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National Innovation System and Sustainability of the UK Renewable Energy Sector

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Abstract

Sustainable innovation emerges and spreads to solve challenging global issues. Through desk research and using secondary data, this article evaluates the socio-economic impact of renewable energy policies, innovations, and opportunities. National Innovation System (NIS) has been applied to analyze the importance of new technology and the role of stakeholders and collaborations in the Open Innovation System (OIS). We examine the major components of sustainable innovation, disruptive innovation, radical innovation, including social, political, technological, and economic drivers influencing the development of renewable energy sector. The United Kingdom (UK) leads the world in installed Offshore Wind Farms (OWF) capacity and has the largest OWF investments. The Helix system provide foundations upon which firms build innovative products, technologies and services through research and development (R&D). However, there are concerns about the impact of Brexit on the UK policies related to the European Union (EU) Green Deal and Paris Agreement on climate change initiatives. With a focus on the UK's OWF and Offshore Renewable Energy (ORE) sector, this article developed a model to explain the Socio-economic benefits of ORE innovations, constituents of successful International Innovation System (IIS), NIS and OIS. These have implications for the achievement of EU renewable energy targets by 2030. The developed ORE innovation model transforms into opportunities in the local economy, entrepreneurship growth, job creation, increased revenues, increased renewable energy production and consumption.

Keywords: *Sustainable renewable energy, Offshore wind farm, Open innovation system, National innovation system, International systems of innovation, Paris agreement and EU green initiatives*

1. Introduction

This article evaluates the UK Renewable Energy policies, innovative practices, and opportunities. Renewable energy technologies and renewable hybrid mini-grid systems are becoming economically viable options in many economies (Keeley & Managi, 2019). As a result, there is now a global shift to low-carbon renewable energy sources (Krozer, 2019). Offshore Wind Renewable Energy (OWRE) represents installed wind turbines in the open sea used to generate renewable energy. The transition towards renewable energy is inevitable while

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reducing the reliance on fossil fuels (Lee, 2018) and reduces Carbon dioxide (Co2) emissions. There have been related studies such as determinants of renewable energy technological innovation (Lin & Zhu, 2019; Osman, 2015), economic evaluation of renewable energy (Georgiou & Areal, 2015), value chain creation due to renewable energies (Lyng et al., 2019; Taghvaee, Mavuka & Shirazi, 2017) and renewable energy-driven desalination opportunities (Mollahosseini et al., 2019). These studies point to the socio-economic and environmental benefits of renewable energy sources.

The EU aims to achieve 20 per cent of energy consumption from renewable sources by 2020 and 32 per cent by 2030 (Bilgili, Yasar & Simsek, 2011). Therefore, major renewable energy developments in the EU have now shifted towards Offshore Wind Farms (OWF) where the resource is high and less likely to be affected by the limitations of Onshore Wind Farms (Mahdy & Bahaj, 2018). OWRE turbines are installed in the deep-sea waters and used to produce renewable energy. OWRE is the sector the UK aims to achieve its renewable energy target. By the end of 2019, the UK had the highest OWF installations in Europe with 931MW of installed capacity (Energy News, 2019) and the UK is the primary coordinator of innovation in Offshore Renewable Energy (ORE) (Danilova, Grant & Menachof, 2016). This has resulted in a hub of activities (local and regional clusters) of big corporations, small and medium enterprises (SMEs).

National Innovation System' (NIS) (Perkmann & Walsh, 2007) explains the recombination of existing ideas or the creation of new processes and products (Watkins, Papaioannou, Mugwagwa, & Kale, 2015). Open Innovation System (OIS) provides opportunities for utilising external as well as internal ideas as inputs to the innovation process (Eckhardt, Ciuchta & Carpenter, 2018). Since the early 1990s, the incorporation of environmental objectives has gradually become common practice in most countries (Labandeira, Labeaga & López-Otero, 2019). Arguably, the development in the ORE is driven by innovating firms. Innovating firms engage in both technology exploitation and exploration to be effective in the short-run and the long-term (Geerts, Leten, Belderbos and Looy, 2018). New competition from the ORE is enabling innovative big companies and SMEs working in the renewable energy sector to explore new technologies and connect with potential stakeholders (Catapult, 2018). By exploring these contexts, this study contributes to the literature on NIS, technology innovations and the impact of renewable energy. It contributes to the sustainability perspective and debate about renewable energy technologies in the context of environmental, economic, and social impact. Sustainability is the ability to maintain at a certain level of ecological, social, and economic ecosystem of the society, including environmentalism.

The rest of the paper is structured as follows. The next section examines the theoretical foundations of NIS, Environmental and Technology Innovations. This is followed by the analysis of renewable energy policies and plans such as the Paris Agreement and European Green Deal. Through desk research and using secondary data, the socio-economic benefits of innovations in the ORE are examined and the framework developed. Finally, the article concludes with implications, limitations, and suggestions for future research.

2. Theoretical background

2.1 National Innovation System (NIS)

NIS describes all the major components of the innovation process, including organizational, social, political, and economic factors (Golichenko, 2016). The concept of NIS arose in the late 1980s and early 1990s due to the dissatisfaction of several economists in the neoclassical mainstream of economic theory (Golichenko, 2016). The model suggests that the research system's goal is innovation and that the system is part of a larger system composed of sectors such as government, university, and industry and their environment (Godin, 2009). Christopher Freeman, Bengt-Ake Lundvall, and Richard Nelson are regarded as the founders of the concept (Golichenko, 2016). The model emphasized the relationships between the components or sectors, as the cause' that explains the performance of innovation systems (Godin, 2009). National innovations in renewable energy are vital to reducing emissions and creating thousands of green jobs and investment in the UK (Department for International Trade, 2015).

OWF is an emerging technology in the wind energy conversion system (Perveen, Kishor & Mohanty, 2014). Wind, solar PV and gas are the three major sources of renewable energy and electricity (Wind Europe, 2017, p. 15). This could be attributed to innovations in renewable energy generation. Wind Turbine suppliers like Siemens have already chosen the UK as the site for future world-class manufacturing facilities, and there are great opportunities for further investment in the supply chain (Department for International Trade, 2015). The report maintains that the Offshore wind sector presents an investment opportunity of between £16 to £21 billion by 2020 and that innovative funding models are being created to attract new sources of capital into the sector.

International innovation plays a critical role in the development of the ORE sector. NIS has been represented as a set of socio-economic, political, organisational, and institutional factors that influence the development, diffusion, and implementation of innovations (Edquist, 2006; Malik, 2013). The idea of 'NIS' was first proposed by Freeman (1982, 1987) in his studies based on the neoclassical approach to economic growth. Freeman (1987:1) defines "NIS as a network of establishments within the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". Since the work of Freeman, there has been a gradual evolution of the study of NIS (Watkins et al., 2015). There are many different local, national, and international systems of innovation engaged in the diffusion of new technologies and knowledge (Malik, 2013).

The rise of the digitally enabled 'disruptive technologies' or 'sharing platform economy has been propelled by advances in Information Communication Technologies (ICT) (Howcroft & Bergvall-Kåreborn, 2019; Wood et al., 2018, Veen et al., 2019). There have been calls for more studies to understand the complex micro-foundations of innovation systems (Razak & White, 2015; Leven, Holmstrom & Mathiassen, 2014). In the beginning, the NIS concept centred on firms as the core institution through which innovations are developed and commercialised (Owen-Smith & Powell, 2004). In the last two decades, there has been a gradual shift from innovating firms to NIS and Regional Innovation System (RIS) (Ornelia, 2015; Razak & White, 2015). Therefore, innovation remains a critical framework for sustained growth and competitive advantage for firms and nations.

Notably, there are four types of innovations: Disruptive Innovation, Radical Innovation, Incremental and Architectural Innovation (Hopp, Antons Kaminski, Salge, 2018). Exploring in detail the four concepts is beyond the scope of this article. Radical innovation is the commercialisation of an entirely novel idea, new to the firm and its markets, and it is the essence of value creation by entrepreneurial ventures (Colombo et al., 2017). Hopp et al. (2018) explain that research on radical innovation focuses on the types of organizational behaviour and structures that explain and predict the commercialization of novel ideas. While radical innovation brings huge economic rewards to firms, it is an activity fraught with risk (Colombo et al., 2017). ORE companies engage in radical innovation to provide clean energy, reduce costs and be profitable.

'Disruptive innovation' describes a process in which new entrants challenge incumbent firms, often despite insufficient resources (Hopp et al., 2018). Hopp et al., (2018) further explain that while disruptive innovation is inextricably linked to variations of business models and low-end market invasion, radical innovation is reliant on organizational capabilities and organizational human capital. The Helix Models (Etzkowitz, 2003; Etzkowitz & Leydesdorff, 2000), highlights the role of education stakeholders in fostering innovation at national and regional levels (Ornelia, 2015; Perkmann & Walsh, 2007). It is grounded on the idea that innovation is the outcome of an interactive process involving different actors according to the European Union Committee of the Regions (European Union, 2016). These actors are the University, Industry, and Government and Civil society (Perkmann & Schildt, 2015).

Since the emergence of the Helix system, some studies focus on International Systems of Innovation (ISI) and the role of Multinational corporations (MNCs) in the production and diffusion of knowledge and technologies (Malik, 2013). Malik (2013) suggests that some elements of institutions of nations positively influence international technology transfer, while other elements negatively influence international technology transfer. Also, globalization has contributed to changes within the dynamics and unfold of innovation activities (Narula, 2014). ISI involves purposive inflows of information and resources (Eckhardt et al., 2018). Therefore, ISI requires diverse stakeholders, resources and expertise. The key stakeholder of the NIS according to Watkins et al., (2015) are (i) governments and related agencies, public-private partnerships; (ii) sectors and industries comprised of firms which generate commercial innovation, research and development (R&D); (iii) universities which conduct basic research and training, and (iv) public and private organisations engaged in research and innovation activities. Engaging with stakeholders and networks to drive innovation requires three levels of capabilities:

"It requires specific operational capabilities, complex first-order dynamic capabilities (to manage the engagement), and second-order dynamic capabilities to allow organisations to co-create value and to learn from the engagements" (Watson, Wilson, Smart, and Macdonald, 2018, p. 256).

Platforms are foundations upon which complementary companies can build complimentary products, services, or technologies (Gawer, 2010). Organisational learning is very important in innovation systems. Dyer and Singh (1998) state that four sources of advantages enable organizations to engage in innovation. These include complementing resources, relation-specific investments, inter-Organizational data sharing, and effective governance (Dyer & Singh, 1998). Among these, knowledge sharing is a crucial element of entrepreneurial learning (Scarmozzino, Corvello, and Grimaldi, 2017).

2.2. Environmental and technology innovation

Sustainable innovation, frugal and reverse innovation and unconventional sources of innovation are emerging in developed and developing economies driven by infrastructures and technologies (Agarwal, Brem & Dwivedi, 2019; Trischler, Johnson and Kristensson, 2020; Zhang et al., 2020). Often, sustainability and innovation are analysed as stakeholders driven phenomena (Jerónimo et al., 2020; Lee and Raschke, 2020). For example, Green Product Innovation (GPI) related to environmental innovation, including the innovation in products promotes energy-saving, pollution prevention, waste recycling, no toxicity, or green product designs (Zhang et al., 2020). GPI contributes to firms' sustainable competitive advantage by development of eco-friendly technology (Zhang et al., 2020).

Research in economic geography has paid increasing attention to RIS as a potential opportunity for growth and development (Rypestøl & Aarstad, 2018). Sustainability has the potential to address societal, economic and environmental challenges simultaneously. Nowadays, many countries derive their energy supply from fossil fuels such as coal and natural gas, and as the energy consumption of countries increases, carbon emission is increasing as well (Güney, 2019). Wind energy currently makes up around 14 per cent of the electricity generation in Europe – up from 12 per cent in 2017 (Energy News, 2019). Environmental technology innovation has become necessary to achieve sustainability, cover the ever-increasing energy need and realize the social and economic benefits necessary for society, and minimize the pollution of the resources.

The concept of 'sustainability focuses on the social, economic and environmental impacts of businesses (Schwartz & Carroll, 2008). The EU defines sustainable development as that which meets the needs of the present without compromising the ability of future generations to meet their own needs (EU, 2019). Environmental innovation represents the subset of innovation system addressing the ecological dimension of sustainability (Adams et al., 2016) concerned with the production, assimilation or exploitation of a product, production process and services (Kemp and Pearson, 2008). These result in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) (Kemp & Pearson, 2008). Geerts et al. (2018) distinguish between technology exploitation and exploration. The earlier refers to the refinement and extension of existing technologies and implies activities like refinement, selection, and implementation (Geerts et al., 2018). Environmental Policy and Technological Innovation comprehensively explores the factors which can influence a firm's behavioural approach towards developing clean technologies (Corral, 2002).

It could be argued that organisations are always embedded in specific institutional contexts (Leppäaho & Pajunen, 2018). Hart (1995) suggests "organisations that adopt product stewardship strategies will evidence the inclusion of external stakeholders in the product development and planning process" (p. 100). This type of innovation is prevalent in rapidly changing environmental contexts, demanding continual resource reconfiguration (Hart, 1995). Environmental innovation poses complex, systemic challenges for how firms engage external stakeholders (Watson et al., 2018). Technology, as always, is a key driver of innovation and enables the business to evolve and maintain a commercial advantage maintains Julian David, chief executive of tech-UK (David, 2013).

3. Renewable energy policies and investments

3.1. Paris agreement and European green deal

The Paris Agreement is a landmark international accord that was adopted by nearly every national leader in 2015 to address climate change and its negative impacts. The aim is to substantially reduce global greenhouse gas emissions, cut climate pollution and provides a pathway for developed nations to assist developing nations in their climate mitigation and adaptation efforts. According to Gabbatiss (2021) "Emissions" is nine of the "Paris Agreement" and climate change described as an "existential threat to humanity".

The Paris Agreement includes commitments to maintaining and "striving to increase" each party's "climate level of protection", which is defined as a 40% economy-wide reduction in emissions by 2030 in the EU, with the UK meeting its share of this target [Gabbatiss, 2021].

Also, the European Green Deal plan is aimed at making the EU's economy sustainable. According to European Commission (2019-2024), the plan focuses on turning climate and environmental challenges into opportunities and making the transition just and inclusive for all including (i) boosting the efficient use of resources by moving to a clean, circular economy; and (ii) restore biodiversity and cut pollution. In October 2014, the EU member states agreed on three binding targets for 2030: a 40 per cent reduction in greenhouse gases, a 27 per cent renewable energy target, and a 27 per cent energy savings target (Wyns & Khatchadourian, 2016). The EU will also provide financial support and technical assistance to enable (i) investment in environmentally friendly technologies; (ii) supporting industry to innovate; (iii) rolling out cleaner, cheaper and healthier forms of private and public transport; (iv) decarbonising the energy sector; (v) ensuring buildings are more energy efficient; and (vi) working with stakeholders to improve global environmental standards (European Commission, 2019-2024).

There have been some concerns about Brexit and its impact on the Green Deal and climate change since about 80 per cent of the UK's environmental legislation comes from Europe (Gabbatiss, 2021). In response, the UK government promises that they would be no relaxing of climate standards following the UK's departure from the EU (Gabbatiss, 2021). European Environment Agency (EEA) maintains that the EU is not on track to meet most of its 2030 objectives and targets specified in the 7th Environmental Action Programme (EAP) (Bodin & Stainforth, 2019). With the Green Deal's roadmap, EU plans to deliver an adequate response, including on waste management and energy efficiency. However, the plan lacked adequate focus and action in areas concerning enforcement of biodiversity legislation and sustainable use of the seas and addressing noise pollution (Bodin & Stainforth, 2019).

3.2. The UK renewable resource capacity and investment

The UK leads the world in installed OWF capacity and has the largest single wind farm off the Cumbrian Coast (Energy News, 2019; Department for Business, Energy and Industrial Strategy, DBEIS, 2020a), as demonstrated by an increase in the total installed capacity [Figure 1]. Germany leads in Onshore Wind Farms installed and the UK in OWF installed [Figure 1]. Despite these challenges of installation, operations and maintenance of renewable wind energy, the UK is expected to maintain its leading position in the OWRE (Danilova, Grant & Menachof, 2016). Offshore wind's share of annual UK generation increased from 0.8 per cent in 2010 to 6.2 per cent in 2017 and is expected to reach around 10 per cent by 2020 (DBEIS, 2020a). While there are often high levels of public protest aganist Onshore Wind Farms, there is less opposition to the installation of OWF turbines. The reasons for less resistance to OWF include fewer concerns about health and safety, negative environmental impacts, noise, and visual aesthetics (Mulvaney, Woodson & Prokopy, 2013).

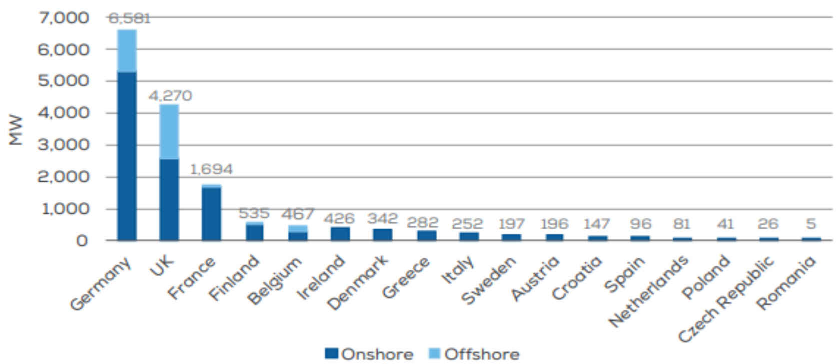

Figure 1. Installed OWRE capacity-onshore and offshore wind farm (Total: 15,638 MW)

Source: Wind Europe (2017, p. 18)

The UK's OWF sector investment pipelines by value are worth £11.5bn (RenewableUK, 2017). According to the statistics from Energy News (2019), the UK installed 931MW of offshore wind capacity, followed by Denmark (374MW), Belgium (370MW) and Germany (252MW). The UK projects have attracted a broad range of integrated suppliers, independent power producers and sovereign wealth funds. Two leading international suppliers of offshore wind foundations, EEW SPC of Germany and Bladt Industries of Denmark, have acquired the former TAG Energy facility in Teesside in the Northeast of England (Department for International Trade, 2015). This hub will become a key part of the European manufacturing base for the firms, generating up to 350 direct jobs in the local area, as well as a significant additional number of jobs in the local supply chain (Department for International Trade, 2015).

The UK has 5.7 GW installed or under construction and is on track to deliver 10 GW, representing the largest expansion in any class of renewable energy technology (Department for International Trade, UK Offshore Wind: Opportunities for trade and investment, 2015). The DBEIS (2019) shows renewable energy projects generated in 2018 (Figure 2). The report notes that whilst bioenergy dominates on a fuel input basis, hydroelectricity, wind power and solar together provide a larger contribution when the output of electricity is being measured.

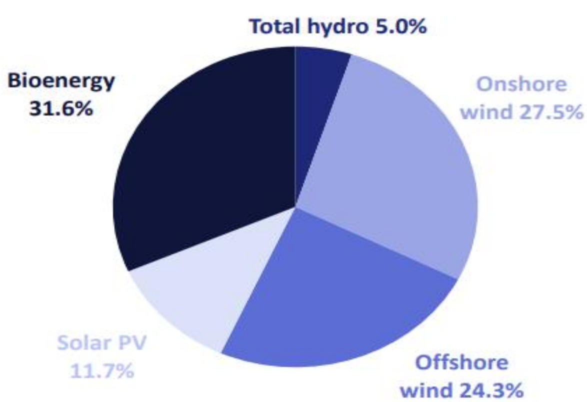

Figure 2. Renewable electricity generation by fuel source

Source: Department form Business, Energy and Industrial Strategy (2019). Digest of United Kingdom Energy Statistics (2019, p. 112)

The UK consistently tops international rankings as the best place to invest in OWRE and has been successful in attracting investment from across the globe (Department for International Trade, 2015). The report maintains that the UK enjoys a reputation for operating stable and predictable policy regimes to support investment in renewable electricity infrastructure. In 2019 the UK obtained 19.8 per cent of its primary energy from low carbon sources, with 7.3 per cent from bioenergy which exceeded nuclear 7.0 per cent (Table 1). Renewable wind source is still low at 2.9 per cent but remains the third-highest renewable electricity source.

Table 1. The proportion of UK energy supplied from low carbon sources, 2000 to 2019

	2000	2010	2016	2017	2018	2019
Nuclear	8.4%	6.3%	8.0%	7.9%	7.3%	7.0%
Wind	0.0%	0.4%	1.6%	2.2%	2.5%	2.9%
Solar	0.0%	0.0%	0.5%	0.5%	0.6%	0.6%
Hydro	0.2%	0.1%	0.2%	0.3%	0.2%	0.3%
Bioenergy	0.9%	2.7%	5.8%	6.2%	6.8%	7.3%
Transport fuels	0.0%	0.6%	0.5%	0.5%	0.7%	0.9%
Other	0.0%	0.0%	0.7%	0.7%	0.7%	0.8%
Total	9.4%	10.2%	17.4%	18.3%	18.9%	19.8%

Source: Department form Business, Energy and Industrial Strategy (2020b, p. 13)

Fairweather (2014) presents an example of the energy imperative and economic impact of Germany investment in renewable energy. The current per capita energy costs (excluding plant investment) were around €2500 per annum (representing a total of €2.5 billion per annum flowing out of this region's local economy to big institutions and investors elsewhere). With the complete transition to a decentralised power supply based on local renewables, the same €2.5 billion remained in the local economy. That is, money normally paid for fuel remained in the consumer's pocket, and the construction and maintenance of the decentralised system remained local (Fairweather, 2014). Despite the benefits of ORE, the main challenge is associated with operations and maintenance (O&M) costs which account for 14 – 30 per cent of total project lifecycle expenditure as indicated in many studies (Martin et al., 2016; Li et al., 2016). OWF has a total lifespan of between 20-25 years and suffers technical failures that reduce their availability to produce electricity beyond the lifespan. Also, there are other bottlenecks when it comes to producing and installing OWF on an adequate scale to support the green transformation. According to Poulsen and Lema (2017), these include scarcity of sites for new turbine installations; technologies for dealing with intermittency; financial resources; reduction in government revenues, etc. (p.759).

Management of the OWRE innovations, O&M activities of the supply chain and logistics is the right place to drive efficiency, reduce cost and create business opportunities (Crown Estate, 2013; Hassan, 2013; WWEA, 2014). This sector includes activities that lead to high-level coordination and management such as turbine design and installation, environmental monitoring, electricity sales, ports facilitate, transportation, marketing and other auxiliary services (Crown Estate, 2013) leading to a hub of activities and entrepreneurship. OWRE stakeholders recognise that stripping costs out of the supply chain will be significant to encourage firms to continue to invest in the sector and promote economies of scale of renewable energy (Athanasia, Anne-Bénédicte & Jacopo, 2012). For this reason, the ORE Cost Reduction Task Force (CRTF, 2012) has recommended that a new project delivery option is known as "alliancing" be used.

Alliancing is an arrangement that includes a structure to share risk and reward among multiple contractors and the owner; thus, the financial success of each of the parties is linked to the overall success of the project (Anvuur & Kumaraswamy, 2007). There has been many joint projects and alliances in the ORE which is creating a hub of large, medium and small industries (such as wind farm owners, developers, manufacturers, surveyors, specialist and professional services, and various engineering, monitoring, electrical and manufacturing industries), each requiring specific technical specifications and accreditations.

4. The socio-economic benefit of innovations in the ORE

Renewable energy not only ensures electric power independence and security but also supports the transition to a low carbon economy and society development (Lin & Zhu, 2019). However, the development requires a high initial investment (Kim & Park, 2016) and large amounts of government subsidies to achieve market competitiveness (Zhanget al., 2017). Organisations take the role of players in the innovation system, while the government role in the provision of the favourable institutional framework is crucial. The UK's Electricity Market Reforms provide long-term stable revenues for low carbon energy projects and reduce investor risk (Department for International Trade, 2015). The UK's draft National Energy and Climate Plan (NECP) contained in the Department for Business, Energy & Industrial Strategy (DBEIS, 2019) states that Government's long-term plan is to maintain a balanced low carbon electricity generation portfolio to help meet UK 2050 carbon targets. Since commissioning the world's first OWF in 1991, UK currently produces more than 20 per cent of the UK's electricity based on this source (Energy UK, 2019).

Industry and government are working together to build a competitive and innovative UK supply chain that delivers and sustains jobs, exports and economic benefits for the UK (Department for International Trade, 2015). Political commitment and regulatory stability, reliability and predictability are all elements that increase the confidence of market actors, reduce regulatory risks and hence significantly reduce the cost of capital (Wyns & Khatchadourian, 2016). Nearly £19bn has been invested in offshore wind in the UK since 2016 (RenewableUK, 2019). The UK Vision for the UK OWF is "Industry and Government work together to build a competitive and innovative supply chain that delivers and sustains jobs, exports and economic benefits, supporting offshore wind as a core and cost-effective part of the UK's long-term electricity mix" (HM Government, 2013: 5).

Therefore, the UK government, private and public sector collaboration has led to the creation of NIS. The landmark success of ORE in the UK is the result of a healthy, vibrant supply chain built with companies such as 3sun, Cwind, Seajacks, Fred Olsen Wind-carrier, etc (RenewableUK, 2017). In turn, the IIS and NIS create industrial clusters of Multinationals corporations (MNCs), supply chain activities, small businesses, and entrepreneurship activities. The outcomes of these activities lead to the development of new environmental technologies, especially in renewable energy as presented in model [Figure 3].

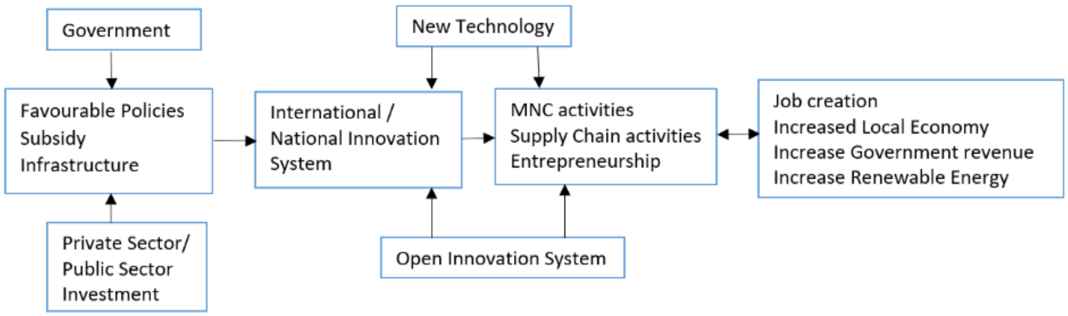

Figure 3. Linkages and Socio-economic benefits of ORE Innovation

Source: Author's model

As shown in [Figure 3], government and MNCs are key players of the ORE innovation. ORE firms engage in radical innovation to safeguard against disruption in technologies. In the Northeast of England, London, Wales, and Scottish coasts, OWF activities have resulted in NIS (Igwe & Howell, 2015). The UK government's target is to use OWF to create economic growth and jobs in the local and regional territories (Copena & Simon, 2018). The long-term visibility of policies for renewable energy provides assurances for investors, as shorter time frames can increase risk and uncertainty (Wyns & Khatchadourian, 2016). Some UK ORE developers include ORSTED - Nasdaq Copenhagen, Scottish Southern Energy (SSE), E. ON, Centrica, Npower, EDF Energy, 2-B Energy (Igwe & Howell, 2015). Major turbine manufacturers include Danish manufacturer Vestas, Siemens, Repower and Samsung. Others include Alstom, MHI Vestas, A2SEA, Statoil, Vattenfall and Navitus Bay (Igwe & Howell, 2015).

These companies engage in inter-organizational and institutional collaborations. However, the government provides the platform for ORE innovation (Eckhardt, et al., 2018; Malik, 2013). Government policies and supports through the creation of favourable institutions (Malik, 2013) and platforms have led to a massive expansion of ORE projects. For example, the UK government in 2016 approved £28 million for innovation in infrastructure systems in the OWF sector (OffshoreWind.biz, 2016). As a result, there are several OWF locations e.g., London Array, Dudgeon, Thanet, Walney, Robin Rigg, etc. (Igwe & Howell, 2015).

The UK Offshore wind offers favourable returns in a stable, regulated environment such as long-dated assets with 25-year asset lives and up to 20 years of contracted revenues; inflation-linked revenue streams backed by UK government legislation; and the Crown Estate offering 50 years lease terms (Department for International Trade, 2015). The economic viability of renewable electricity will depend on the functioning of the wholesale market, intra-day market, balancing market and, for certain producers, retail market (Wyns & Khatchadourian, 2016). More so, favourable institution enables diffusion and implementation of innovations (Malik, 2013) and public and private sectors are taking advantage of this to create value. Public sector intervention in the economy is usually justified by overcoming market and system failures (Edquist, 2006).

Leveraging on the platform provided by the government, many big corporations, including Siemens, EDF Energy, E.ON, SSE Renewables and RenewableUK are pledging long-term commitment to investing in plants, facilities, research & development and innovation according to the Centres for Offshore Renewable Engineering (2011). In this sense, the hub of activities has been a result of MNCs' activities. Small-medium enterprises (SMEs) involved in the supply chain of the O&M activities also contribute to economic activities. The ecosystem or platform (Eckhardt, et al., 2018) is creating a new form of businesses start-ups and entrepreneurship.

These have been achieved through new technologies and collaborations from key stakeholders. The impact of the cluster of activities has led to job creation activities. As of 2015, about 1,183 offshore wind turbines have been installed in the UK with a capacity of 4,042 megawatts (MW) (Igwe & Howell, 2015).

By doubling its installed capacity to 30GW by 2030, the UK government hopes to deliver thousands of additional skilled jobs (Catapult, 2018). There is another dimension, currently, only 16 per cent of the OWF workforce are women. Under the government industrial energy strategy, the target is to double more than the number of women employed in the industry to at least 33 per cent by 2030, with the ambition of reaching 40 per cent (DBEIS, 2019). Another aim is to increase the number of green-collar jobs in the industry to 27,000 jobs by 2030, up from 7,200 in 2019 (UK DBEIS, 2019). By innovating products, services, production, and processes, companies generate economic and social value (Colombo et al., 2017). An increase in OWF investment could lead to billions of pounds worth of export opportunities (Catapult, 2018).

Industrialized countries are now faced with the international trend of sustainability; hence, they need to develop strategies to maintain economic growth whilst at the same time undergoing a carbon reduction (Chou, Walther & Liou, 2019). Linked to disruptive and radical innovations, ORE companies leverage core competencies to develop new technological breakthroughs. As Hopp et al. (2018) put it, the ability to envision the future of technology is important to the generation of the novel ideas required for radical innovation. Therefore, hiring competent employees enables ORE companies to cope with changes in technology. The UK government position is that ORE represents a unique opportunity for the UK to pursue economic growth through support for high-growth entrepreneurship, increase in highly skilled jobs, increase energy security and reduced carbon emissions (HM Government, 2013). The UK Government estimates that by 2021, the sector could deliver £7bn Gross Value Added (GVA) to the UK economy (excluding exports).

Another impact of the ORE innovation is an increase in the generation and usage of renewable energy. The UK National Grid announced in March 2017 that new wind energy provided 35.7 per cent of UK electricity, while gas produced 20.3 per cent, nuclear supplied 17.6 per cent, coal 12.9 per cent and imports 6 per cent (RenewableUK, 2018). Already, offshore wind powers the equivalent of 4.5 million homes annually and will generate over 10 per cent of UK electricity by 2020 (RenewableUK, 2019). Another impact of the ORE innovations is that the cost of new offshore wind has fallen by 50 per cent since 2015 and it is now cheaper than gas and nuclear power (RenewableUK, 2019). The benefit of OWF is that despite being 150 per cent more costly to install than Onshore Wind Farms, the quality of the resources is greater, and the sea sites are readily available (Mahdy & Bahaj, 2018). Despite the high rate of installation of renewable wind energy across Europe, Wind Energy (2019) warns the rate of installations won’t be enough to help the EU reach its renewable energy goal of 32 per cent for 2030.

5. Conclusion, implications, and limitations

Sustainability is embedded in practices that support the management of natural resources in order to maintain an ecological balance, social equity and economic development. Towards this direction, turning climate and environmental challenges into opportunities has become a major agenda of global political and economic treaties. With President Joe Biden elected as the new United States of America (USA) President, the “2015 Paris Agreement” and Climate Change Agenda is back on the World Agenda after the formal President Donald Trump ceased all participation in the Paris Agreement, contending that the agreement would "undermine" the USA economy. Concerning the UK renewable energy plan and government target using ORE post-Brexit, it is unclear what impact Brexit will have on the UK government’s ORE strategy. However, the key focus remains to deliver economic growth by creating tens of thousands of short-time and long-term jobs. The government’s target is to provide a transparent and sustainable foundation for new technologies to develop and generate renewable energy at a cost-competitive level when compared with other low carbon technologies.

There is a need to focus on cost reduction and improvements in the supply chain capabilities of the OWF. Open innovation and collaboration among major energy companies will be key to achieving the UK and EU renewable energy and reduced Co2 emissions targets. The UK government must continue to complement private investments by offering financial assistance, expertise, support to manufacturers to improve productivity and growth. Also, the government must continue to provide technical assistance in key areas of investments, research & development, port improvements and supply chain development. A collaborative strategy enables MNCs (such as SSE, E.ON, Centrica, Npower, EDF-Energy, Samsung, Vestas, Siemens, Repower, Alstom, and many others) to develop new technologies, products, and services. OWF requires higher investment and faces more complicated environmental challenges when compared to an Onshore wind farm. However, there are many advantages associated with OWF such as reduced negative publicity, less harmful effects on local wildlife and ecosystems and noise pollution since turbines are always a few miles away from the shore.

This article contributes to the literature on micro/macro foundations of the innovation system and research that focuses on environmental and socio-economic goals (Govindan et al., 2015). The impacts of large-scale investment in OWF in the UK need to be investigated (Perveen, Kishor & Mohanty, 2014). There have been calls for a more integrative approach to research that focuses on social goals (Govindan et al., 2015) and the need to understand value creation (Wyns & Khatchadourian, 2016). Also, this article responds to the calls for new studies on how dynamic capabilities (Schilke, 2014). There have been calls for a rethink on how to analyse implementation processes of sustainable energy transformations (Miller, Richter & O’Leary, 2015; Nance & Boettcher, 2017) and their embeddedness in socio-institutional processes (Fraune & Knodt, 2018).

To conclude, the limitations of this study is related to the over-reliance on desk research and secondary information. Despite its shortcoming, this has provided the opportunity to respond to call calls for studies to examine how firms effectively integrate new technology and network perspectives into their innovation processes, particularly in the context of environmental innovation (Watson et al., 2018). There is an opportunity to advance future research on UK renewable energy strategy post-Brexit. Another opportunity is to examine the types of ISI and OIS developing among EU firms. It is also possible to investigate how OWF firms use OIS and ISI to improve their operations and capacity?

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