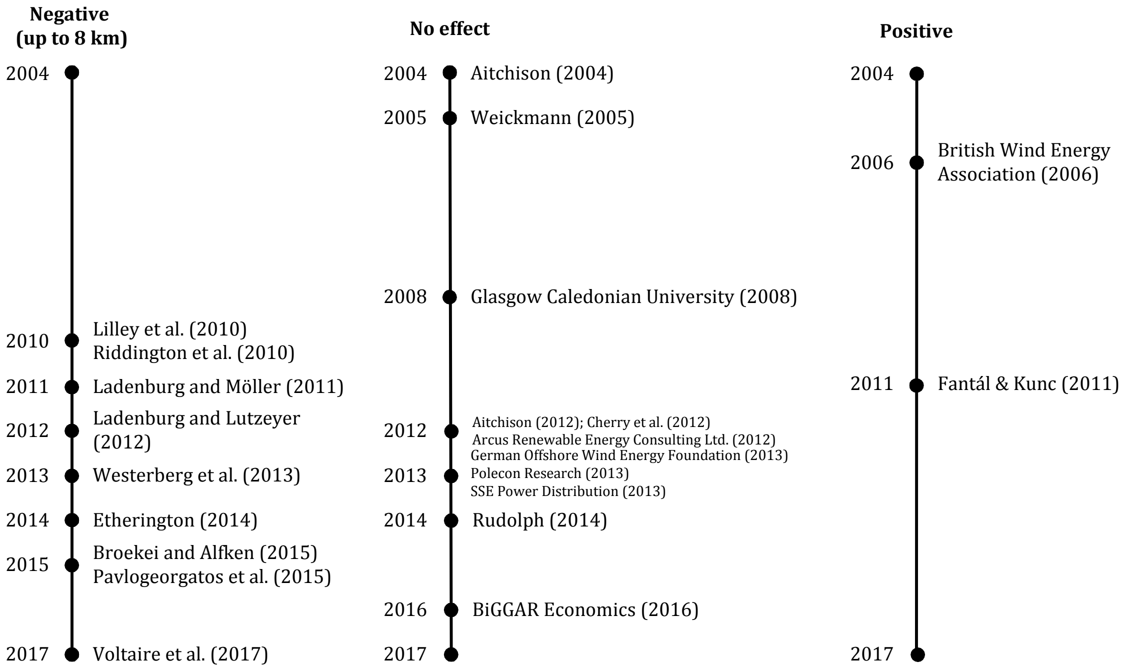

Figure 2. Timeline of papers on the topic of wind farm's effects on recreational users and tourists arranged in three categories of impact - negative, no effect, and positive

Overall, the majority of the body of evidence appears to suggest that offshore wind farms do not impact recreational users and tourists. Studies have shown that the perception of impact on tourism depends on individual attitudes toward aesthetics, or renewable energy, rather than on empirical analysis of how the behaviours and expenditures of visitors are influenced. The impacts of electrical infrastructure (such as substations and cables) on tourism is still unclear. Data collection, analysis and evaluation of projects after construction is important to understand visitor's satisfaction and travel behaviour during long-term developments.

3.3. Catalytic effects of supply chain clustering

It is considered that renewable energy in general, wind in particular, represents an opportunity for sustainable development not only for the economy at large but also for the local community (Slattery et al., 2011). This narrative is a common theme in most wind energy proposals and policies. In this section, the attempt is to identify an evidence base on the notion that offshore wind farms create local community benefits by creating employment opportunities through their operation and maintenance requirements.

The available resources and literature point to the fact that wind farms create direct and indirect employment in the economy and some of these benefits are indeed available for the local community (Ladenburg et al., 2020). The studies conducted in Scotland, Wales and Ireland show that there have been community benefits through the use of locally manufactured content and local contractors for construction, operation and maintenance. But these benefits have not been permanent and had a marginal economic impact on the community in terms of employment (Honvári & Kukorelli, 2018).

The majority of the literature available on the employment generation of wind farms in the local economy are projections on the potential of a project to generate employment rather than a study of employment opportunities created by a project (Hamilton et al., 2013) There is limited empirical investigation into the economic consequences of wind power as none of the studies uses historical data to make conclusions (Cameron & Zwaan, 2015).

The studies suggest that wind farms as a sector have very limited opportunities for genuine local purchasing of goods and services in local authority areas surrounding wind energy sites. This is because of the types of goods and services used during the development phase. The turbine itself makes up the largest proportion of the capital cost, and in most cases, the turbines are imported. On-site installation services are also normally provided by the turbine manufacturers themselves. This activity together with the process of making grid connections typically involves specialist teams. In these respects, the projects exhibit limited local linkages typical of foreign inward investment with the turbine manufacturers' regional presence normally limited to a representative office (Glasson et al., 1988).

Civil engineering work normally comprises a fifth of the capital investment and these inputs are often sourced from the region. Funding involved with civil engineering work can nonetheless be substantial. Other development costs, including those connected with feasibility and planning, may involve regional consultants. However, such business services are typically purchased through the headquarters of the developer, which is usually a multinational firm headquartered outside of the local community. It is also noted that because of the warranty conditions,, the turbine makers tend to use their own staff for on-site maintenance and, with turbine management being largely automated, inspection needs are infrequent (Munday et al., 2011).

To better understand the employment impact of investments and large projects in general, car manufacturing plants and their impact on the local economy were studied. There is significant data in this area to prove the impact such projects have had in the local economy in the long run (Foley et al., 1996). However, applying this to the wind farm sector is difficult, to the extent that each sector presents different trade-offs for recipient localities.

Figure 3 shows the timeline of the papers on the topic of wind farm's catalytic effects on supply chain clustering concisely arranged in two categories of impact - no effect or lack of evidence, and positive.

In general, while wind farms create direct and indirect employment, there is limited evidence to acknowledge the employment benefits in the local economy. This review has also shown that the impact of a wind farm on the local economy can greatly vary depending on the nature of the project and the way the project is executed. The projects have the potential to generate employment by getting contractors on-site to recruit and train locally, with local authorities and economic development agencies working to identify and encourage potentially qualified local contractors. While this could mean long-term sustainability of the sector, economic incentives for individual projects in this regard remain to be better understood.

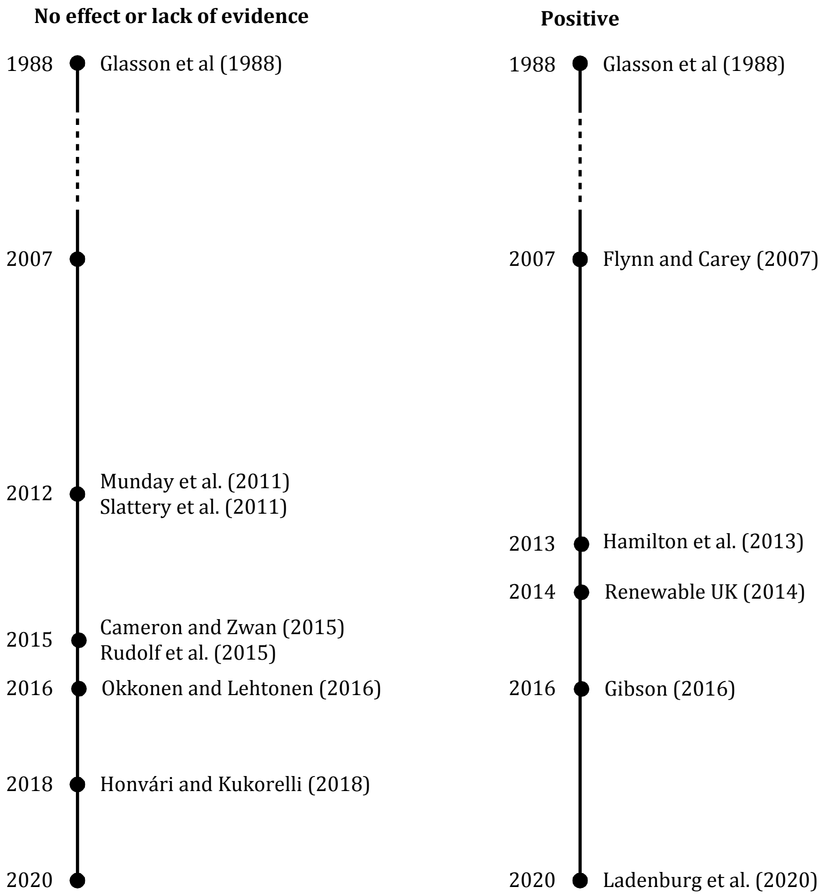

Figure 3. Timeline of papers on the topic of wind farm's catalytic effects on supply chain clustering arranged in two categories of impact - no effect or lack of evidence, and positive

3.4. Port development and social change

Offshore wind development requires ports from where workers and materials can be transported to the sea. For this purpose, existing ports are redeveloped, or new ports are developed when consent is given for the construction of an offshore wind farm. Positive and negative social change occurs in communities where these developments take place. The positive social change includes economic growth, jobs and indirect benefits for local firms and agencies while the biggest concern involved worker-related problems in one particular project (Glasson, 2005). While vast evidence exists concerning the positive impacts of infrastructure development, there is a lack of evidence for negative impacts. Also drawing upon evidence from the offshore oil and nuclear energy industry, this section examines the negative impacts of offshore wind developments on port communities.

There is evidence that the offshore oil industry has significant impacts on port communities which is partly related to alcohol abuse. A study from the 1980s found that approximately 30 per cent of offshore oil workers are very heavy drinkers (Aiken & Mccance, 1982). Other studies found that there is a link between substance abuse and shift work, especially due to the enforced period of offshore abstinence (Parkins & Angell, 2011; Sutherland & Flin, 1989). A study from the US found that communities involved in energy development experience changes in crime, mental health and community satisfaction (Seydlitz et al., 1993). In contrast, a study from Canada found that in a project with peak employment of 5,780 people there had been virtually no increase in crimes reported (Storey & Jones, 2003). Furthermore, concerns about alcohol and drug abuse failed to emerge as real issues once the project was underway. Another problem related to offshore development is the increased demand for housing, schools, roads, and utilities outstripping local supplies (Mitchell, 1976).

Social changes have also been observed in communities where nuclear power plants were built. For Sizewell B nuclear power station in the UK, 20,000 individual jobs have been created (Glasson, 2005). Positive impacts observed are economic growth, jobs and indirect benefits for local firms and agencies. Concerning local recruitment, it was noticed that a balance between leakage of benefits and negative impacts on other local businesses must be found. One proposed measure is employment and training initiatives. During the construction of Sizewell B, 40 arrests due to drink-driving involving in-migrant Sizewell B employees occurred in 1990 but then reduced to 5 in 1993 (Glasson, 2005). 15 arrests due to public order and drunkenness involving in-migrant Sizewell B employees occurred in 1990 but then reduced to 5 in 1993 (Glasson, 2005). The reduction was due to effective management such as a free shuttle minibus and attractive facilities on site (Glasson, 2005). Another example is the ongoing Hinkley Point C project, which has a peak employment of over 5,500 workers and takes over 10 years (EDF Energy Ltd., 2011). Between the 4th quarter of 2016 and the 2nd quarter of 2018, 117 instances of reported crime linked directly to the Hinkley Point C Project occurred.

Offshore wind farms are expected to have long-term positive impacts for the harbour communities which are used for maintenance and operation (e.g. the Port of Ramsgate is used as the operational basis for the Thanet and London Array Offshore wind farms) (Rudolph et al., 2015). The North-east of Scotland lost 84,000 jobs linked to the oil industry in 2015 and 40,000 losses were expected in 2016 which suggests that a diversification of industry is urgently needed (Oxford Brooks University, n.d.). Furthermore, ports are often located in deprived areas where the provision of job opportunities is of high importance (Atkins Ltd & ABP Marine Environmental Research Ltd, 2014). In Wick Harbour, for example, offshore wind development will generate 4,600 jobs during construction, and up to 580 during operation (Munro, 2014). In Port of Hull more than 1,000 jobs are estimated to be generated during the operation, for the Able Marine Energy Park, 260 full-time equivalent jobs will be created and for the Marine Energy Park, 300 jobs for the construction stage and 370 jobs for the operation and maintenance stage will be generated (Atkins Ltd & ABP Marine Environmental Research Ltd, 2014).

Nevertheless, the population increases from 200 to 2,000 as expected for Blackdog in Scotland will incur social changes (Oxford Brooks University, n.d.). A shift in port use (e.g. from fishing to OWF) may also cause increased social tensions amongst the community but limited evidence is available for such social impacts (Atkins Ltd & ABP Marine Environmental Research Ltd, 2014). Another study came to similar conclusions, arguing that a significant challenge is the lack of appropriate data for assessing well-being impacts of offshore wind farms (Hattam et al., 2015).

Table 4 shows the timeline of the papers on the topic of port development and social change concisely arranged in three categories of impact -negative, no effect or lack of evidence, and positive.

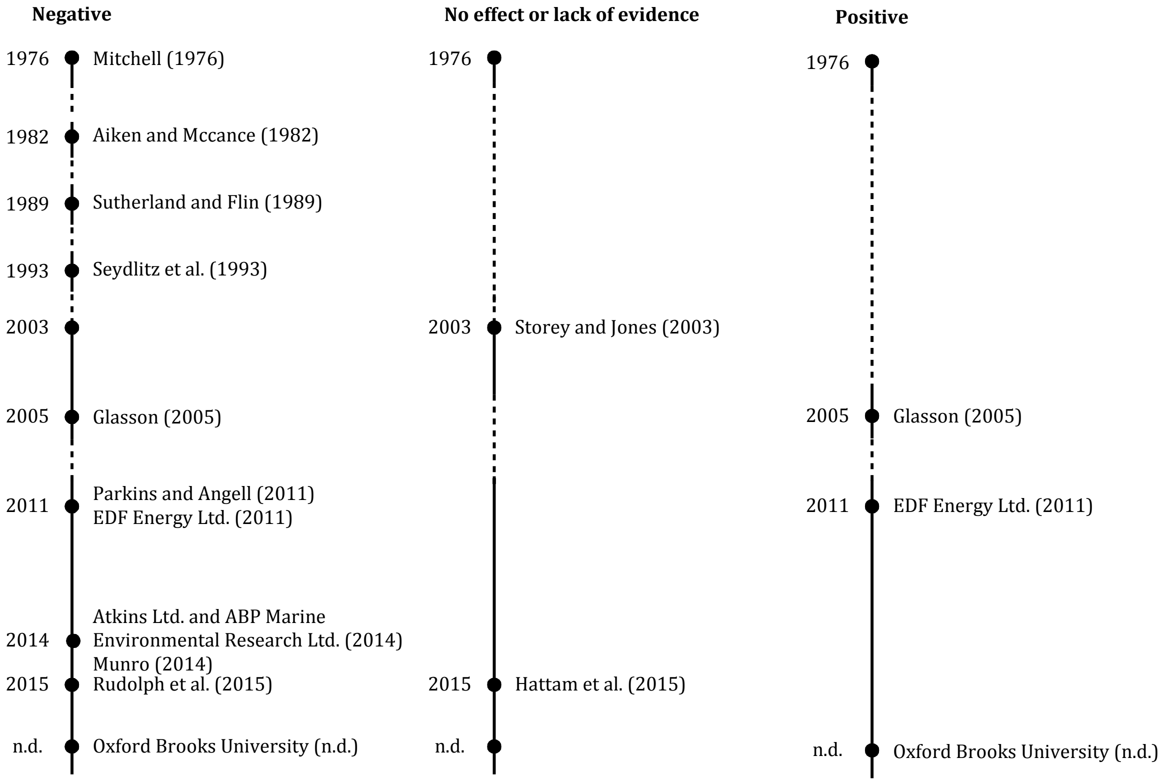

Table 4. Timeline of papers on the topic of port development and social change arranged in three categories of impact -negative, no effect or lack of evidence, and positive

In summary, considering the lack of research, data and information regarding social change due to port development, reliable conclusions cannot be drawn. When comparing offshore wind with offshore oil, it must be noted that the nature of shift work is not the same. While workers stay on oil platforms for weeks, offshore wind workers do not. What becomes apparent when comparing offshore oil, nuclear energy and offshore wind is that far fewer people are employed in offshore wind projects. While peak employment for one project can be over 5,000 jobs for offshore oil or nuclear energy, large offshore wind projects employ 5,000 people or less over the entire lifecycle of the project. Therefore, the changes due to offshore wind farms can be expected to be less significant compared to observations in the nuclear and offshore oil industry.

4. Conclusion

Wind energy is indispensable to achieve the urgently needed energy transition away from fossil fuels and to reduce the contribution from the energy sector towards climate change. The construction, operation, maintenance and decommissioning of wind farms can have positive and negative socio-economic effects. Understanding and mitigating the negative externalities of wind farms is crucial in attaining social acceptance of wind energy.

From the analysis conducted as part of the study under the four areas, this paper deducts strategies that can improve the socioeconomic outcomes of wind farm projects. Concerning tourism and housing prices, negative impacts are minimised when the offshore wind farms are located more than 40 km away from the shore.

In tandem with the mitigation measures, communities need to be educated on the importance of wind farms and preconceptions surrounding offshore wind farm projects that this study shows are not grounded in evidence. The lack of evidence to prove the effect of wind farms on tourism and house prices should be communicated to the local community in the early phase of the project to avoid stigma and concerns.

Wind farms have substantial economic and social impacts on the community. Therefore, they have the potential to create outcomes that are both positive and long-lasting. However, this study shows that there is a lack of evidence to suggest how the projects actually perform on these parameters in the long-term. Projects should, therefore, be monitored post-construction to track the socioeconomic impacts and assess them against the assumptions and projections made before construction.

Adequate monitoring should be implemented to mitigate unintended social changes when an offshore wind farm exceeds a certain size. Furthermore, this study identified areas within the socio-economic effects of offshore wind farms that require further research. Studies on offshore wind farm's catalytic effects on supply chain clustering and social change effects of offshore wind port development are scarce. Therefore, research should be conducted to fill these gaps. The body of evidence on the socio-economic effects of offshore wind farm's electrical infrastructures is thin or non-existent. This research gap should also be explored.

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