Master's thesis

The Impact of Brexit on the Marine Renewable Energy Industry in the UK

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Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

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Abstract

Climate change and renewable energy targets have stimulated the growth and investment in marine renewable energies (MREs), that refers to the energy created by offshore wind, tidal and wave devices. However, with the referendum to separate from the EU commonly referred to as Brexit, uncertainty over the future of MRE in the UK exists. The purpose of this research was to explore the impacts of Brexit on the UK MRE industry. A state of knowledge review of the MRE industry in the UK provided the foundation. This was supported by a content analysis which identified seven main themes in the literature review. Following this state of knowledge review, additional content analysis identified the impact of Brexit on the MRE sector. Three main categories emerged from the research which shaped the discussion on Brexit; legislation and regulations, funding and investment and the supply chain. Indeed, depending on the type of Brexit chosen by the UK and the EU, the intensity of the consequences will vary. A "no-deal" Brexit would put pressure on legislation, funding and the supply chain, thus jeopardizing the MRE industry's leadership, while a "Norwegian model" would enable the UK to maintain a similar relationship with the EU. The thesis concludes with insights and recommendations on how the MRE industry can be sustained and reach its potential in the UK following Brexit.

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I would also like to thank my mother, my brothers and Maddie for keeping me sane throughout this journey.

Executive Summary

Overview

Growing concerns related to environmental issues including rising CO2 emissions and associated environmental targets have resulted in the growth of renewable energy development including marine renewable energy (MRE). MRE refers to the energy created by offshore wind, tidal and wave devices. The United Kingdom (UK) emerged as a leader in MRE developments, however, the industry's growth in the UK could be hampered by the Brexit referendum of June 2016, when the majority of the UK population voted in favour of leaving the European Union (EU). Under Brexit, many industries in the country may be impacted differently according to their dependence on the EU. In this thesis, the objective was to explore and determine the impact of Brexit on the MRE industry in the UK. Content analysis served as the key method for exploring this objective.

To understand the consequences of Brexit, a state of knowledge review of the MRE industry in the UK explored key facets of the industry. It was also critically important to review the different type of Brexit models. For example, scholars identified five Brexit models likely to occur, ranging from a close relationship with the EU to a no-agreement model: the "Norwegian model", the Energy Community model, the "Swiss model", the "Canadian model" and the "no-deal" or WTO model. These five scenarios present advantages and disadvantages for the UK and will require trade-offs between more freedom (environmental legislation and regulations) and less support (funding, facilities) certainty and freedom (trade, free-movement of workers).

Brexit will have some consequences on the UK's economic system and this will vary according to the type of Brexit. If the UK leaves the EU without any agreement, the country will not benefit from a transition period, which would be the case if the UK concludes an agreement with the EU. In that regard, businesses will not have the 2-year period to adapt their business plan to the new situation. However, even if the country concludes an agreement with the EU, its economic system will require adaptation as a large range of industries will be impacted and its currency, the sterling, is not as strong as it was prior to the referendum.

Research Methods

Content analysis served as the primary method of analysis. Information was retrieved from various online sources such as scholarly articles, government reports, industry organizational reports, newspapers articles. Key word analysis identified the most frequent words associated with MRE and Brexit, providing information on the intensity and on the scale of Brexit's consequences to MRE in the UK. The analysis identified three themes including:

- legislation and regulation in the UK
- funding and investment in the UK
- the UK supply chain

Legislation and Regulations in the UK

The Great Repeal Bill will transfer all EU environmental legislation in the UK statute book, regardless of the model of Brexit. However, following the departure, the UK government will have the freedom to modify its legislation and regulations. For instance, certain EU policies protect birds' habitat or require complete and thorough environmental impact assessments. Depending on the Brexit model, the UK government will be able to erase those policies and lower standards, in order to facilitate MRE developments. Also, Brexit brings vagueness concerning CO2 emission and renewable energy targets, and it could jeopardize the industry's future. Indeed, currently, the UK adheres to EU environmental legislation and regulation; therefore, leaving the EU could negatively affect the MRE sector in the UK if the country decides to switch its focus to non-renewable sources of energy such as coal. Moreover, weaker emission and/or renewable energy targets would be detrimental for ongoing and future investments in MREs in the UK.

Funding and Investment in the UK

The UK relies heavily on the European organization for financing its offshore wind farms and, a loss of support would be detrimental to the industry. Regardless of the Brexit model agreed upon, access to funding mechanisms will decrease for the UK. Also, access to research facilities and research connectedness between the UK and EU countries will be reduced, putting more pressure on the tidal and wave energy industry, in need of research to reach commercial viability. Another issue raised by Brexit is the uncertainty for investors. As the type of Brexit will determine the level of EU funding, without any agreement between the UK and the EU, investors could switch their focus to other countries, with a more stable political roadmap.

The UK Supply Chain

The current relationship the UK holds with the EU allows the free movement of people, goods and services, and enables the country to trade with EU state members without any barriers or tariffs. Leaving the EU could hinder the free movement of goods and workers, an important component of the MRE sector in the UK. Also, depending on the scenario, the EU could set taxes on imports and therefore increase the costs of production for MRE developers. These trade barriers will be exacerbated by the depreciation of the sterling, reducing the purchase power of UK companies. Finally, if the UK leaves the internal energy market, the EU will terminate their trade agreements concerning electricity coming from renewable sources, due to higher UK prices.

The Best Model

Regarding the consequences of Brexit on the UK MRE sector for each model, the "Norwegian model" appears as the most reliable one. The UK will maintain most of its advantages with respect to trade and environmental legislation and will continue to be stable despite drawbacks such as reduced access to funding and weaker influence on the ongoing MRE development in the EU.

Final Thoughts

Overall the research indicated that the impacts to MRE development will occur with Brexit and the extent of these impacts will be determined largely by the model of Brexit. Recommendations to reduce the consequences and for a more stable UK MRE industry are suggested in the last part of this thesis. They address the main issues identified during the content analysis concerning legislation and regulations, funding and the supply chain. Also, future research will be required post-Brexit in order to assess the consequences of the model, and if necessary, suggest new recommendations.

1. Introduction

1.1. Climate Change and Shift Toward Renewable Energy

With global warming coupled with growing globalization and an increasing of the world's population, the ecosystems on our planet have been under tremendous pressure. The level of greenhouse gas (GHG) emission keeps increasing, and every year a new threshold is reached (Ritchie et al., n.d). One of the most important sources for those emissions are anthropogenic and come from the burning of fossil fuels such as coal and oil. Technological improvement has extended the flow of possibilities with increase exports and imports between countries and favourable conditions for intense resource exploitation and thus plunder (Kirby, 2016). Our oceans and seas are particularly vulnerable to these phenomena (National Geographic, 2010). Ocean acidification is resulting in behavioural changes in many marine organisms and is leading to the death of numerous marine organisms (Waters, 2017). Among the most dramatic consequences are coral reefs destruction that support 25% of the fish with food, shelter and a reproduction site (National Marine Sanctuaries, n.d.). Moreover, the increase of water temperature has led to coral bleaching, one of the major catastrophes occurring in the ocean also impacting coral reefs (Davidson, 2018). Both the North and South pole suffer from greenhouse gas emission with melting of the ice leading to a diminishing production of algae (Pink, 2018). The entire trophic cascade in the poles depends on this organism and its decrease could have significant impacts on seals, bears or whales (Pink, 2018). Finally, the global sea-level is also progressively rising with potential dramatic consequences in the next decades for human through migration (NASA, 2018). "*The Fifth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) in 2013 revealed that the ocean had absorbed more than 93% of the excess heat from greenhouse gas emissions since the 1970s"* (NASA, 2017). Oil and coal have been listed as causes of CO2 emission, thus climate change, and one way to address the issue would require a global shift to renewable energy.

1.2. Marine Renewable Energies

The issue of climate change has led to the development of new techniques for providing energy: renewable energies (Stegman et al., 2017). In 2017, *"renewables had the highest growth rate of any fuel, meeting a quarter of world energy demand growth, as renewables-based electricity generation rose 6.3%, driven by expansion of wind, solar and hydropower*" (International Energy Agency, 2018). The energy generated comes from natural sources and has considerable advantages over non-renewable energies as they are inexhaustible and sometimes easily predictable (Borthwick, 2016; Australian Renewable Energy Agency, n.d.). Multiple ways of producing low carbon renewable energy exist, including solar energy where the power of the sun is converted into electricity, hydropower which harnesses the power of moving water or wind energy where wind turbines capture the power generated by the wind to transform it into energy (Australian Renewable Energy Agency, n.d.). In this thesis, the focus will be on marine renewable energy (MRE). Amongst this subgroup of renewable energies, offshore wind farms, tidal energy and wave energy are the most popular (Ocean Sonics, n.d.). Offshore wind farms, (Figure 1) are the most advanced marine renewable energy technology commercialized. Offshore wind farms can be either fixed or floating and can be deployed in areas with maximal depth of 300 meters (Dubranna, 2017). Tidal power is a source of renewable energy that has an advantage over the other MRE options given that is 100% predictable (Figure 2) (Ocean Sonics, n.d.). The vertical movement of water between tides, the flow or the current can generate energy (Ocean Sonics, n.d.). Wave energy (Figure 3) is created by the wind, blowing on the sea and producing movement in the water taking the form of swells. This energy is then captured and used to drive turbines, generating electricity (Ocean Sonics, n.d.). MRE technologies are being considered in the energy mix, albeit a small part for now, and will allow the UK and Europe to support renewable energy and greenhouse gas reduction targets.

Figure 1. Offshore wind farm (Nelson, 2017)

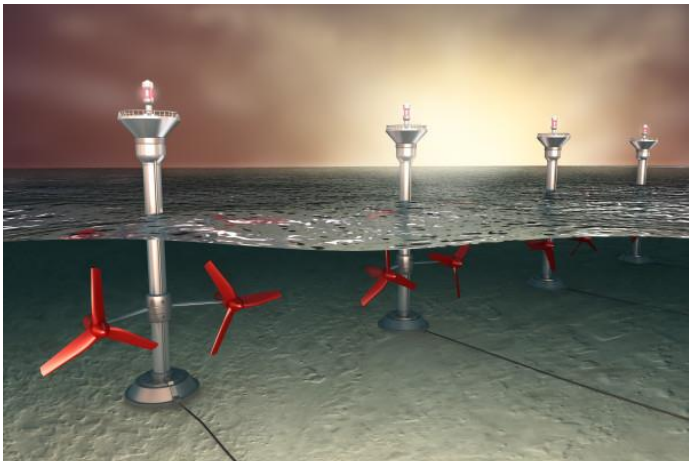


Figure 2. Tidal energy device (Plunkett, 2015)

Figure 3. Wave energy device (Bureau of Ocean Energy Management, (n.d.))

1.3. MRE Legislation and Regulation in the EU

The European Union (EU) and the United Kingdom (UK) renewable energy targets represent a key political motivator for movement toward renewables and are closely linked to GHG emission targets. The EU, created in 1993, is a political and economic organization composed of 28 states created in order to foster, inter alia, peace, freedom and sustainable development (Gabel, 2018). The organization has set energy and GHG emission's targets for three periods: 2020 (short-term), 2030 (medium-term) and 2050 (long-term) (Climate Action Network Europe, n.d.) (Figure 4). Figure 4 shows the percentage of reduction in GHG emission set by the European Commission under the Renewable Energy Directive compared to 1990 and the amount of energy produced by renewable sources to be reached for the three periods (Commission of the European Communities, 2004; Deutsche Bank Group, 2011).

EU Targets	GHG emission	Energy from renewable sources
2020	20%	20%
2030	40%	27%
2050	80%	-

Figure 4. Targets set by the EU in terms of GHG emission and energy coming from renewable sources (European Commission, 2017)

The UK has also set objectives in their National Renewable Energy Action Plan of 2009 with a 15% level of energy coming from renewable sources (Department of Energy & Climate Change, 2010). Scotland, Wales and Northern Ireland, three of the four countries forming the UK, have established national energy targets (Department of Energy & Climate Change, 2013). Scotland established a target of 100% clean electricity by 2020, Wales aims at doubling the amount of electricity generated by renewable sources by 2025 and Northern Ireland wants to attain 40% of renewable energy by 2020 (Department of Energy & Climate Change, 2013). However, the short-term objectives established by the EU are not going to be met by all of the countries, the UK being one of them (Climate Action Network Europe, n.d.). Moreover, according to Climate Action Network (CAN) Europe, the Paris Agreement and the 2009 Renewable Energy Directive's objectives are not aligned and in order to address the issue of climate change, the EU should establish more ambitious targets (Climate Action Network Europe, n.d.).

1.4. EU Investment in MRE

Countries in Europe such as the UK, France or Germany invest in MRE technologies because of the countries' access to resources such as offshore wind, strong waves and tides (Sawin et al., 2017). One of the most important actors in the EU concerning MRE is the UK (Marsh, 2016). Substantial MRE development has occurred in the UK. Currently, the UK leads the world for offshore wind energy (Global Wind Energy Council 2017). It also has strong potential for tidal power (Burrows, 2009). *"Of about 500–1000 TWh/year of tidal energy* *potentially available worldwide, the UK is estimated to hold 50 TWh/year, representing 48% of the European resource, and few sites worldwide are as close to electricity users and the transmission grid as those in the UK."* (Burrows, 2009). Wave energy, still trailing behind in terms of commercialization, has however the capacity to provide around 20% of the electricity required in the UK (Marine Energy, 2017). Nonetheless, the MRE sector in the UK faces serious challenges that will need to be addressed.

In 2016 a major political earthquake hit the country, with probable significant repercussions on the UK and on the EU concerning the development of MRE, when the majority of the population (51%) of the UK decided to vote in favour of leaving the EU (labelled as Brexit) (Marsh, 2016). The wind farm industry, being the most developed industry of the country, will stand at the forefront of these potential impacts from Brexit (Marsh, 2016). One of the main issues concern funding received by companies from the European Bank (Marsh, 2016). The terms of the contracts will need revision and a possible outcome is the removal of this financial support (Marsh, 2016). Issues linked to Brexit are not understood and research is needed to better understand the impacts on the growth and development of MRE in the UK in the context of Brexit.

1.5. Objectives and Purpose

The purpose of this research is to review and determine the current state of MRE development in the UK and the impacts of Brexit on ongoing MRE developments in the UK. Research objectives include:

- To develop a state of knowledge review on the involvement of the UK in the development of MRE
- To assess the impact of Brexit for the UK concerning MRE

No document on the state of the MRE sector in the UK has been developed. The information is available but scattered across a range of scholarly, government, news media and other sources. It is therefore important to create a document that assembles all the components that drive this industry. The impact of the Brexit can only be predicted and is a major concern for MRE and the relationship with the EU. This research will be supported by a case study approach. This will include extensive text analysis of government, industry and scholarly documents.

1.6. Summary of the Sections

The thesis is organized around five chapters. The literature review compiles a description of the MRE sector in the UK and in the countries that make up the United Kingdom. UK MRE industry strengths, opportunities and weaknesses will be discussed and the state of the industry will then be analysed. Furthermore, methods and methodology will highlight the research approach and how results are analysed. Finally, the results of content analysis will be explored in the discussion.

2. Background

The following chapter provides a state of knowledge review that describes and evaluates the state of the MRE industry in the UK. Furthermore, the research based on government, industry and scholarly documents discuss the opportunities and challenges the sector will face in the next decades. The chapter will be divided into seven sections each focusing on one aspect of the industry:

- Market resource potential
- The technology
- Supply chain
- Funding
- Environmental implications
- Legislation framework
- Brexit

2.1. Market Resource Potential

2.1.1. Global Geographical Potential

In order to reduce greenhouse gas emissions and produce clean energy, countries have started to invest in marine renewable energies in the past decades. Investments can be divided into two distinct families:

- offshore wind energy and;
- ocean power that refers to the energy that can be produced by harnessing the power of waves, tides, temperature difference or salinity

Offshore Wind Energy

Offshore wind energy is the most advanced commercially viable technology with high potential. The energy potential of this source of power is estimated at approximately 340’000 Terawatts-hour (TWh) (Borthwick, 2016). 1 TWh corresponds to the energy produced during one hour by a device with a power of 1 TW (1 million Megawatts) (Centre National de la Recherche Scientifique, n.d.). To put it in perspective, a household in the UK in 2016 consumed approximately 4 Megawatt-hour (MWh) per year of electricity, therefore with one TWh, 250’000 houses could receive electricity (Statista, 2018).

Figure 5 shows the distribution of annual wind speed in the world; 100 meters above land and sea-level. The East and West coasts of Canada and the United States of America are areas prone for the development of offshore wind farms. Similarly, along the Atlantic coast of France and up to the United Kingdom, there is potential, that is already exploited, to invest more in the technology.

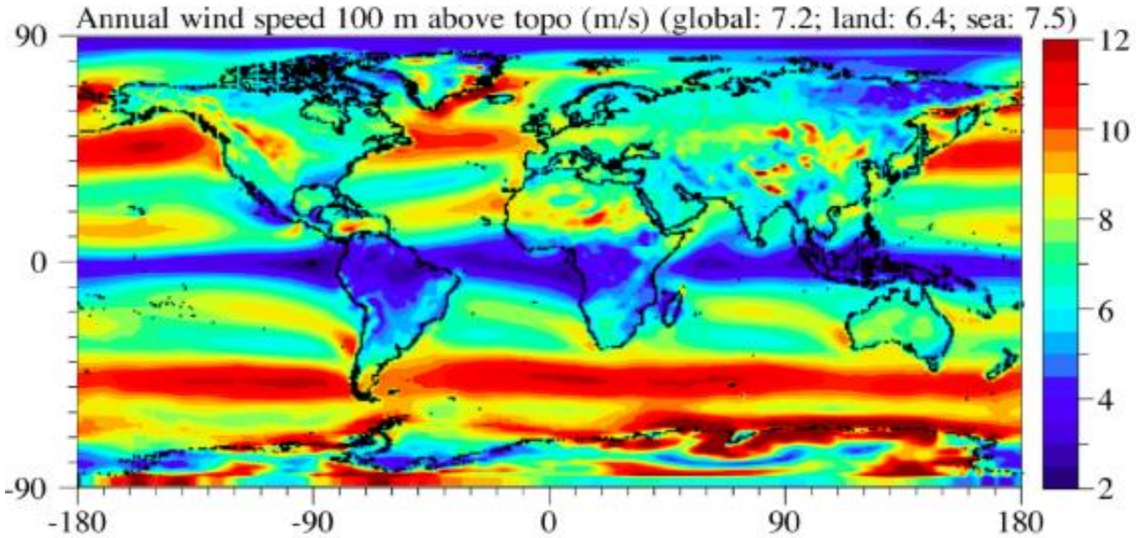


Figure 5. Global wind speed 100m above ground (Jacobson et al., 2018, p. 11)

Ocean Power

MRE related to wave and tidal energy has significant potential (Magagna et al., 2015). Figure 6 shows the distribution of wave power potential across the globe. The coast of the UK sits in an exposed location with great prospect. South America and Australia also feature attractive geographical potential to develop wave power. According to a study by Mørk et al. (2010), wave power could generate 32’000 TWh worldwide. This number represents half the amount of the world’s electricity supply in 2008 (Schiffer et al., 2016). Table 1 displays the estimates for every region of the world of the wave energy potential. The difference that can be observed between the total in the table (29’500 TWh) and the 32’500 TWh stated above is due to the fact that the latter one did not take into account wave power smaller than 5 KW/m and only took in consideration latitude below 66.5 degrees (Schiffer et al., 2016).

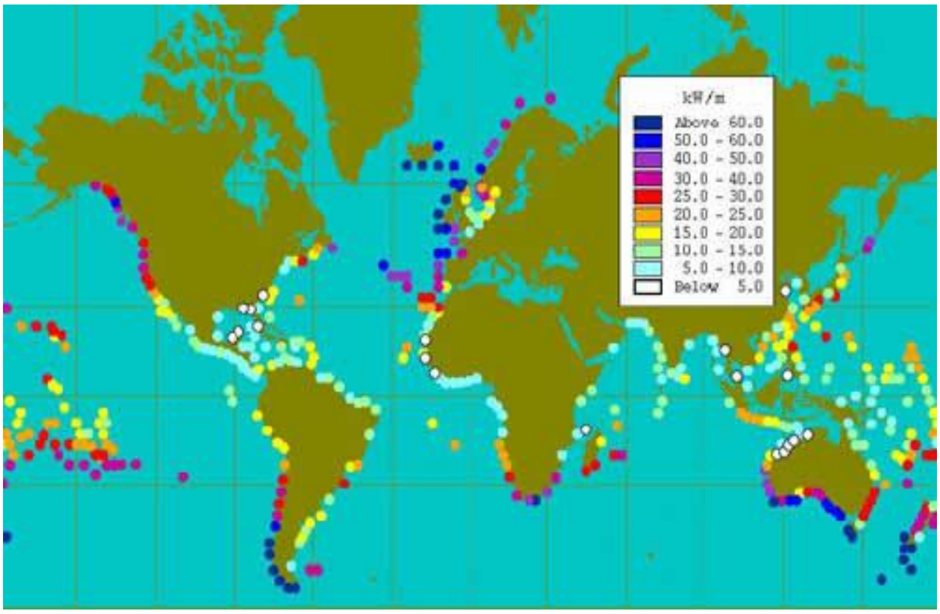


Figure 6. Global wave energy distribution in kilowatts per meter (Hagerman, 2002, p. 9)

Areas	TWh/year
Western and Northern Europe	2'800
Mediterranean Sea and Atlantic Archipelagos (Azores, Cape Verde, Canaries)	1'300
North America and Greenland	4'000
Central America	1'500
South America	4'600
Africa	3'500
Asia	6'200
Australia, New Zealand and Pacific Islands	5'600
Total	**29'500**

Table 1. Wave energy in TWh per year in different regions of the world (Schiffer et al., 2016, p. 7-8)

Tidal power is the other marine renewable source to generate clean energy with great potential. According to Burrows et al. (2009), the global energy potential coming from tidal power could generate between 500 and 1’000 TWh per year. Certain regions of the world have a clear advantage in investing in tidal power due to their geographic exposure. Figure 7 shows those areas with important tidal ranges (the vertical difference between low and high tide) such as the North Atlantic coast of Africa, Greenland or the Western Pacific coast of Canada. The greater the tidal range, the more potential energy can be exploited through in-steam tidal energy (Schiffer et al., 2016). The topography of the location will influence the power of the flow and areas with narrow passages or headlands will have more potential energy (Schiffer et al., 2016).

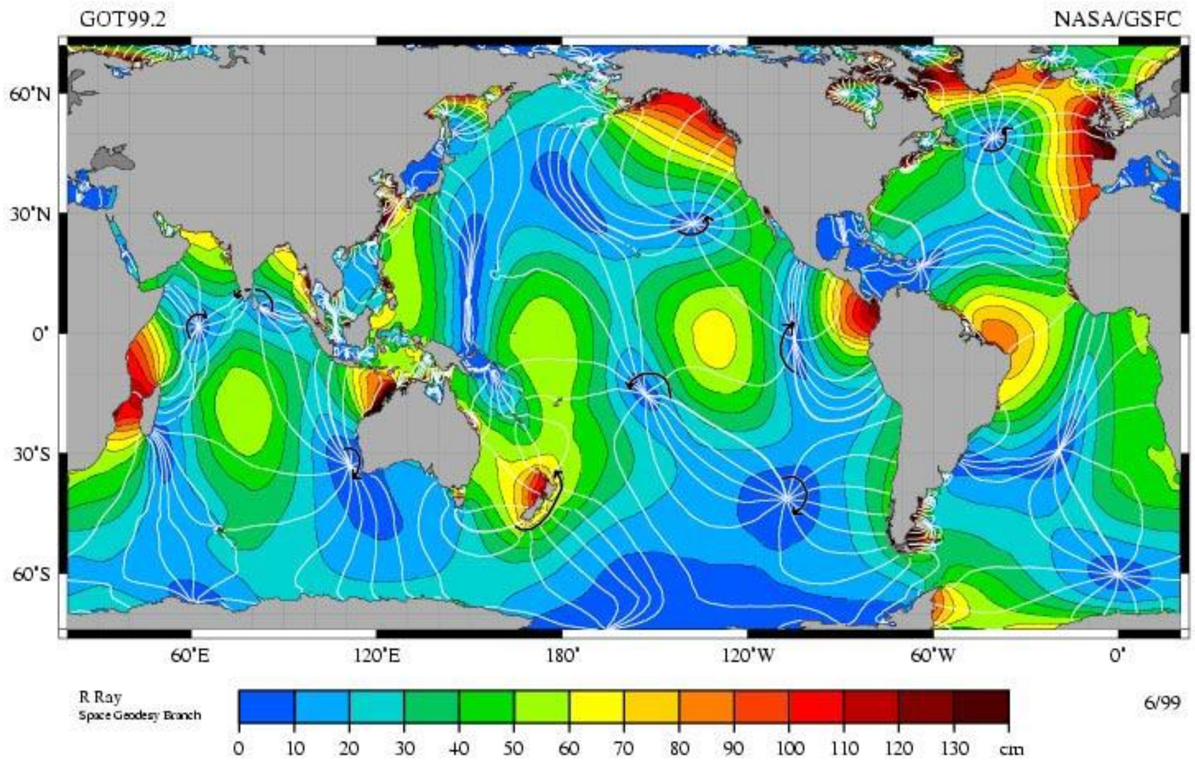


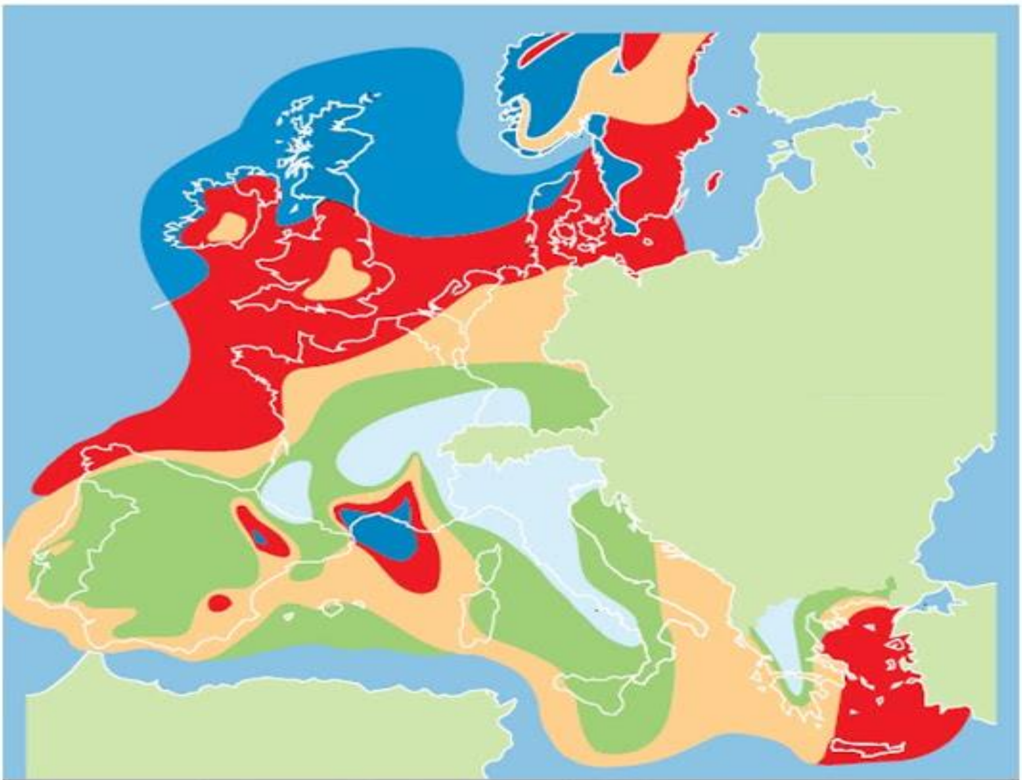
Figure 7. Global tidal range potential (Hanania et al., 2017)

The Bay of Fundy, situated in Nova Scotia Canada, is most famous for its significant tidal fluctuations and the movement of 160 billion tonnes of water coming in and flowing out of the Bay (Force, n.d.). The total energy potential of the Bay of Fundy is estimated at 50’000 MW (Force, n.d.). According to Dr. Richard Karsten, researcher at Acadia University, 2’500 MW of energy could be extracted from the Bay without modifying the environment (Force, n.d.). Other regions of the world have high potential for harnessing the power of tides such as Le Mont Saint Michel in France with a tidal range of 13.5 meters or the Severn Estuary in England (UK) with 15 meters difference between low tide and high tide.

2.1.2. UK's Geographical Potential

Offshore Wind Energy

The UK's coastline is exposed to strong waves, tides, and winds, among the highest in Europe, and can capitalize on its geographical advantage with MRE development and more specifically offshore wind energy (Deutsche Bank Group, 2011). Figure 8 shows the wind speed in Europe and the UK is sitting in areas with the highest wind class (4 and 5). According to the Calverton Energy Research Group (2009), the UK has an offshore wind energy potential of 2.2 TW. Half of the available resource is situated in relatively deep waters (100m-700m) still accessible but more expensive (Smith, 2009). This number represents more than a third of the offshore wind energy potential of the continent (Oswald et al., 2008).



Wind resources at 50 m above ground level for five different topographic conditions											
		Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
		$m\ s^{-1}$	$W\ m^{-2}$	$m\ s^{-1}$	$W\ m^{-2}$	$m\ s^{-1}$	$W\ m^{-2}$	$m\ s^{-1}$	$W\ m^{-2}$	$m\ s^{-1}$	$W\ m^{-2}$
Wind class	5	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	4	5.0–6.0	150–250	6.5–7.5	300–500	7.0–8.5	400–700	8.0–9.0	600–800	10.0–11.5	1200–1800
	3	4.5–5.0	100–150	5.5–6.5	200–300	6.0–7.0	250–400	7.0–8.0	400–600	8.5–10.0	700–1200
	2	3.5–4.5	50–100	4.5–5.5	100–200	5.0–6.0	150–250	5.5–7.0	200–400	7.0–8.5	400–700
	1	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400

Figure 8. Wind speed in Europe (Milton, 2015)

Ocean Power

This source of energy is not as developed in the UK as offshore wind; however, it holds strong theoretical potential (Marine Energy, 2015). According to a study by Offshore Renewable Energy Catapult, the UK has 15GW and 23GW of practical resource for respectively tidal power and wave power. Wave energy resource in the UK is distributed in the North and South of the peninsula and Northern Ireland (Global Energy Network Institute, n.d.). The strong winds coming from the West are slowed down by Ireland, preventing the middle coast of the UK of having good wave energy potential (Figure 9). The mean wave power potential estimated in 2007 by Kerr (2007) ranged between 700 TWh/year and 850 TWh/year. These numbers take into account the distance from shore and only 15% of the total resource is located near shore (Kerr, 2007).

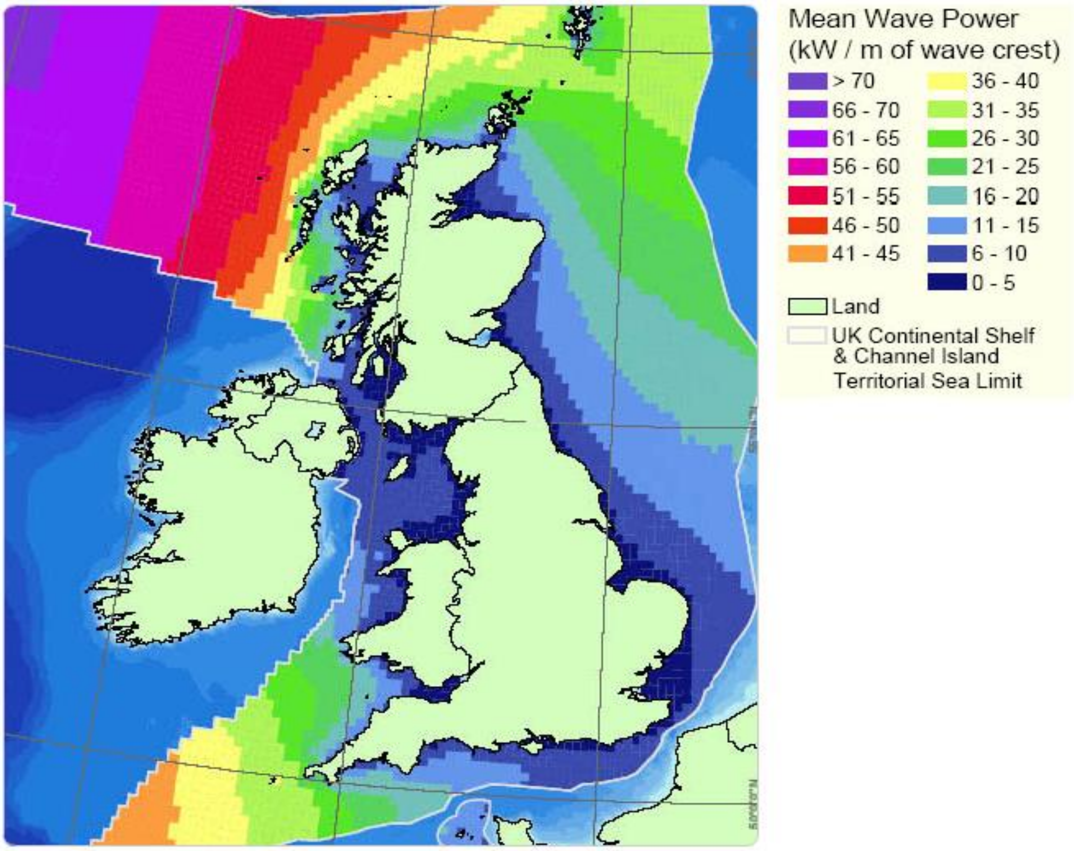


Figure 9. Average wave power in the UK (Kerr 2007, p. 987)

The UK holds 48% of the European tidal resource, representing 50 TWh per year, and includes exposed areas such as Scotland, the North West of England and the Severn Estuary, located between Wales and England (Burrows et al., 2009). "*The Dee, Mersey, Ribble and Wyre estuaries, Morecambe Bay and the Solway Firth all have […] a total installed capacity of 12 GW was estimated (Ribble excluded), with a potential energy yield of at least 17.5 TWh/year, which is approximately 5% of UK national need"* (Burrows et al., 2009). Scotland holds 25% of that resource and can also rely on an advantageous geographical exposition with notably Pentland Firth which has an energy potential of 16.5 TWh of electricity per year (Marine Energy, 2015). Exploiting the resource of this area would enable Scotland to reach the 2020 target of 100% of renewable electricity (Marine Energy, 2015).

2.1.3. Global Market Potential

In 2017, the global installed capacity of the offshore wind industry reached 19 GW with 3 countries leading the sector (Keivanpour, 2017; Global Wind Energy Council, n.d.). At the end of the year, Europe held 84 % of this capacity (Global Wind Energy Council, n.d.). On a global scale, the leadership of the industry is shared between the UK, Germany and China cumulating altogether 80% of the installed capacity (Figure 10) (Global Wind Energy Council, n.d.). Developments are still occurring in the UK and in May 2018, there were six projects under construction in the offshore wind industry: the Hornsea Project One that will

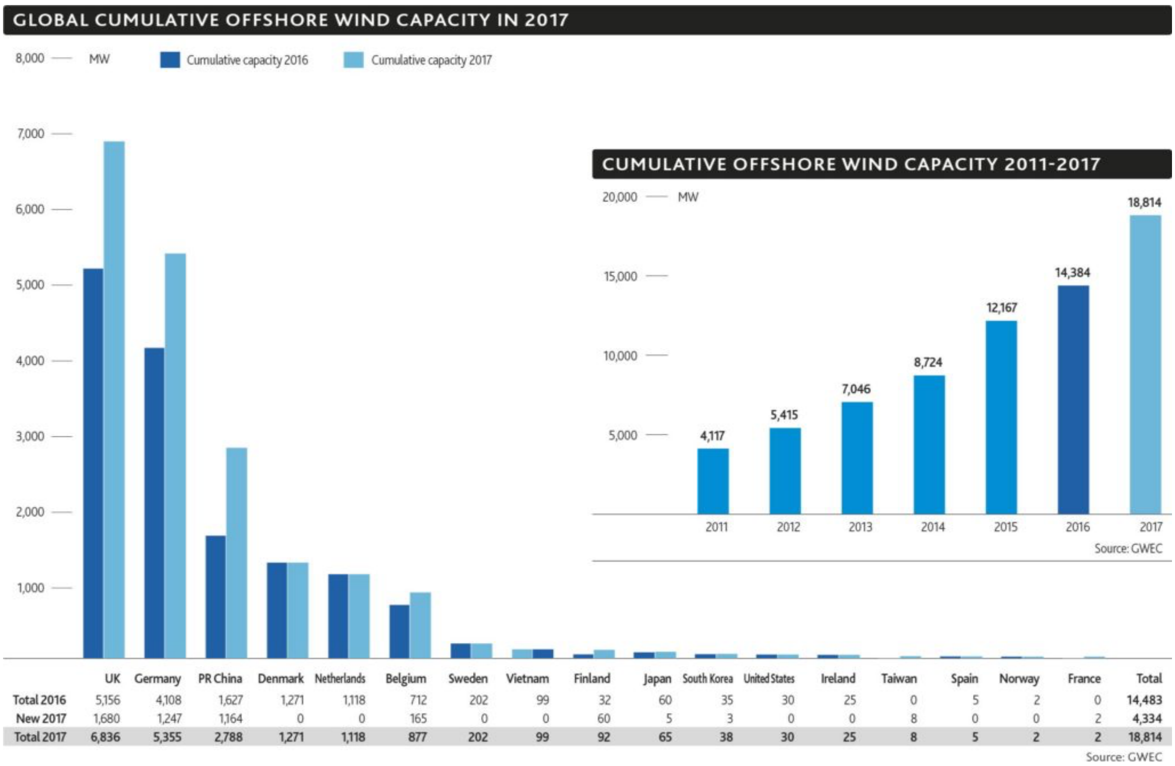


Figure 10. World installed offshore wind capacity (Global Wind Energy Council, n.d.)

deliver 1.2 GW of electricity and will be operational in 2020 or the East Anglia ONE with a capacity of 714 MW off the coast of Ipswich are amongst those projects (OffshoreWIND, 2018; ScottishPower Renewables, 2018; Eunomia, 2018). Despite the UK's historical experience in the offshore wind sector and its substantial developments, investments in China could modify the global hierarchy in the upcoming years (Global Wind Energy Council, n.d.). At a smaller scale, countries such as the Netherlands are also developing their industry with the first non-subsidized wind farm launched in 2017 and a plan for a wind farm island in the North Sea is under consideration (Global Wind Energy Council, n.d.).

Currently, only 20 MW of wave power has received consent out of the 838 MW in development in the world (Schiffer et al., 2016). According to the World Energy Council, the little progress made by the industry does not encourage optimism for new developments. Figure 11 shows the installed capacity for wave energy and the forthcoming projects that are numerous in the UK and the United States of America (USA).

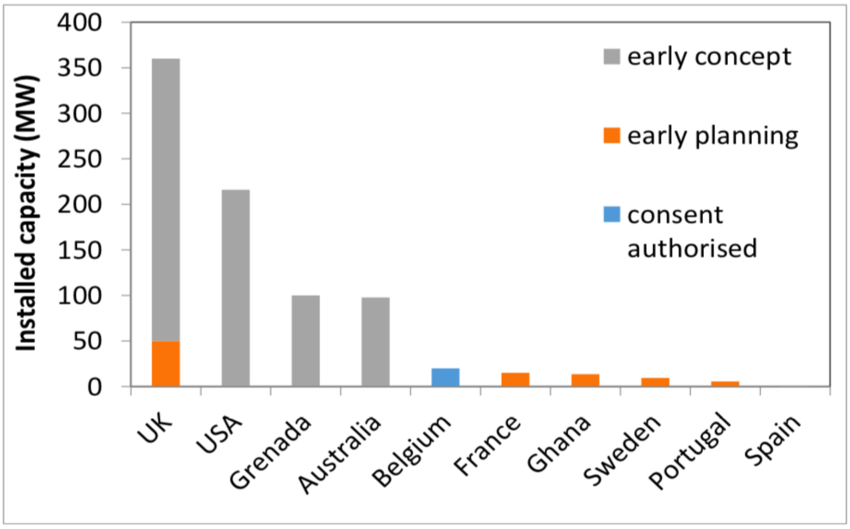


Figure 11. Wave energy installed capacity (Schiffer et al., 2016 p. 32)

Despite newly commissioned projects in the UK in 2017 with the promise of 8 MW installed, tidal energy is still trailing behind offshore wind power and wave energy (Eunomia, 2018). The industry's total world-wide installed capacity reached only 4.3MW in 2016, however the UK, France and Canada recorded many projects in construction or holding a planning permission (Schiffer et al., 2016). For example, in the UK in May 2018, 11 projects were awaiting construction totalizing a future installed capacity of 164.7 MW and in France, Sabella's D10 turbine (1 MW) is undergoing full-scale testing (Eunomia, 2018).

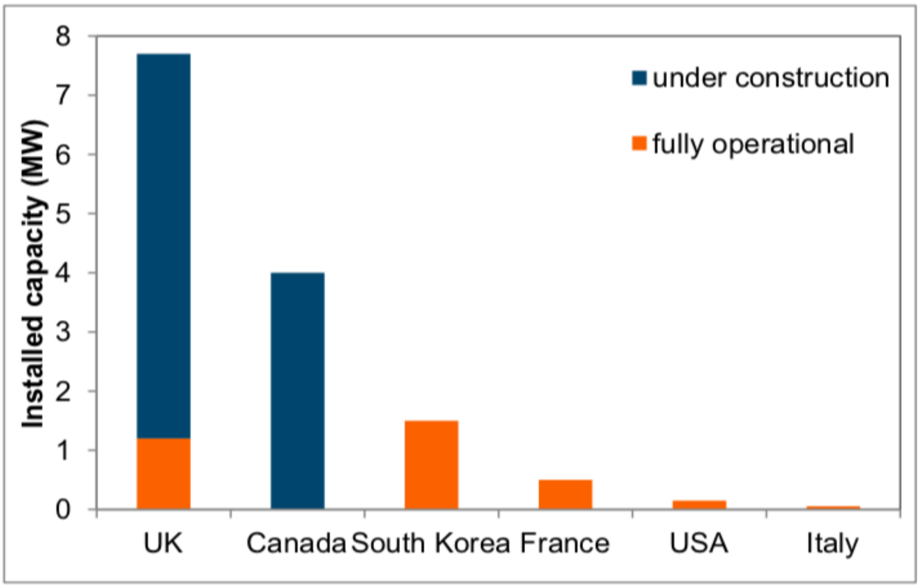


Figure 12. Tidal energy installed capacity (Schiffer et al., 2016 p. 32)

2.1.4. UK Market Potential

Offshore Wind

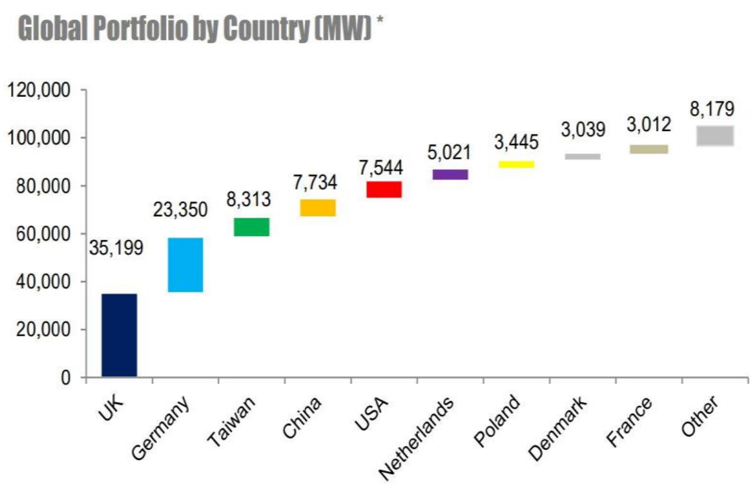


Figure 13. Global offshore wind portfolio in 2018 (Hill, 2018)

The UK is the leader in offshore wind energy and has planned to expand the installed capacity to 10 GW by 2020 (Department for International Trade, 2014). Figure 13 shows the UK's offshore wind portfolio reaching approximately 35.2 GW. The portfolio comprises projects that are: on hold, in development, in planning, consented, approved, in pre-construction phase, under construction and fully commissioned.

The UK's leadership on the offshore wind market relies on substantial investment. During the period 2010-2017, £35 billion were injected in the sector through capital spending, accounting for almost half of the new investments (Wind Europe, 2017). Furthermore, it is expected that between 2017 and 2021 £19 billion will have been allocated throughout different projects (Norris, 2018). These investments aim at developing the industry to reach the targets set by the EU for 2020 and for 2030. The roadmap for the 2030 deadline released in 2018 by the UK government set an objective of 30 GW of operational installed capacity, an increase of 23 GW compared to June 2018 (Norris, 2018). As a result, offshore wind energy could supply 30% of the needs of the UK (Norris, 2018). The latest substantial investment decision in the UK concerned the Hornsea Two offshore wind project, that will generate up to 1.2GW of power (Wind Europe, 2017). Moreover, at the end of 2017, the Crown Estate declared that developers could obtain new areas for offshore wind farms (Offshore Wind, 2018). In 2017, the country held half of the consented wind capacity, representing 6'975 MW (Hill, 2018; Skorupska et al. 2018).

The UK's market holds great potential for growth with the rapid expansion of the sector in the UK (Kern et al., 2014). According to a study by RenewableUK, the industry should grow by more than $30 billion every year from 2018 to 2030, with strong emerging markets such as Taiwan, China and the USA (RenewableUK, 2018). Consequently, the UK's expertise and experience in offshore wind design, financing or deployment is a significant asset to develop its industry abroad (Department for International Trade, 2014). In 2017, 22 countries received UK's support through a broad range of products and services such as turbine blades and underwater cables, maintenance or environmental assessments (RenewableUK, 2018). For example, in December 2017, the UK's research centre Offshore Renewable Energy Catapult agreed upon a collaboration with China for the development of the industry, leading to a $200 million deal for UK companies and universities (Offshore Wind, 2017). The UK's intellectual capital helped companies win contracts, ranging from £1'000 to £7.5 million, in Canada, the Philippines or Taiwan (RenewableUK, 2018). (RenewableUK, 2018). CWind, a British company delivered technical assistance to European country with contracts varying from £40'000 to £7.5 million (RenewableUK, 2018). As a matter of fact, £40 billion worth of development needed to be granted to construction companies and other suppliers for short-term and long-term projects in 2015 (Department for International Trade, 2014). During the same year, projects worth 15 GW in total expected to be commissioned by 2020, requiring management expertise and maintenance services (Department for International Trade, 2014).

Finally, recent cost reduction in the UK facilitated investing in offshore wind farms. The price to generate 1 MWh of electricity is determined during auction rounds in the UK, where the government delivers contracts to the winning bidder (Offshore Wind, 2017). In 2015, during the first auction round, two offshore wind companies were awarded contracts with a price of £119.89 and £114.39 per MWh (Department for Business, Energy & Industrial Strategy, 2015). Between the first and second round in 2017, major technological improvement occurred and two of the three winning projects obtained a 57.50 per MWh price, representing a 50% decrease compared to 2015 (Offshore Wind, 2017).

Tidal Energy

The UK's market for tidal based MRE holds potential for the upcoming years. In July 2018, the country's operational tidal energy capacity reached 11.2 MW (Eunomia, 2018). The UK is one of the most advanced countries in the world for tidal power and its experience could enable the country to substantially decrease the cost of the technology (Marine Energy, 2018). Currently tidal stream costs £150 per MWh for 100 MW device; however, according to a study by Smart et al. (2018), 1 GW infrastructures would decrease significantly the costs to £90 per MWh and 2 GW infrastructures to £80 per MWh, opening attractive opportunities for developers. Reducing the cost would represent a significant breakthrough for the industry as the financial constraint has always been the most restrictive. Moreover, according to the Offshore Renewable Energy Catapult report, by 2030 the UK economy could be credited by up to £1.4 billion of potentially significant energy exports (Marine Energy, 2018).

Despite the positive predictions on the future of the tidal energy industry, some conundrums still remain. The prospect of operational technology before 2030 is low and with the targets set by the UK, it is unlikely that tidal energy and more generally marine energy can help attain the renewable energy objectives (Zeyringer et al., 2018). Moreover, the sector is still at its early stages and reaching the 2030 targets and even 2050 targets would require considerable investments by the UK government, and funds could be invested in other technologies, like wind, with better chances of reaching full-scale development before 2030 (Zeyringer et al., 2018).

However, market potential exists in different parts of the world where tides are a substantial source of energy and on which the UK can capitalize (Hendry 2016). In 2017, British companies exported knowledge and material to 14 countries (RenewableUK, 2018). Among them, China collaborates with Atlantis Resource to deploy a tidal stream turbine by the end of 2019 (RenewableUK, 2018). Countries in South East Asia and Canada also invest in the technology and collaborate with research centres and developers like Sustainable Marine Energy (RenewableUK, 2018). The UK can therefore rely on advanced testing infrastructures and intellectual capital to maintain its global leadership (Hendry, 2016).

Wave Energy

With its strong national supply chain and by mid-2018, 137 MW of wave projects at different levels of development, there is a potential bright future for wave energy with, (Smart et al., 2018). Also, the country exported to 11 countries in 2017, selling components for devices and selling its knowledge through environmental monitoring related technology (Renewable UK, 2018).

However, wave energy's current situation does not raise optimism among stakeholders (Zeyringer et al., 2018). The industry is at its early stages and no commercially viable technology has yet been developed (Zeyringer et al., 2018). The cost of wave energy is approximately twice as high as tidal energy with £300 per MWh (Zeyringer et al., 2018). According to the Energy Technologies Institute (ETI), a government funded research institute, the technology costs too much and focus should be orientated to tidal energy (Vaughan, 2017). However, the declarations of the institute were disputed by members of the industry who defended the sector by insisting more time is needed in order to reach commercial viability (Vaughan, 2017). The foundations of wave energy rely on financial support and without substantial investments, the industry's contribution to energy target will remain insignificant.

2.1.5. Conclusion

The binding targets as well as the geographical opportunities confirm the UK's plan to invest in the energy of tomorrow. Offshore wind holds great potential in the UK with the highest installed capacity in the world and major upcoming undertakings. Tidal energy and wave energy, despite trailing behind the MRE's mammoth, displays promising opportunities. However, the increased probability of a hard Brexit in March 2019 raise issues for the country with potential repercussions on exports and employment especially. In that regard, leaving the EU could severely hamper the industry's development and undermine the country's leadership in the MRE sector.

2.2. The Technology

2.2.1. Offshore Wind

The technology used for offshore wind is based on onshore wind turbine technology (Borthwick, 2016). The three blades mounted to the structure capture the kinetic energy coming from the wind and rotate around the hub (Borthwick, 2016). Consequently, the rotation activates the system connected to the hub and spins the low-speed shaft (ACCIONA, 2016). In order to produce electricity, the turning speed of the shaft must be increased (ACCIONA, 2016). For this reason, a gearbox connects the low-speed shaft to a high-speed shaft, accelerating the spin (ACCIONA, 2016). For the kinetic energy to be transported and used, a generator converts it into electricity and send it to an offshore substation via underwater cables (ACCIONA, 2016). Once the electricity is conveyed to the substation, another set of cables transfers it to an onshore substation that distributes it to consumers (ACCIONA, 2016).

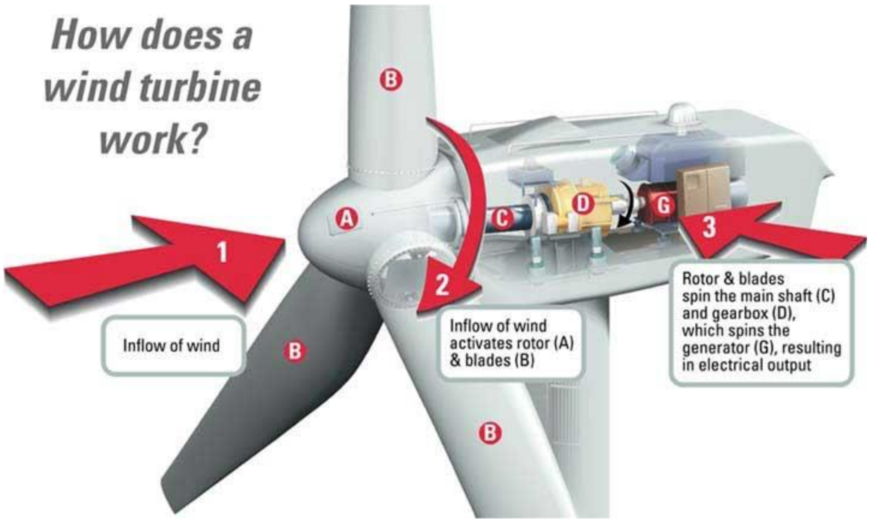


Figure 14. Offshore wind turbine mechanism (Sohail, 2017)

When the first offshore wind farm was developed in Denmark in 2002, the turbines could only be fixed in shallow water and had small capacity (2 MW); however technological improvement enabled developers to better harness wind energy (Bailey et al., 2014). At the end of 2013, investments in the industry enabled companies to build wind farms 30 kilometres (km) away from the coast and in waters 16 meters deep (Bailey et al., 2014). However, despite the rapid improvement of the sector, bottom-fixed turbines were restricted to relatively shallow waters. More recently in 2017, Equinor developed the first floating wind farm in Scotland (Equinor, 2018). Not only does this new technology allow the possibility to build further away from the shore, but the costs and construction time are lower than for bottom-fixed turbines (The Economist, 2016). Figure 15 shows an example of the different structures for floating turbines where the tower remains high in the water column and is held straight by stabilizing mechanisms (Office of Energy Efficiency & Renewable Energy, 2017).

Currently, the largest offshore wind turbine commercially available is the MHI Vestas V164-9.5 MW; nonetheless technological breakthrough opened the possibility for bigger devices (Duit, 2017; GE Renewable Energy, 2018). The 80-meter blade is longer than the previous record holder with a swept area of 21’124 square meters (MHI Vestas, n.d.). Furthermore, the probability of reaching the double-digit MW turbine has increased since General Electric Renewable Energy’s investment decision of $400 million has been announced (GE

Renewable Energy, 2018). This 12 MW offshore wind turbine with a swept area of 38,000 square meters and a turbine height of 260 meters high could power 16,000 households (GE Renewable Energy, 2018).

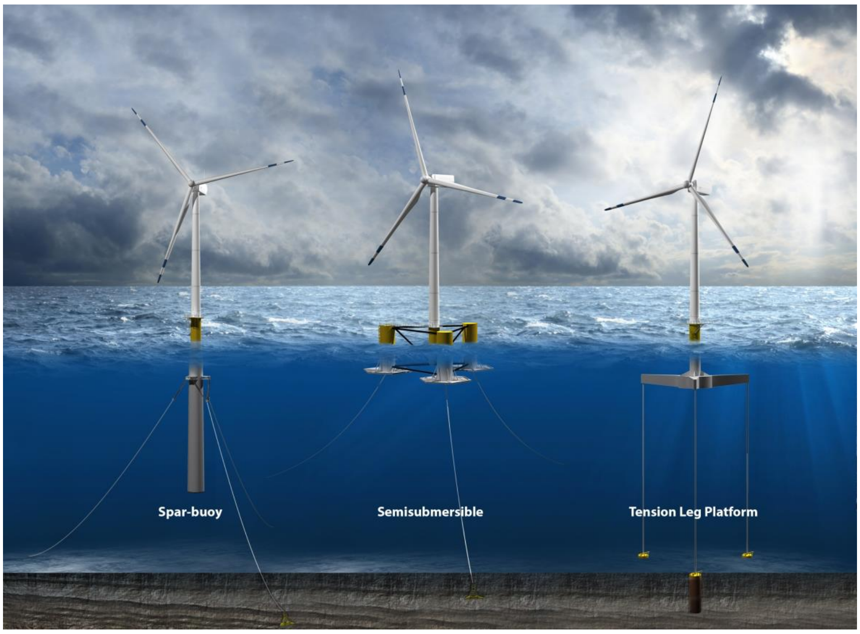


Figure 15. Floating wind turbines (Bauer, 2017)

Projects Development

The UK Department for Business, Energy & Industrial Strategy releases a monthly database which keeps track of the progress projects related to MRE are making under different development status, from inception to decommissioning. In July 2018, the UK recorded:

- 38 operational projects representing a total capacity of 7’156 MW
- 5 projects under construction representing a total capacity of 3’255 MW
- 16 projects awaiting construction representing a total capacity of 11’566 MW
- 5 projects awaiting approval representing a total capacity of 4’540 MW

Over the years, the UK capitalized on its technological progresses by developing larger and more powerful wind farms. Amongst the projects commissioned, the London Array became the largest in 2018 (Eunomia, 2018). This 630 MW wind farm generates electricity for 446’201 homes annually with 175 3.6 MW turbines (4C Offshore, 2018). However, new technologies opened the possibility of decreasing the costs and increasing the power generated by wind farms and currently, 3 projects under construction are exploiting these improvements: Walney 3 (660 MW), East Anglia 1 (714 MW) and Hornsea Project One (1.2 GW) (Eunomia, 2018). The latter one will use more advance technology with 174 7 MW turbines, powering 862’655 homes and despite doubling the capacity, the costs will not follow the same trend, increasing from €2.42 billion for London Array to €3.36 billion for Hornsea Project One (4C Offshore, 2018). Moreover, amongst the projects awaiting construction, larger wind farms are to be expected. This is the case for the Dogger Bank Creyke Beck A & B project, a substantial undertaking where the company is aiming for an installed capacity of 2.4 GW by 2020 (Eunomia, 2018). The park will be situated in the Dogger Bank, in the North Sea, with 360 5 MW turbines (Eunomia, 2018).

2.2.2. Tidal Energy

Gravitational forces exerted by the moon and the sun cause the attraction of water particles on earth towards the stars (Borthwick, 2016). This phenomenon results in the bulging of oceans and seas where the attraction is located, creating a high tide (Borthwick, 2016). Moreover, the gravitational effect of the moon on the earth pulls the planet towards it, creating another bulge opposite to the first one and thus a second high tide as shown on figure 16. This constant movement of the water moving towards the shore or away from the shore generates two high and low tides per day. In order to create energy, two systems can

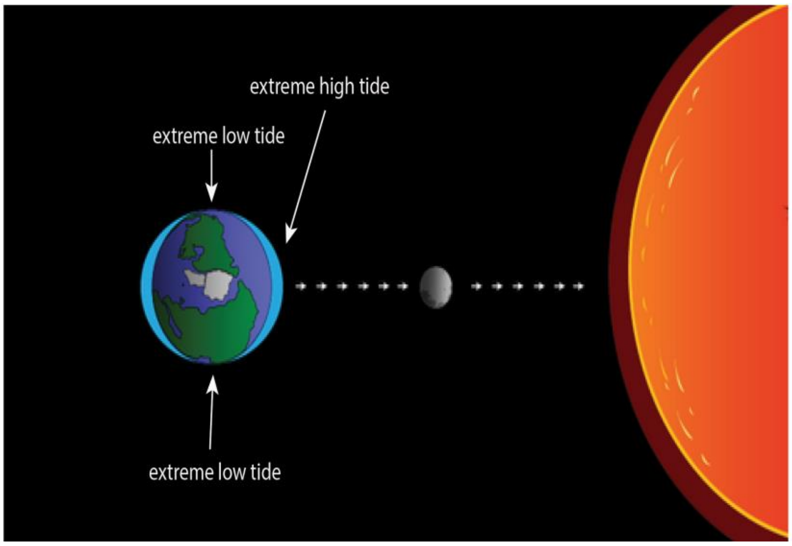


Figure 16. Tides explained (National Oceanic and Atmospheric Administration, n.d.)

be applied to harness the power from the tide: tidal range and tidal stream (Schiffer et al., 2016).

Tidal Range

Tidal range technology uses the vertical height difference in the water and captures the potential energy created by the tide (Schiffer et al., 2016). The most common infrastructures used to generate electricity are barrages or lagoons (Schiffer et al., 2016). Tidal barrages operate with low-head turbines and generates power through three different sources: flood generation, ebb generation and two-basin schemes (Borthwick, 2016; Schiffer et al., 2016). Flood generation uses the incoming high tide that funnels through the turbine tunnel into the tidal basin, making the turbine spin (Figure 17) (Borthwick, 2016). The second operational approach uses the outgoing tide to spin the turbine as the water leaves the reservoir to the ocean (Figure 18) (Borthwick, 2016). Finally, the ebb tide and flood tide can both be combined to spin the underwater turbines creating a two-way generation scheme generating electricity for 20 hours per day (Prandle, 2009; Kerr, 2007).

Tidal lagoon generates power similarly to a tidal barrage, with water flowing in and out of a breakwater through underwater turbines (Figure 19) (Tidal Lagoon Power, n.d.). However, while a tidal barrage covers the whole width of an estuary, tidal lagoons impound water along the coastline (Tidal Lagoon Power, n.d.). When the high tide arrives, the gates close and the water is held back from entering the lagoon, unbalancing the water distribution (Tidal Lagoon Power, n.d.). Once the water height difference is large enough, the gates open and the water flows through the turbines, generating electricity until the lagoon's level of water matches the sea's level (Tidal Lagoon Power, n.d.). The reverse scenario also happens with low tide and this process occurs two times per day (Tidal Lagoon Power, n.d.). This technology benefits from the ebb tide and the flood tide, generating power 14 hours per day (Tidal Lagoon Power, n.d.). Moreover, the predictability of tides makes it an attractive source of renewable energy.

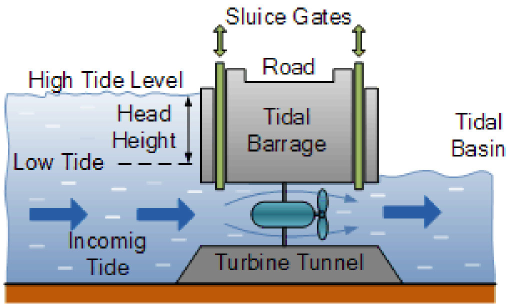


Figure 17. Tidal barrage flood generation (Alternative Energy Tutorial, n.d.)

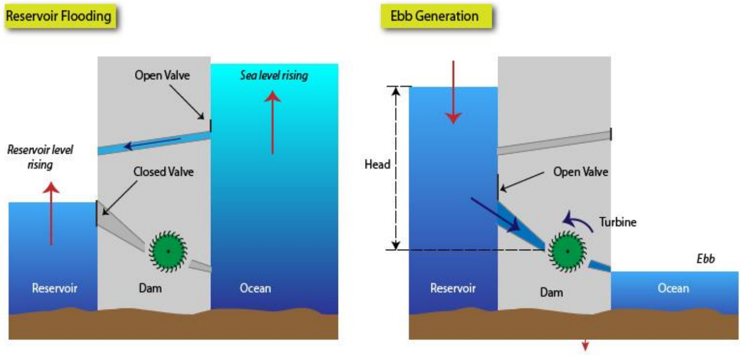


Figure 18. Tidal barrage ebb generation (Green Rhino Energy, n.d.)

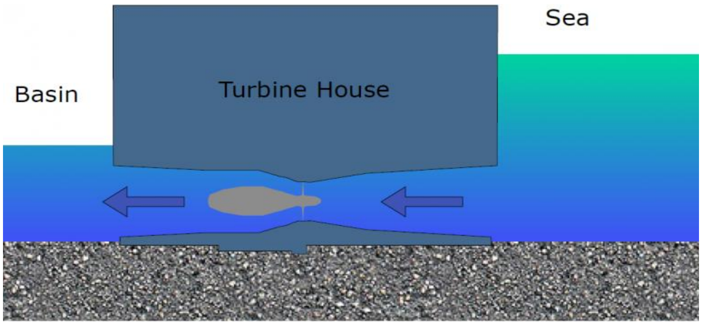


Figure 19. Tidal lagoon (Tidal Lagoon Power, n.d.)

Tidal Stream

While tidal range bases its technology on the vertical movement of the water, tidal stream capitalises on the horizontal movement of the water (Land Information New Zealand, 2015). According to the European Marine Energy Centre (EMEC), the technology converting kinetic energy to electricity has been classified into seven categories: horizontal-axis turbines (Figure 20 (a)), vertical-axis turbine (Figure 20 (b)), oscillating hydrofoil (Figure 20 (c)), enclosed tips (Figure 20 (d)), Archimedes screw (Figure 20 (e)), tidal kite (Figure 20 (f)) and others (EMEC, n.d.; Schiffer et al., 2016).

Axial-flow turbines combine the first two categories and use the power of the incoming or outgoing tide to spin the blades (Borthwick, 2016). These categories replicate the technology used for wind turbines, with the blades rotating either around the horizontal axis or the vertical axis, depending on the mounting (EMEC, n.d.). Another popular device exploits hydrofoils, where a wing mounted on an oscillating arm will be lifted by the current (EMEC, n.d.). Furthermore, enclosed tips aim at capitalizing on the power of the current by accelerating the movement of the water particles with a funnelled-shaped duct (Schiffer et al., 2016). The Archimedes screw uses the horizontal movement of the water to spin the corkscrew-shaped helix (Schiffer et al., 2016). Finally, the tidal kite is a turbine with a fixed wing and follows an infinity-shaped movement to accelerate the water velocity spinning the turbine (Schiffer et al., 2016; EMEC, n.d.).

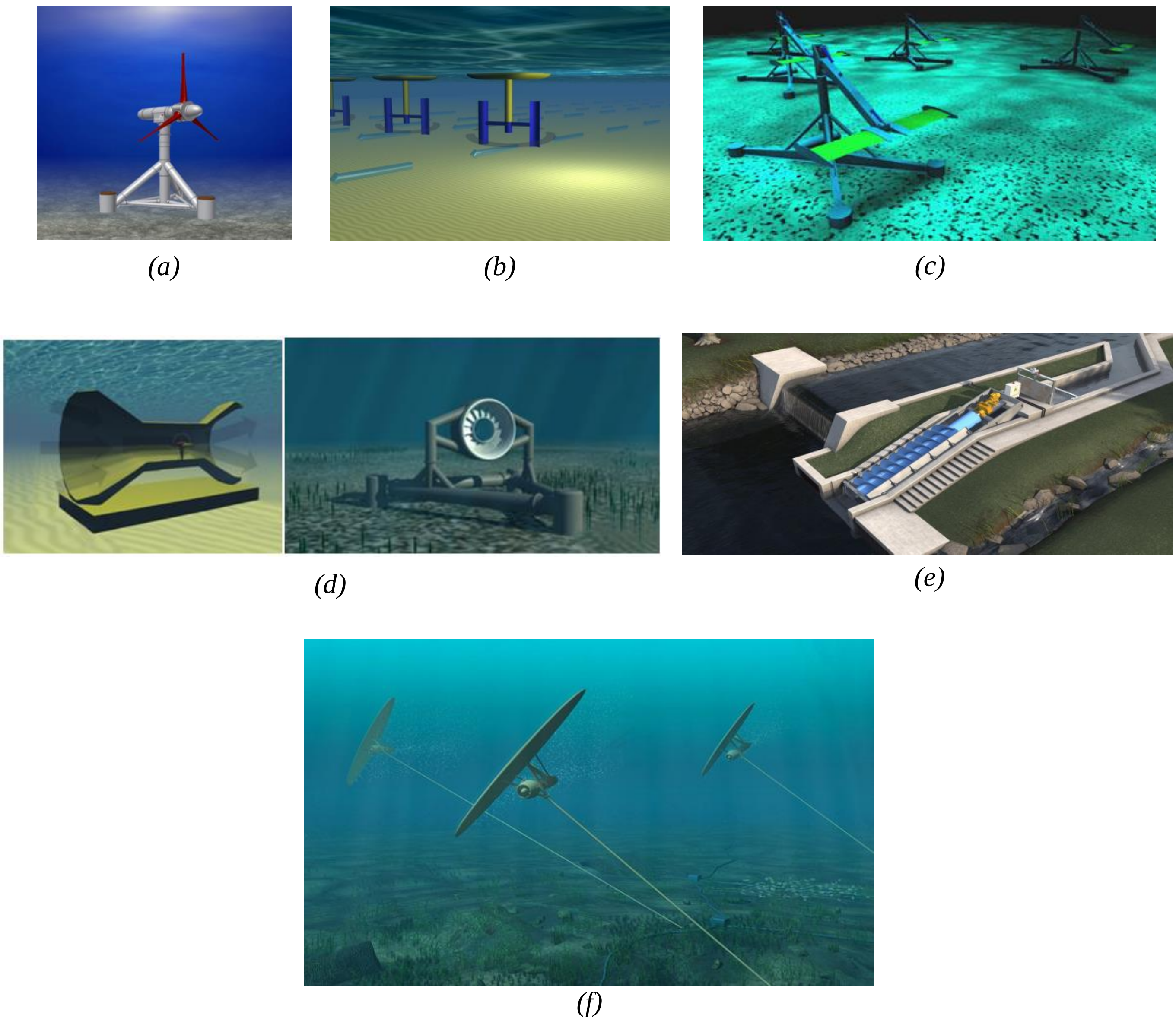


Figure 20. Illustrations of tidal energy devices. (a) Horizonzal axis turbine (Small et al., 2014); (b) Vertical axis turbine (Aquaret, n.d.); (c) Oscillating hydrofoil (Megansch, 2014); (d) Enclosed tips (Lemeckhart, 2012); (e) Archimedes screw (de Prieëlle, 2012); (f) Tidal kite. (Timperley, 2015)

Projects Development

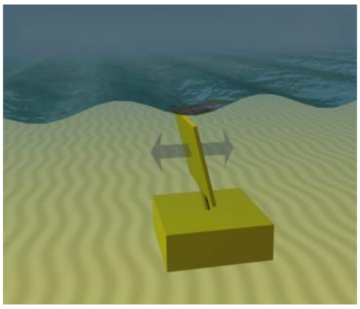
Tidal energy development remains limited to a few projects (Marine Energy, 2015). In July 2018, the UK recorded:

- 4 operational tidal energy projects representing a total capacity of 11 MW
- 0 projects under construction
- 12 projects awaiting construction representing a total capacity of 485 MW
- 2 projects awaiting approval representing a total capacity of 300 MW

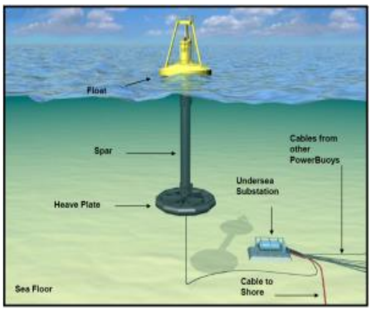
Tidal industry holds strong potential development; however most of the projects are pending. Currently, MeyGen Limited owns the largest tidal project with an installed capacity of 6 MW (Eunomia, 2018). However, despite the low amount of electricity the turbines can generate, the project is part of a long-term undertaking divided into two phases (MeyGen, 2017). The first one aims at reaching 86 MW installed capacity by 2022 and the second part would extend the capacity to 398 MW (MeyGen, 2017). Therefore, the already operational device of 6 MW represents a first step in attaining MeyGen's target (MeyGen, 2017). Yet, only the first phase of the project has been granted permission, therefore MeyGen's 398 MW objective could be modified in the upcoming years (MeyGen, 2017; Eunomia, 2018). Also, unforeseen decisions block development of projects such as the Swansea Tidal Bay Lagoon in Wales (Tidal Lagoon Power, n.d.). Recent resolutions made by the UK government rejected the 320 MW plan to provide electricity for 155'000 households due to its pricing (£1.3 billion) (BBC News, 2018). This project represented an important breakthrough for Wales in reaching the UK's CO2 emissions target and will curtail the country's progress in tidal energy.

2.2.3. Wave Energy

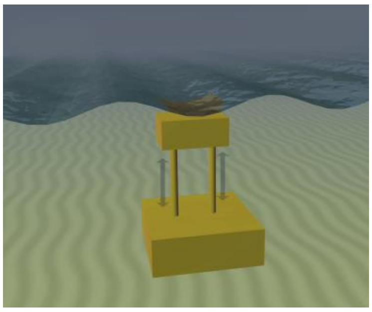
Wave power represents a great source of energy for the UK and technology has improved enough to extract energy under various conditions. The devices used to harness the power of waves depend on the distance from the shore (Schiffer et al., 2016). Consequently, three families of wave energy can be distinguished (Schiffer et al., 2016). The first one, nearshore devices, operates close to the shore where the power of waves is weakened due to the friction with the seabed (Kerr, 2007; Schiffer et al., 2016). As a result, less energy can be captured, but on the other hand, the device is easily maintained (Schiffer et al., 2016). Three types of devices fall among this category: oscillating wave surge converters (Figure 21 (a)), point absorbers (Figure 21 (b)) and submerged pressure differential devices (Figure 21 (c)) (Schiffer et al., 2016). Figure 21 (d) gives a description of their functionality.



(a)



(b)



(c) Submerged pressure differential devices (Aquaret, n.d.)

Oscillating wave surge converter	**Point absorber**	**Submerged pressure differential device**
A flap, mounted on a rectangular-shaped structure, oscillates under the pressure of wave surges (Schiffer et al., 2016)	This device converts the energy created by the buoyancy difference between the upper part and the lower part of the structure (Schiffer et al., 2016)	The system uses the pressure produced by the waves to create a vertical movement of the device (EMEC, n.d.). Electricity is produced by the continuous pressure differential that injects fluid in the structure

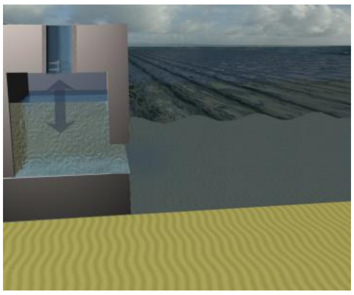
(d)

Figure 21. Illustrations of nearshore wave energy devices. (a) Oscillating wave surge converter (Aquaret, n.d.); (b) Point absorber (Koca, 2012); (c) Submerged pressure differential devices (Aquaret, n.d.); (d) Nearshore devices.

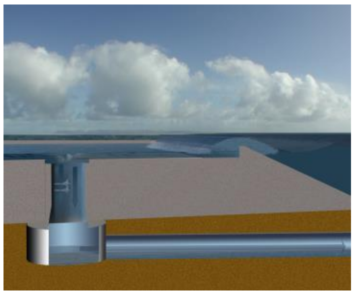
The second family, shoreline devices, are tethered to the seabed, providing the same advantages and disadvantages of nearshore devices discussed previously (Kerr, 2007; Schiffer et al., 2016). Figure 22 (a) gives an overview of the two sets of technologies: oscillating water columns (OWC) (Figure 22 (b)) and overtopping devices (Figure 22 (c)) (Schiffer et al., 2016).

Oscillating water columns (OWC)	Overtopping device
OWC was one of the first wave energy device to be developed (Schiffer et al., 2016). The structure is partially immerged with an air turbine sitting above the water in a chamber (EMEC, n.d.). The vertical movement of the water is going to compress the air in the chamber and subsequently make the turbine spin (EMEC, n.d.)	Waves breaking against the structure fills a reservoir of water and as it flows back to the sea, drive a low-head turbine, generating energy (EMEC, n.d.)

(a)



(b)



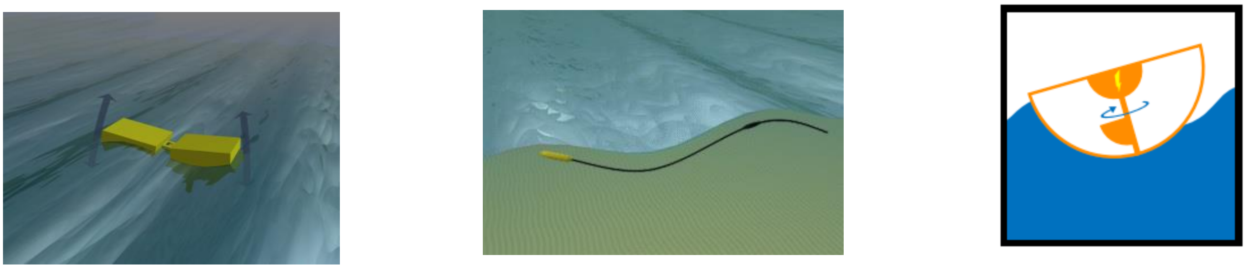
(c)

Figure 22. Illustrations of shoreline wave energy devices. (a) Shoreline devices; (b) Oscillating water column (Aquaret, n.d.); (c) Overtopping devices (Aquaret, n.d.).

Finally, the last category of wave energy devices consists of offshore structures (Kerr, 2007). They differ from the two previous families by their distance from shore, as they can be attached to the seabed in deeper waters (tens of meters deep) (Schiffer et al., 2016). Moreover, they can harness the power of stronger waves but have to withstand intense conditions (Schiffer et al., 2016). As a result, the technology used requires better protection to survive damaging waves (Schiffer et al., 2016). Figure 23 shows the various types of devices that can be used to exploit wave power.

Attenuator	Bulge wave devices	Rotating mass converters
This floating device rides parralel to the waves and generate energy with an oscillatory movement of the arms (EMEC, n.d.)	A a bulge wave device consist of a rubber tube, attached to the seabed, in which water passes from one side to the other driving a low-head turbine (EMEC, n.d.)	The movement of the waves sways a floating structure, inducing the movement of the eccentric mass. The mass's rotation activates the generator to which it is connected and produces energy (Schiffer et al., 2016)

(a)



(b) *(c)* *(d)*

Figure 23. Illustrations of offshore wave energy devices. (a) Offshore devices; (b) Attenuator (Aquaret, n.d.); (c) Bulge wave devices (Texas A&M University, n.d.); (d) Rotating mass converter (Goodwin et al., 2013).

Projects Development

The wave energy sector groups numerous types of devices; however, only a small number reaches commercial maturity. Despite improvement of the technology, the UK only recorded:

- 2 operational projects representing a total capacity of 24 MW
- 0 projects under construction
- 1 projects awaiting construction representing a total capacity of 40 MW
- 1 projects awaiting approval representing a total capacity of 7 MW

The industry’s growth relies on four projects at different stages of development with pessimistic results yet promising undertakings. Amongst the two operational projects, Wave Hub had an expected installed capacity of 23 MW but in reality, recent studies reported that the undersea electrical socket did not generate any electricity (Eunomia, 2018; Vergnault, 2018). In the interim, the sector depends on the success of a 40 MW device awaiting construction by the Lewis Wave Power Limited (Royal Haskoning, 2012). The development would deliver electricity for 38’000 houses and help meet the 2020 renewable targets set by the Scottish government (Royal Haskoning, 2012). The meagre progress realized by the wave energy industry in the UK displays the serious challenges it is facing, exacerbated by a possible reduction in funding in the next years (Zeyringer et al., 2018).

2.2.4. Conclusion

The UK developed a strong leadership position in the offshore wind market, supplied by substantial domestic and foreign investments. Funding allowed developers to improve their technology to harness more power and increase the share of offshore wind in the UK energy mix. Following the same trend, tidal energy is also growing with strong potential for development and power generation. However, recent decisions disrupted auspicious projects from increasing tidal power in the energy mix. Finally, the least develop technology remains wave power and despite operational projects, the electricity production is close to zero. Besides, the little confidence investors have in the technology coupled with the success of offshore wind and tidal energy renders wave power's growth intricate.

2.3. Supply Chain

A supply chain groups all the participants involved in the production and lifecycle of a certain good or service, from the early conception to the customer service after delivery. It is important to distinguish the offshore wind's supply chain from the tidal and wave energy's supply chain as the level of development differs (Schiffer et al., 2016; Smart et al., 2018). Offshore wind exploited the knowledge gained from onshore wind technology to accelerate its development, leading to a robust and sustainable supply chain, unlike both ocean energies (Borthwick, 2016). Contrariwise, marine energies' development has not followed the same pace and there are not any strong companies with significant expertise and experience supplying the market.

A country depends on a strong supply network for the success of its industries for two reasons. Firstly, it will influence the level of exports and imports needed to supply the sector and therefore the contribution to the gross domestic product (GDP). A well-organized supply chain, composed of reliable and advanced companies will enable the country to sell its knowledge and material to other countries, leading to substantial benefits and making the country a leader of the industry. Consequently, the ocean energy supply chain being under developed worldwide, UK companies could seize a significant opportunity (Schiffer et al., 2016). Offshore wind utilities, on the contrary, are well implemented in the market and benefit from clusters (European Commission, 2015). For instance, turbines developers nearby a port would significantly reduce the cost of shipping the device from the construction site to the harbour.

2.3.1. Offshore Wind

The Government's Vision

The UK government aims at developing the offshore wind supply chain to enhance the current leadership of the country worldwide (Department for International Trade, 2014). The main objectives are to create a sustainable and profitable supply network that will support the exports and the jobs (Department for International Trade, 2014). In order to reach the targets, the government needs to open the markets to new entrants to create competition and foster innovation to deliver efficient and cost competitive products and services (UK Government, 2013). Furthermore, there should be an improvement in the access to funding for developers, an important barrier to entry, and in the workers skills (Department for International Trade, 2014). Finally, renewable energies being a recent contribution to the energy mix, companies in the supply chain should therefore learn from other more advanced sectors such as the oil and gas, the aerospace or the automotive industry (UK Government, 2013).

State Review of the Supply Chain

The UK's high potential for offshore wind development attracts foreign companies to invest in the energy source and contribute to the growth of employment in the sector (Zeniewski 2017). Six European utilities, amongst the seven largest renewable energy developers in the country, dominate the industry and intend to expand their leadership by investing in Scotland, where great potential exist (6 GW by 2030) (Zeniewski 2017). The involvement of large companies such as DONG (Denmark), Iberdrola (Spain) or EDF (France) allows the creation of jobs and perspectives for small and medium-sized companies to join the supply network (Zeniewski 2017). Cambridge Econometrics realized in 2017 a projection for employment in the offshore wind industry, according to market trends in the UK and in Europe. During the year 2017, the country recorded 10'000 direct full-time equivalents (FTE) jobs and 21'000 direct FTEs jobs were announced by 2032 (Cambridge Econometrics, 2017). In comparison, the number of FTEs jobs rises to 60'000 by 2032 when direct and indirect employment is taken into consideration (Cambridge Econometrics, 2017).

According to Renewable Energy View, 976 UK companies were involved in the offshore wind supply chain in 2017 and Scotland held 20% of them (Zeniewski 2017). For the United Kingdom, it represents 48% of national content and according to forecasts, it will increase to 50% by 2020 and 65% by 2030 (Figure 24) (RenewableUK, 2017; Smart et al., 2017). To reach the 2030's prediction, the country's production should be aligned with the expected installed capacity of 19 GW and follow a 70% decrease of capital and O&M costs (Smart et al., 2017).

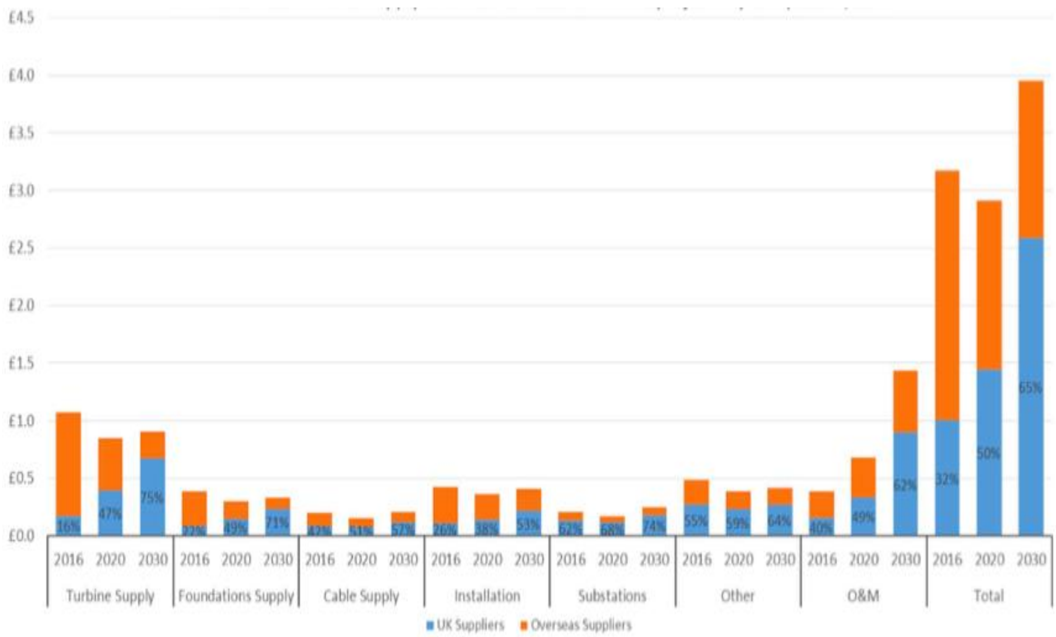


Figure 24. The composition and growth of the offshore wind supply chain (Smart et al., 2017)

Composition of the Supply Chain and Opportunities

The composition of the supply chain can determine the level of economic benefits displayed by offshore wind (Gilmartin et al., 2014). Indeed, the more national content is in the supply chain, the more jobs support the national economy, enhancing employment (Gilmartin et al., 2014). BVG Associates created a report in 2014 with a cost breakdown of the different sections in the supply process for a 500 MW wind farm with 6 MW turbines (Figure 25). The most important one is the operation, maintenance and service section, accounting for 39% of the costs (Roberts et al., 2014). Compared to 2015, operation and maintenance (O&M) activities with UK content increased to 75%, and grows to 85% for minor repairs and routine check-up (RenewableUK, 2017). The country's advanced experience and knowledge made it an attractive partner for foreign developers and despite its high level of development, the UK could improve the sector by selling the accurate weather forecasting devices it uses for O&M activities (Smart et al., 2017).

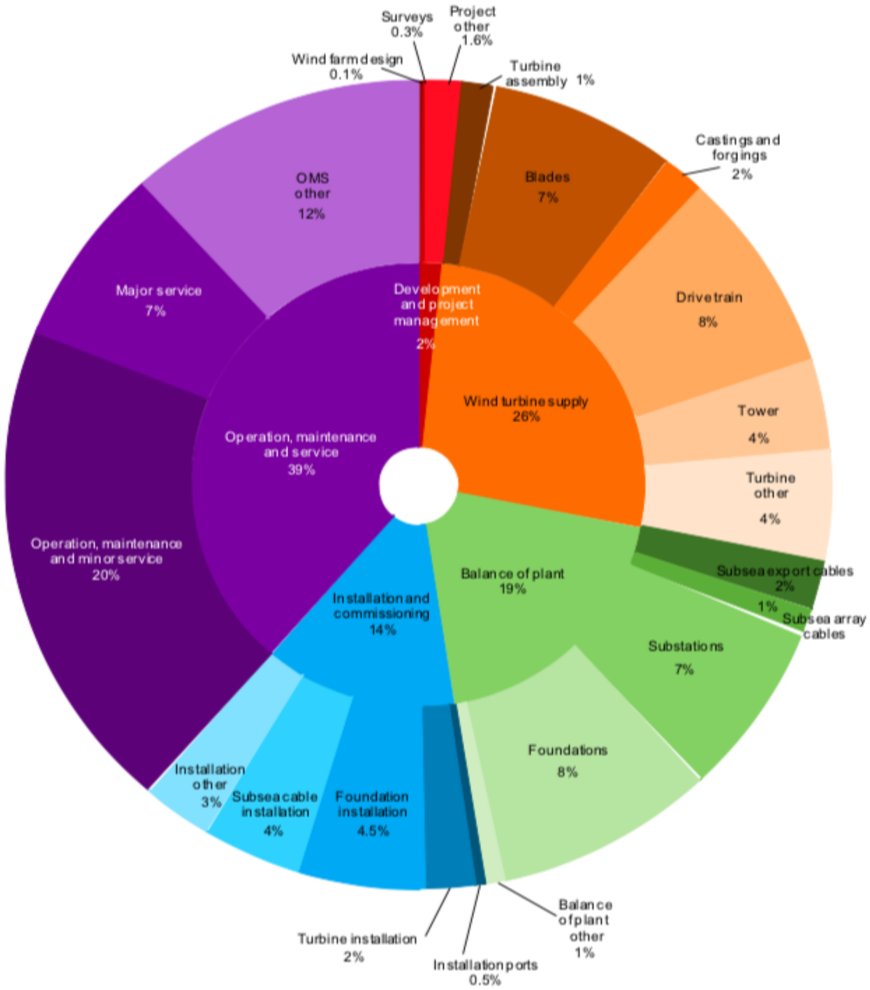


Figure 25. Composition of the UK supply chain for a 500 MW wind farm (Roberts et al., 2014)

For a 500 MW wind farm project, turbines supply accounts for 26% of the cost structure and currently, the country's involvement in the supply chain is limited (Roberts et al., 2014). The UK manufactures and assembles only a trivial portion of the sector (3%), and despite investments in facilities in the last five years in Hull and on the Isle of Wight, the country still relies on the foreign market (Smart et al., 2017; Zeniewski 2017). Thus, costs remain high for turbines and could be reduced by investing more in facilities clustered near ports. Not only would it increase the UK content and enable the country to become more selfsufficient, but it would open new perspectives to commercialize knowledge and expertise. Furthermore, the “Balance of Plant” section holds 20% of the cost structure and can exploit the experience from other industries such as oil and gas to improve the components’ reliability and target exports development (Smart et al., 2017). The current large projects under construction in the UK will operate with jacket-mounted turbines, a technology adapted for deeper waters and able to withstand harsher environments, and upcoming projects will possibly use the same foundations (Smart et al., 2017). Therefore, the experience gained from oil and gas platforms will enable the country to expand UK content in the supply network (Smart et al., 2017).

Concerning the installations, potential exists to increase the UK share and companies have started utilizing it (Smart et al., 2017; UK Government, 2013). Currently, an important part of the vessels is owned by foreign companies with UK crews, and upcoming developments in the turbine industry could modify the present situation (Smart et al., 2017). The production of larger turbine will require adapted vessels to transport the components offshore, and will also induce an upgrade of ports (Deutsche Bank Group, 2011; Smart et al., 2017). In the Irish Sea, some investments have already been made in different locations for construction of foundations and turbine assemblage (UK Government, 2013). For instance, Belfast spent $53 million to improve the local supply chain through the construction of the first harbour dedicated to offshore wind power (UK Government, 2013).

Finally, despite the little share in the cost structure, development and project management holds strong potential for UK companies, leading the market, as it requires important labour content (Roberts et al., 2014). Moreover, they have designed an important amount of wind farms in the UK and have been mandated for most of the country’s survey work (Roberts et al., 2014).

2.3.2. Tidal and Wave Energy

In 2018, the UK lead globally the supply chain for tidal and wave energy and planned on expanding to optimal locations (Smart et al., 2018). In 2016, it recorded 1’700 people working in the network across 850 companies with specific expertise in foundations, subsea activities and manufacturing (Smart et al., 2018). Employment opportunities will increase with the growing of the industry and oil and gas or offshore wind companies will most certainly diversify their operations to both wave and tidal energy (Smart et al., 2018). By 2040, employment could grow respectively to 8'100 and 14'500 (Smart et al., 2018). The supply chain aims at clustering the activities in certain regions of the UK in order to reduce costs and develop key places such as coastal areas and peninsulas (Smart et al., 2018; RenewableUK, n.d.). Four different locations have been targeted for development currently occurring: the South West England, the Scottish Highlands and Islands, Wales and the Isle of Wight and the Solent Region (RenewableUK, n.d.).

The South West of England's growth process commenced with multiple developments in different sectors of the supply chain. Cornwall's harbour witnessed some upgrades with transport infrastructures included around the area (RenewableUK, n.d.). Moreover, companies started providing vessels for offshore development, cables and other components for marine energy development (RenewableUK, n.d.). In Scotland, diverse types of unrelated industries are now investing in renewables. For instance, oil and gas provides support for developing construction sites and companies previously supporting the petroleum industry are now shifting to marine energies by giving engineering assistance to the renewable sector

Component	UK Projects UK Content	UK Projects 2040 spend £m	UK GVA from UK projects in 2040 £m	Non UK Projects 2040 spend £m	UK GVA from Exports £m	Total UK GVA creation in 2040 £m	FTE supported by 2040
Wave energy converter	65%	101	48	1,549	226	275	2,970
Foundations/ Moorings	80%	21	10	327	19	30	280
Electrical	70%	38	21	587	58	79	940
Installation	60%	20	11	299	27	37	910
Other Capex	72%	19	14	297	76	89	830
O&M[23]	75%	73	51	773	42	93	1,820
Development	75%	6	5	92	37	42	380
Total	**70%**	**280**	**159**	**3,924**	**486**	**645**	**8,140**

Figure 26. Components of the UK offshore wind supply chain (Smart et al., 2018)

(RenewableUK, n.d.). Fishers also offer help to developers for offshore deployment and maintenance activities and in the Isle of Wight and the Solent Region, companies previously supplying the defence industry are now designing products and delivering marine autonomous vehicles (RenewableUK, n.d.). Finally, Wales possess some facilities enabling the development of tidal and wave through steel and other materials assemblage facilities (RenewableUK, n.d.).

Due to the worldwide under developed supply chain, UK companies retain most of the national contracts and UK content remains at a good level (70%) for tidal and wave energy projects (Smart et al., 2018). Figure 26 and 27 displays the different section of the supply network and the projected costs of each of them for 2030 for tidal energy and 2040 for wave energy (Smart et al., 2018).

Component	UK Projects UK Content	UK Projects 2030 spend £m	UK GVA from UK projects in 2030 £m	Non UK Projects 2030 spend £m	UK GVA from Exports £m	Total UK GVA creation in 2030 £m	FTE supported by 2030
Tidal Platform	65%	111	53	403	59	112	1,210
Foundations/ Moorings	80%	23	11	85	5	16	160
Electrical	70%	42	23	153	15	38	460
Installation	60%	21	12	78	7	19	450
Other Capex	72%	21	15	77	20	35	330
O&M[22]	75%	80	56	247	13	69	1,240
Development	75%	7	5	24	10	15	130
Total	**70%**	**307**	**175**	**1,066**	**129**	**304**	**3,970**

Figure 27. Components of the UK tidal supply chain (Smart et al., 2018)

Project development groups 75% of UK content and yet, technological innovation could render the industry more attractive to investors and large utilities (Hundleby et al., 2015). A breakthrough device would enhance expertise and knowledge, increasing exports, and ultimately improve the UK supply chain (Hundleby et al., 2015).

Concerning the foundation and mooring system, UK content reaches 80% and little improvement can be realized for now (Hundleby et al., 2015). The shared knowledge of oil and gas companies and of the offshore wind sector to current utilities in the market will help respond to the low expected demand in the next five to ten years (Hundleby et al., 2015).

Tidal platform and energy converter sections require investment in the upcoming years to perform sustainably and efficiently and each sector should concentrate on different strategies as the level of development differs between wave and tidal energy. For the former one, less advanced, developers ought to focus on the technology likely to succeed by investing money for an array-scale development (Hundleby et al., 2015). Tidal energy companies on the other hand should reduce the devices' costs by attracting investors (Hundleby et al., 2015).

Concerning installations, present companies can meet the market demand, yet a fierce competition exists for vessels between tidal and wave sector with oil and gas and offshore wind industries (Hundleby et al., 2015). Moreover, most of the vessels available on the market are not well equipped for installation activities, adding another cumbersome issue (Hundleby et al., 2015). For these reasons, companies should increase capability (Hundleby et al., 2015).

Finally, the electrical system, well developed in the UK supply chain with the experience of both oil and gas and offshore wind sectors, can supply the demand through its capability and capacity (Hundleby et al., 2015).

Countries partially rely on their supply chain to lead certain industries, and the UK aims at capitalizing on the existing strong supply network it has to develop its MRE sector and increase its global leadership. Despite the high UK content in MREs, the country can still make improvements. Among the solutions are to develop the workers skills, innovate to reduce the costs and attract investors and implement the knowledge gain from other industries more advanced than the MRE sector. Offshore wind energies as well as tidal and wave power represent key opportunities to increase employment and enhance the economy.

2.3.3. Research & Development and Testing Infrastructures

MRE development depends on innovation to deliver efficient and cost-effective devices. In that regard, it requires developers to undertake research on the best product to deliver and testing infrastructures to assess the effectiveness of the product. Consequently, the MRE industry in the UK orientated part of its funding and time to the construction of testing facilities and to research and innovation (UK Government, 2014). Many infrastructures have been developed and only part of them are going to be discussed in that section.

Concerning research and development, among the most important ones are:

- the SuperGen UK Centre for Marine Energy Research (UKCMER). This Centre includes 15 British universities with the universities of Edinburgh, Strathclyde, Exeter and Queen's University Belfast as the core members and aims at supporting the MRE sector through research with members of the industry and researchers (SuperGen UKCMER, n.d.).
- Offshore Renewable Energy (ORE) Catapult Centre currently the leader in MRE research and innovation in the country (ORE Catapult, n.d.). This Centre provides developers and main MRE companies support through testing facilities as well as research operated by academia (ORE Catapult, n.d.).
- the Carbon Trust Offshore Wind Accelerator (OWA), a research program orientated towards offshore wind and focusing on decreasing costs of development through innovation (Carbon Trust, n.d.). The program groups nine European developers such as Ørsted, Scottish Power Renewables or Shell (Carbon Trust, n.d.).
- Northern Ireland Centre for Advanced Sustainable Energy (CASE) created by Invest Northern Ireland is a research centre aiming to reduce turbines' costs of MRE devices (CASE, n.d.).

Furthermore, facilities to foster research, development and testing were created in the UK and among them:

- the European Marine Energy Centre (EMEC) (EMEC, n.d.). This centre, established in 2003 aims to develop wave and tidal energy in a particularly harsh environment, the Orkney Islands, by fostering research and innovation (EMEC, n.d.). The EMEC is the first centre to offer such opportunities for ocean energy developers (EMEC, n.d.).
- the FloWave Ocean Energy Research Facility, this centre provides an indoor testing area to experiment devices before offshore testing (FloWave, n.d.). Located in Edinburgh, the facility allows developers to improve their devices without risking too much damages, and it therefore decreases costs (FloWave, n.d.).

Moreover, other facilities were built for testing only, and among the most important ones are:

- Wave Hub Limited with the largest testing site in the world for MRE off the coast of Cornwall and two others in Pembrokeshire and in the Devon, respectively for wave and tidal demonstration (PRIMaRE, n.d.). It provides developers with various advantages such as access to ports, grid connection and wave resources (WaveHub, n.d.).
- the European Offshore Wind Deployment Centre near Aberdeen (UK Government, 2014). This centre focuses on offshore wind deployment and aims to develop the industry with the first project launched in 2016 and operational in September 2018 (Power Technology, n.d.).
- the Falmouth Bay test site (FaBTest), a 2012 award winning test site in Falmouth harbour, providing moderate conditions to test in open water offshore devices (FaB Test, n.d.). It reduces the risk for developers and gives the opportunity to experience different depths (20m to 50m) (FaB Test, n.d.).

2.3.4. Conclusion

The ideal geographical location of the UK has attracted national and foreign investors for MRE developments, contributing to the improvement of the UK supply chain. To capitalize on this support, both the offshore wind industry and the wave and tidal industry plan on increasing the installed capacity and develop the supply chain by reducing costs or improving workers' skills. This will benefit to employment and contribute to the economic growth of the country. Also, the UK has a strong research and innovation sector, increasing the country's leadership in the MRE sector and allowing it to export its knowledge abroad. However, despite the UK's global lead in the MRE sector, it still relies on imports for certain components, such as turbines.

2.4. Funding

Funding is the most important component of MRE development. To make this sector viable in the UK, companies need substantial financial support. Indeed, the costs of production remain high for offshore wind, wave and tidal energy devices and it requires funding to decrease the prices (UK Government, 2013). As the company produces more turbines, the cost per unit decreases and creates economies of scale (Thomas, 2017). Moreover, entering the market and developing a long-term viable technology necessitates substantial investments in the supply chain and in capital expenditures (UK Government, 2013). For these reasons, in the UK and in the EU, multiple schemes and infrastructures are available for companies to develop their technologies.

2.4.1. Funding from the UK

In the UK, developers can apply to one of the most important funding scheme of the country for renewable energy companies to help them undertake a project: Contracts for Difference (CfDs) (Department for Business, Energy & Industrial Strategy, 2017). In 2013, the UK introduced CfDs through the Electricity Market Reform of 2013 to grant contracts to renewable electricity generators and allow them to secure future benefits (Department for Business, Energy & Industrial Strategy, 2017). During an auction, the UK government will award to an electricity generator a 15-year contract to develop a certain project in renewable energy (Department for International Trade, 2014). The auction winners will then provide a supplier with the electricity they produce at the fixed price it was auctioned, the strike price (in £/MWh) (Low Carbon Contracts Company, n.d.). Furthermore, the strike price is then compared to the national average market price of electricity in the UK and the generator or the Low Carbon Contracts Company (LCCC) will pay the difference of the two prices (Low Carbon Contracts Company, n.d.). The LCCC, a government-owned company, covers the difference if the strike price is lower than the market price and contrariwise, the generator pays the difference (Figure 28) (Department for International Trade, 2014). The supplier will then pay the supplier via the LCCC when it received the electricity (Department for International Trade, 2014). This scheme is advantageous as it protects from potential losses given the volatility of the energy market, it covers from any legal modification in the CfDs and it gives 15 years for the company to make its way in the market (Department for International Trade, 2014).

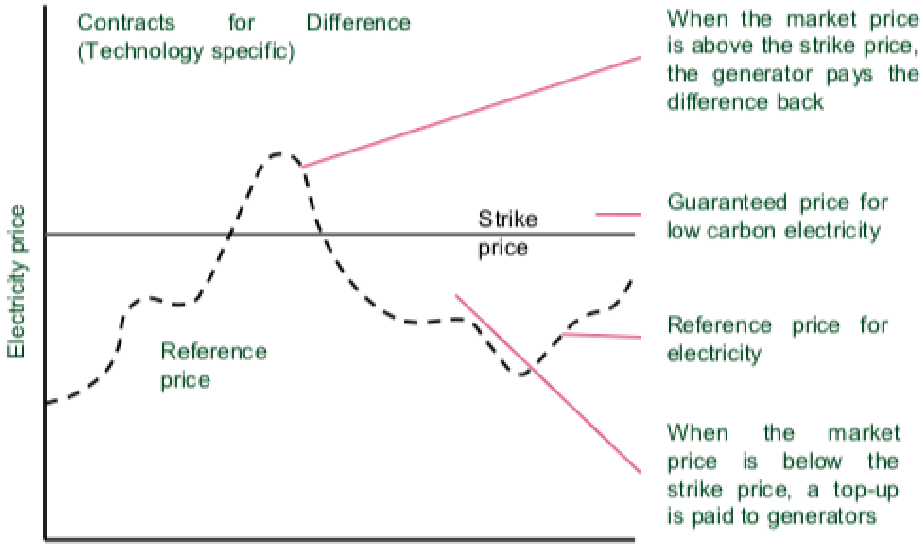


Figure 28. How CfDs work (Department for International Trade, 2014)

The government programmed three auction rounds with the objective of improving the technology and decreasing the strike price every round. Currently, two rounds have been implemented with significant improvements over the years. The first one occurred in 2015 and two offshore wind projects received a contract with a strike price of respectively £119.89/MWh and £114.39/MWh (Department for Business, Energy & Industrial Strategy, 2015). In 2017, the year of the second round, three offshore wind companies obtained a contract and they managed to reduce the strike price to £74.50/MWh and £57.50/MWh (Department for Business, Energy & Industrial Strategy, 2017). In comparison, nuclear power generator EDF signed a contract with a £92.50/MWh strike price, making offshore wind cheaper than nuclear power (Clover, 2017). The three awarded projects are Triton Knoll Offshore Wind Farm, Hornsea Project 2 and Moray Offshore Windfarm (East) with installed capacity of respectively 860 MW, 1'386 MW and 950 MW (Department for Business, Energy & Industrial Strategy, 2017). In terms of benefits for the economy, with a strike price of £105/MWh and 50% of UK content in the supply chain, the net benefit reaches £1.2 billion (Smart et al., 2017). According to Smart et. al (2017), each £10/MWh decrease in the strike price results in an increase in benefits of £240 million to £350 million. *"As an example, a strike price of £90 with 50% UK content would have an estimated net benefit of £1.7bn per GW"* (Smart et al., 2017). Moreover, the three offshore wind developments will improve employment with thousands of jobs created (SmartestEnergy, 2017). CFDs are an essential tool for reaching clean energy targets as it allowed the UK to increase its energy production from renewable sources and decrease its price.

Another governmental scheme that is no longer available in the UK, as it has been replaced by the CfDs, is the Renewables Obligation Contract (ROC), introduced in the UK's Utilities Act 2000 (Department for International Trade, 2014). Under this support mechanism, all electricity suppliers need to create a certain proportion of electricity through renewable sources and will receive a Renewable Obligation Contract (ROC) corresponding to the amount of electricity they produced from a renewable source (Office of Gas and Electricity Markets, 2017). In the case that the company fails to reach the intended target, it has to give a corresponding amount of money to a buy-out fund that will be used to pay companies that have met their renewable targets (Office of Gas and Electricity Markets, 2017). Figure 29 displays the evolution of the buy-out price from 2010 to 2019 and the number of ROCs obtained for 1 MWh of electricity (Office of Gas and Electricity Markets, 2018). The Renewables Obligation Contract program provides energy generators with a potential second revenue added to the one coming from the electricity market (Department for International Trade, 2014). In 2016, ROCs enabled the development of 4'716 MW of offshore wind power whereas tidal and wave power had not received ROCs (Figure 30) (Office of Gas and Electricity Markets, 2017).

OBLIGATION PERIOD (1 APRIL - 31 MARCH)	BUY-OUT PRICE	OBLIGATION FOR ENGLAND & WALES AND SCOTLAND (ROCS/MWH)	OBLIGATION FOR NORTHERN IRELAND (ROCS/MWH)
2010-11	£36.99	0.111	0.0427
2011-12	£38.69	0.124	0.055
2012-13	£40.71	0.158	0.081
2013-14	£42.02	0.206	0.097
2014-15	£43.30	0.244	0.107
2015-16	£44.33	0.290	0.119
2016-17	£44.77	0.348	0.142
2017-18	£45.58	0.409	0.167
2018-19	£47.22	0.468	0.185

Figure 29. Evolution of the buy-out price from 2010 to 2019 (Office of Gas and Electricity Markets, 2018)

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Onshore wind	694	603	495	499	1,231	1,485	853	390	739	2,109
Offshore wind	190	90	352	1,063	645	882	1,024	420	50	0.0
Fuelled	33	13	70	278	60	63	69	130	59	42
Solar PV	1	0.4	0.3	0.3	6	285	1,170	2,485	1,233	662
Landfill gas	37	28	22	32	0	8	0.5	4	0	1
Other	15	124	11	15	1	12	11	14	3	30

Figure 30. Capacity awarded from 2007 to 2017 for each technology (Office of Gas and Electricity Markets, 2017)

In order to improve the Marine Renewable Energy industry, the UK government created the Green Investment Bank (GIB) in 2012, renamed the Green Investment Group in 2017 (GIG) with the objective to help meet the renewable targets by supporting offshore wind development specifically (Department for International Trade, n.d.; Green Investment Group, 2018; Hill, 2018). The fund was supported by a capital investment of 3.8 billion pounds at its creation with the government as its sole shareholder (Department for International Trade, n.d.). This bank funded approximately 100 green infrastructure projects with £3.4 billion since 2012 and supported 9 wind energy projects worth £1.6 billion (Department for International Trade, n.d.; Green Investment Group, 2018). Amongst the projects that the GIG financed are the operational London Array wind farm with an installed capacity of 630 MW and the Walney wind farms with 370 MW of installed capacity and 660 MW under construction (Eunomia, 2018).

In order to support the development of the MRE sector in the UK, more funding schemes and infrastructures are available for developers. Figures 31 shows a non-exhaustive list of the main funding programs available for companies.

Funding scheme	Sectors	Funding available	Description
Co-Fund NI	All sectors	£50m	The Access to Finance program is located in Northern Ireland and aims at developing business and the economy of the country (UK Government, 2014). Offshore wind sector is among the sectors that can benefit from the funding (UK Government, 2014)
Development Fund	All sectors	£48m	
Growth Loan Fund	All sectors	£50m	
Small Business Loan Fund	All sectors	£5m	
Business Angel Co-investment Fund	All sectors	-	The funds help developers with financing ranging from £100k and £1m (UK Government, 2014)
Enterprise Capital Funds	All sectors	-	The funds help developers with financing up to £2 million (UK Government, 2014)
Enterprise Finance Guarantee	All sectors	-	The Government supports developers from various sectors through loans ranging from £1,000 to £1.2m(UK Government, 2014)
Enterprise Zones	All sectors	-	Enterprises Zones are areas in the UK holding attractive benefits for companies that want to implement such as Enhanced Capital Allowances or automatic planning permission (UK Government, 2014)
Regional Selective Assistance	All sectors	-	The scheme aims to develop the economy of Scotland by providing support to companies operating in 'assisted area' (UK Government, 2014)
Repayable Business Finance	All sectors	Multi million pounds	The plan aims to develop the economy of Wales by providing support to companies operating in the country (UK Government, 2014)

Figure 31a. Funding available from the UK (non-exhaustive)

Funding scheme	Sectors	Funding available	Description
Energy Entrepreneurs Fund	Energy	£35m	The funds help developers with financing to develop viable technologies that will help reach the 2020 targets (UK Government, 2014)
Energy Technologies Institute	Energy	-	The objective of the institute is to finance projects that aim to reduce GHG emissions and help reach UK's energy targets (Energy Technologies Institute, n.d.)
Low Carbon Infrastructure Transition Programme	Low-carbon project	-	The program aims at developing industries operating in low-carbon projects in Scotland (Scottish Government, 2015)
Marine Renewables Commercialisation Fund	MRE	£18m	The objective of the fund is to develop MRE in Scotland by providing money to developers (Magagna et al., 2015)
Marine Renewables Proving Fund	MRE	£22.5m	In 2015, the fund directed by Carbon Trust had supplied 6 projects (Magagna et al., 2015)
The Crown Estate	MRE	£3m	In 2015, the Government planned to invest £25.7 million in addition, to develop MREs (Magagna et al., 2015)
Grants for Business Investment	Offshore wind	£60m	This scheme aims at supporting the offshore wind industry in assisted areas in England by enabling manufacturers to apply for grants (UK Government, 2011)
National Renewables Infrastructure Fund	Offshore wind	£70m	The plan aims at developing ports infrastructures to attract offshore wind companies in Scotland (UK Government, 2014)
Offshore Wind Manufacturing Support Funding	Offshore wind	-	The fund was created by the Department of Energy and Climate Change to support the development of offshore wind projects in specific areas of England (UK Government, 2014)
Renewable Energy Investment Fund	Renewables	£103m	The fund aims to develop the economy of Scotland by providing financial support to companies operating in the country (UK Government, 2014)
Marine Energy Array Demonstrator	Wave and tidal	£20m	The MEAD aims to develop wave and tidal energy in the UK by providing financial support (Wave Hub, n.d.)
Saltire Prize	Wave and tidal	£10m	This price was created to fund the tidal and wave enery sector in Scotland (Saltire Prize, n.d.)

Figure 31b. Funding available from the UK (non-exhaustive)

2.4.2. Funding from the European Union

The funding programs available in the UK can be coupled with funding from the EU, and one of the major schemes available for offshore wind, tidal and wave energy is Horizon 2020 (European Commission, n.d.). This €79 billion program started in 2014 and aims at addressing three global areas: excellent science, industrial leadership and societal challenges (European Commission, 2014). It provides funds to diverse infrastructure such as universities, research centres or companies until 2020 with an objective of developing Europe's potential in research and innovation and boost the EU economy and employment (European Commission, 2014). Between 2014 and 2017, it devoted €600 million to improve clean energy, and €380 million was dedicated to MRE in the UK (European Commission, 2014; Zeniewski, 2017). In 2015, the UK was the country with the most application for this funding leading to the development of the Floating Tidal Energy Commercialisation (FloTEC) project in Scotland (Zeniewski, 2017). The UK is also a main actor of the EU scheme as "*at least one UK research organisation is either a coordinator or a partner in about 60% of all Horizon 2020 funding made available for energy and climate research"* (Zeniewski, 2017).

Furthermore, the EU supported Framework Program (FP) aims at developing energy systems and more specifically, improve the efficiency of sustainable energy sources (Van der Veen et al., 2014). Under FP6 and FP7, the sixth and seventh edition of the Framework Program, wave and tidal energy received €109 million globally, shared between hydro power and other types of projects whereas wind power, comprised of offshore and onshore wind, received €179 million (Van der Veen et al., 2014).

NER 300, another global funding program, funds projects orientated towards low-carbon energy development via the European Investment Bank (EIB) (Commission Européenne, 2014). NER 300 aims at bringing to maturity technologies, that will reduce carbon emissions, by supporting them financially (Commission Européenne, 2014). For the UK, the first two rounds in 2012 and 2014 awarded funding for MRE only in 2012 for two tidal energy projects of €18.4 million and €20.7 million (Commission Européenne, 2014). However, one of them, Kyle Rhea Tidal Stream Array has withdrawn its application and the second one, Sound of Islay is awaiting construction (Commission Européenne, 2014;

Eunomia, 2018). The withdrawn application resulted in the loss of the funding, redirected to other EU financial programs (European Commission, 2018).

Furthermore, the European Investment Bank plays an important role in the funding of MRE programs with objectives to finance projects capable of helping meet the 2020 targets and reduce GHG emissions (European Investment Bank, 2018). Concerning MRE, the EIB funded the Sound of Islay, as previously noted, a 10 MW tidal array, and Beatrice Offshore wind farm through a £525 million loan, one of the most important funding examples for an offshore wind project (Zeniewski, 2017). Moreover, the EIB manages and funds schemes in partnership with the European Commission with similar objectives of addressing climate change issues through renewable projects (European Commission, 2018; European Commission, n.d.).

The European Union created multiple funding arrangements and infrastructure support orientated towards renewable energies. Figure 32 displays a list of some of the programs

Funding scheme	Sectors	Funding available	Description
Cohesion Fund	All sectors	€63.4bn	*"The EU's €63.4 billion Cohesion Fund aims to reduce economic and social disparity between EU countries and promote sustainable development. The Fund supports energy-related projects that benefit the environment such as by reducing greenhouse gas emissions, increasing the use of renewable energy or improving energy efficiency." (European Commission, n.d.)*
European Fund for Strategic Investments	All sectors	€335bn	The objective of the plan is to develop economic activities in Europe through lending, blending and advising (European Investment Bank, n.d.). For the period 2014-2020, €100,428,444 was awarded to the welsh tidal and wave sector (Marine Energy Wales, n.d.)
European Regional Development Fund	All sectors	€3.6 billion (for England)	*"The ERDF aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions"* (European Commission, n.d.)
Interreg	All sectors	€10.1bn	The objective of the scheme is to increase the share of renewable energies in the energy mix and help reach the 2020 targets. For the period 2014-2020, the EU increased the funding available from €8.2bn to €10.1bn in order to adress key issues such as climate change and therefore renewable energies (European Commission, n.d.)
European Energy Efficiency Fund	Energy	€265m	The fund support renewable energy projects through funding of small scale projects (European Energy Efficiency Fund, 2016)
European Energy Programme for Recovery	Energy	-	Established in 2009, the programme aims at reducing the GHG emissions via the development of renewable energies, the offshore wind being one of them (European Energy Programme for Recovery, n.d.; European Commission, n.d.). Two projects in the UK benefited from the programme in Scotland (European Energy Programme for Recovery, n.d.; European Commission, n.d.)
InnovFin Energy Demo Projects	Energy	-	In order to develop the renewable energy industry, the European Investment Bank manages the InnovFin Energy Demo Projects with funding ranging from €7.5m to €75m (European Commission, 2018)
The Marguerite Fund	Energy and Transport	€710m	This european fund targets the energy and transport sectors with a global budget of €710m, coming partially from the EIB (Marguerite, 2016). Between 35% and 45% of the funding is directed towards renewable energies (Marguerite, 2016). Moreover, it aims at addressing the climate change issues by funding mature renewable energies such as wind power (Marguerite, 2016)
Life	Environment, climate change and nature conservation	€3.4bn (2014-2020)	This EU's financial instrument has funded 4500 projects since its creation in 1992 (European Commission, n.d.). One of the aims is to preserve the environment by investing in renewable energies (European Commission, n.d.)

Figure 32. Funding available from the EU (non-exhaustive)

available for the UK where funding has already been granted for offshore wind energy or tidal and wave energy available for the UK where funding has already been granted for offshore wind energy or tidal and wave energy.

2.4.3. Conclusion

To increase the share of MRE in the energy-mix, developers need funding from the UK and also from the EU. With the degradation of the environment, the UK Government and EU authorities increased available funding for MRE development. In the UK, the CfDs replaced RO and awarded contracts to multiple offshore wind farms in the first two auction rounds. This allowed developers to reduce substantially the cost per MWh from the first round to the second one. Moreover, ocean energies also benefit from funding with schemes developed only for wave and tidal energy like the Saltire Prize in Scotland or the Marine Energy Array Demonstrator for the entire UK. The EU also proposes programs for developers in both the offshore wind industry and in the wave and tidal industry; however, most of the funding is allocated to the former one, presenting more viable commercial perspectives. Despite improvements in funding over the years in the UK and in Europe, the Brexit could cast a dark shadow on the future of MREs in the country.

2.5. Environmental Implications

Despite benefits from renewable energy, MRE's impacts on the environment still pose issues for developers. Both offshore wind, wave and tidal energy present concerns for the fauna and the flora of the oceans. Therefore, environmental assessments must be conducted prior to implementing an MRE project in order to evaluate the potential damages made to the environment. Currently, the knowledge of MRE environmental related impacts remains limited and more investment is required to improve the understanding of MREs and interaction with flora and fauna.

2.5.1. Compliance to Regulations

Strategic Environmental Assessment

The UK government created its Strategic Environmental Assessment (SEA) in order to target the relevant environmental impacts of MRE developments and structure future research. The UK government describes the SEA as *"the process of appraisal through which environmental protection and sustainable development may be considered, and factored into national and local decisions regarding Government (and other) plans and programmes – such as oil and gas licensing rounds and other offshore energy developments, including renewables and gas and carbon dioxide storage"*. The SEA therefore targets the potential impacts link to a policy or a plan, and proposes actions to eliminate these impacts (Convention on Biological Diversity, n.d.). In contrast, an Environmental Impact Assessments (EIA) focuses on a single project, and is determined by the type of development a company will undertake (Convention on Biological Diversity, n.d.). For instance, a construction of a house will require different analysis than an oil and gas project or a wind farm development.

In its offshore energy SEA, the UK government exposes the risks linked to offshore wind, wave and tidal array development under five activities (Department of Energy & Climate Change, 2016):

- prospection and selection of an area. During this phase, developers undertake geotechnical and geophysical surveys and can impact marine mammals (Department of Energy & Climate Change, 2016). According to the Department of Energy & Climate Change's SEA, these surveys' noise intensity can have detrimental impacts on cetaceans and fish
- construction and installation. Some studies showed the impact of this development phase on marine mammals as well as on the seabed, yet, more information is still missing to entirely assess construction and installation's damages (Department of Energy & Climate Change, 2016). For instance, noise pollution stands among main consequences with pile-driving of foundations, especially for large undertakings such as the Walney Extension (87 turbines) (Brueck, 2018; Department of Energy & Climate Change, 2016)

- operation of the devices. The potential impacts on the surrounding environment depends on the type of MRE developed. In the case of wind farms, turbines can for example modify entire ecosystems, endanger species of birds through collisions and modify marine mammals' behaviour with electromagnetic fields (Department of Energy & Climate Change, 2016). Moreover, wave and tidal infrastructures display similar issues with risk of collisions with marine mammals and fish or wave/current energy removal (Department of Energy & Climate Change, 2016)
- maintenance. Among the five steps of MRE development, maintenance is the least harmful for the environment despite potential threats in case of large operations (Department of Energy & Climate Change, 2016)
- decommissioning. This phase comprises the removal and cleaning of the infrastructures and devices (Department of Energy & Climate Change, 2016). The two main risks targeted by the SEA are the noise pollution and the consequences of the post-decommissioning phase with expected disturbances for pelagic and benthic organisms (Department of Energy & Climate Change, 2016)

Moreover, the SEA set some guidelines to follow, to prevent consequences on the environment such as improving the knowledge through studies and research. From prospection to decommissioning, MRE development exerts pressure on the marine and terrestrial environment and the SEA identified the most important environmental impacts (Figure 33). From these impacts, the Department for Business, Energy & Industrial Strategy created three themes grouping the most important research areas: marine mammals, birds and seabed and water column (Department for Business, Energy & Industrial Strategy, 2018). The Department aims to gain knowledge on these key sectors to better understand MRE development and reduce the underlying risks (Department for Business, Energy & Industrial Strategy, 2018). For this reason, it funded multiple projects and created a database with all the research realized and the undergoing studies (Department for Business, Energy & Industrial Strategy, 2018). In July 2018, researchers had submitted 16 papers on the impacts on birds, 18 on marine mammals and 5 concerning the seabed and the water column (Department for Business, Energy & Industrial Strategy, 2018).

Impacts on the Environment
Accidental events – major chemical spills, or major releases of carbon dioxide (water column, seabed and air quality related effects and socio-economic consequences)
Artificial reef effect due to hard structures. However, it is unclear whether it has a positive (enhance biodiversity) or a negative (attracts predators and invasive species) effect on the environment.
Barriers to movement of birds, fish and marine mammals
Behavioural and physiological effects on marine mammals, birds and fish from noise (e.g. seismic or other geophysical surveys, construction, operation and decommissioning phase noise)
Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities
Biofouling (development of microorganisms on the structures) that can lead to eutrophiciation and species invasion
Changes in seawater or estuarine salinity, turbidity and temperature from discharges and impoundment
Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)
Chemical contamination (routine) from produced or treated water, drilling and other discharges, antifouling coatings etc.
Collision risks to birds, bats and water column megafauna (e.g. fish, marine mammals)
Contamination by soluble and dispersed discharges saline discharges (aquifer water and halite dissolution in relation gas storage and CCS), and foundation construction
Effects of reinjection of produced water and/or drill cuttings and carbon dioxide
Electromagnetic Field (EMF) effects on electrosensitive species
Energy removal downstream of wet renewable devices
Modification of the flow (waves and current) by the fixed or floating structures
Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, “sanctuary effects”) and other users including shipping, military, potential other marine renewables and other human uses of the offshore environment
Offshore disposal of seabed dredged material
Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)
Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access
Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour), and changes to sedimentation regime and associated physical effects
Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, in situ cabling etc.
Potential air quality effects including on human health resulting from atmospheric emissions associated with plan activities, or with discharges of naturally occurring radioactive material in produced water
Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them))
Sediment modification and contamination by particulate discharges from drilling etc or resuspension of contaminated sediment
The introduction and spread of non-native species

Figure 33. Potential impacts of MRE development on the environment (Department for Business, Energy & Industrial Strategy, 2018)

Environmental Impact Assessment

To start a project, developers need to comply to environmental regulations set by the UK government and by the EU. The Crown Estate owns the right to accept or refuse any offshore wind farm, tidal or wave array development carried out on the seabed such as lying of cables or tethering of structures and delivers its consent through a site lease (Department of Energy & Climate Change, 2016). To receive this authorization, the companies must undertake an environmental impact assessment (EIA) in order to start the underlying project as required by EU Council Directives (85/337/EEC and 97/11/EC) (Department of Energy & Climate Change, 2016). The UK law integrated this directive into multiple regulations and requires companies to determine the impact a certain project will have on the surrounding environment by taking into account multiple factors inherent to the project (Department of Energy & Climate Change, 2016). The EIA process can be divided into seven distinctive steps (Convention on Biological Diversity, n.d.):

1. screening, to determine the projects needing an EIA
2. scoping, to determine the potential consequences and solutions that need investigation
3. assessment and evaluation of impacts and development of alternatives
4. reporting the Environmental Impact Statement (EIS) or EIA report
5. review of the Environmental Impact Statement (EIS)
6. decision-making, to determine the status of the project (rejected or accepted and under what conditions)
7. monitoring, compliance, enforcement and environmental auditing

2.5.2. Legal Requirements' Issues

Lack of Research

Assessing the potential impact of a wind farm or of an ocean energy device requires time and money for companies and can hinder a project's development (Wright, 2015). Indeed, the knowledge on the positive and negative consequences made to the environment remains limited and therefore more studies are required, especially with the increasing size of projects (Wright, 2015).

For instance, the reef effect still raises questions among the scientist to determine its relative impact (Bonar et al., 2015). The hard structure of wind towers enables organisms to find shelter and develop marine life (Bonar et al., 2015). This artificial reef could, on the one hand help the reproduction of certain species and enhance biodiversity, but on the other hand, it could attract predators and invasive species leading to potential dramatic consequences (Bonar et al., 2015).

Moreover, the impact of noise on marine mammals also requires in depth studies as researchers remain uncertain of the effect of MRE developments (Department of Energy & Climate Change, 2016). Scientists have tested the impact of noise of pile drivers on marine mammals over a short period of time; however, the long-term effects are unknown (Department of Energy & Climate Change, 2016). In that regard, the UK's SEA required researchers to focus on areas prone to MRE development and to marine mammals' passages (Department of Energy & Climate Change, 2016).

Furthermore, MRE developments raised the issue of birds' collision with devices or the displacement of species (Department of Energy & Climate Change, 2016). This could lead to a decrease in birds' population and a modification of species distribution. Therefore, to preserve the balance of ecosystems, the SEA required scientists to undertake surveys and studies to assess MREs' impacts (Department of Energy & Climate Change, 2016).

Precautionary Principle

The UK government uses the precautionary principle in dealing with environmental consequences, putting the burden of the proof on the developers (Wright, 2015). The principle states that *"when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically"* (Kriebel et al., 2001). Currently, a gap exists between technological progress of devices and their impact on the environment (Wright, 2015). Monitoring of offshore wind farms is more advanced than for tidal and wave energy devices but remains incomplete about short-term, and especially long-term effects (Wright, 2015). Therefore, as required by the precautionary principle, developers undertake EIA, increasing time and costs (Wright, 2015). Moreover, assessing environmental impacts requires field study and the ocean can display harsh conditions, hindering the experiments and adding more costs to the development (Wright, 2015). To address this issue, the UK government created its SEA, to target the potential effect of MRE development and orientate the EIAs towards these consequences (Wright, 2015; Department of Energy & Climate Change, 2016). Wright (2015) also suggested to shift from the precautionary approach to a risk-based approach. With that approach, developers focus on predetermined risks rather than on potential risks and it therefore eliminates preventable research (Wright, 2015).

2.5.3. Conclusion

Despite the benefits provided by MRE development in terms of green energy, developers need to address potential negative environmental impacts. For this reason, the UK government requires companies to undertake an EIA prior to a MRE development. This legal requirement set by the government raises challenges for developers as it necessitates time and funding. Consequently, the UK created an SEA to narrow down the probable consequences of MRE projects, and based on this assessment, companies can tailor their EIA according to the impacts assessed. Regardless, more studies need to be realized in order to understand fully the impact of MRE on the environment as sometimes, positive consequences can arise.

2.6. Legislation Framework

Along the years, countries gathered to put in place international cooperation and legal framework to reduce GHG emission, the main contributor to climate change. The Paris Agreement in 2015, the latest in date, reunited 196 countries with 195 signing a binding agreement to maintain global temperature below 2 degrees compared to the industrial revolution, coupled with multiple environmental objectives and measures (European Commission, 2017). Consequently, the EU and UK transposed and adapted the measures to its European and national legal framework, including more challenging objectives (Zeniewski, 2017).

2.6.1. EU Legislation

Throughout time, the EU developed numerous legislations in order to support the GHG emission reduction targets (The Scottish Parliament, 2016). Since the creation of the EU in 1952 with the European Coal and Steel Community, energy has always been part of the union's development and the EU improved its framework and directives during the years (The Scottish Parliament, 2016). The EU's goals are numerous and among them are (The Scottish Parliament, 2016):

- to implement a green energy system that will support employment and enhance the economic growth

- to secure energy supply
- to reduce consumers' cost by enhancing competition among suppliers
- to preserve the environment by setting up strict regulations on the usage of the oceans and seas

2.6.2. The 2020, 2030 and 2050 Targets

To achieve its targets, the EU set a number of objectives for the upcoming decades (Stegman et al., 2017). The first one in 2007, described as the 2020 Climate & Energy Package, gives the goals fixed by EU leaders (European Commission, 2017; The Scottish Parliament, 2016). These 20-20-20 targets state that by 2020, the EU should (European Commission, 2017; The Scottish Parliament, 2016):

- decrease GHG emissions by 20% compared to 1990 levels
- increase by 20% energy consumption coming from renewable sources
- increase energy efficiency by 20%

In 2016, most of the EU countries were on track to meet their three targets but important European powers, such as the UK, were trailing behind for renewable energy (Climate Action Network Europe, 2016).

In 2014, following the first set of objectives, the European Commission presented improvements for the subsequent decade with the 2030 Climate and Energy Framework aiming to (European Commission, 2017; The Scottish Parliament, 2016):

- decrease GHG emissions by 40% compared to 1990 levels
- increase by 27% energy consumption coming from renewable sources
- increase energy efficiency by 27%

The 2030 Climate and Energy Framework is part of the global objective set by the Paris Agreement and will enable countries in the EU to develop their economy through a leadership in the renewable energy sector (The Scottish Parliament, 2016).

Finally, in order to transform the energy production in the long-term, the EU put in place the Energy Roadmap 2050 (European Commission, 2017). The targets set aims to (European Commission, 2017):

- decrease GHG emission by 80-95% compared to 1990 levels
- decrease GHG emission by 40% by 2030 compared to 1990 levels
- decrease GHG emission by 60% by 2040 compared to 1990 levels

All in all, the EU described three potential roads for the countries to take in order to give a chance to reach the intended targets (European Commission, 2014). The overarching idea puts forward the development of renewable energies, as it will enable countries to decrease GHG emissions and also enhance their economy (European Commission, 2014).

2.6.3. EU Directives

To enforce the roadmaps and the framework, the EU developed numerous Directives (The Scottish Parliament, 2016). Among the most important ones are:

- the Industrial Emission Directive (2010/75/EU)
- the Renewable Energy Directive (2009/28/EC)
- the Energy Efficiency Directive (2012/27/EU)
- the EU Emission Trading System

The first one, the Industrial Emission Directive aims at reducing the release of pollutants and discharges of waste by allowing a certain amount of emissions per year (European Commission, n.d.). Therefore, this legislation promotes renewable energies.

The second directive, directly orientated towards MRE, is the Renewable Energy Directive that set the different targets for each country in terms of renewable energies, according to the potential it has (European Commission, 2018). The EU required the UK to generate 15% of energy consumption from renewable sources (European Commission, n.d.). As an order of comparison, the country sourced 1.3% of its energy consumption from renewable energies in 2005 (European Commission, n.d.). Moreover, the directive fosters cooperation between the states through joints projects (European Commission, 2018).

The Energy Efficiency Directive covers the objective set for 2020 (20%) and 2030 (27%) in terms of energy efficiency (European Commission, 2018). It gives some measures to adopt globally for countries to reach the intended objectives and at national level to help consumers save energy (European Commission, 2018).

Finally, the EU Emissions Trading System (ETS), the last main directive created by the EU to reduce GHG emissions. According to the European Commission, it is *"a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively"* (European Commission, 2017). In that system, the EU sets a limited amount of GHG emissions, reduced after each year, and companies that do not comply to the regulation receive a substantial fine (European Commission, 2017).

2.6.4. UK Legislation

In line with the energy component of the Kyoto Protocol of 1997, the Lisbon Treaty of 2009 and more recently the EU's objectives, countries developed their own national action plan, setting a roadmap with key targets and measures (The Scottish Parliament, 2016; Conserve Energy Future, 2017). In that regard, along the years the UK developed numerous legislations supported by schemes and plans (The Scottish Parliament, 2016).

The Climate Change Act of 2008 represented the first stage in the completion of the overarching environmental framework in the UK (The Scottish Parliament, 2016). Through this act, the country gave the general route to reach the objective of 80% reduction of GHG emissions compared to 1990 level by 2050 (Department of Energy and Climate Change, 2016). Moreover, the government also set an intermediate target of 34% reduction of GHG emissions by 2020 (Department of Energy and Climate Change, 2016). The legislation established the Committee on Climate Change, an independent body, to advise the government on the plan to create in order reach the climate change objectives (The Scottish Parliament, 2016; Committee on Climate Change, n.d.). Similarly to the EU ETS' scheme, the Climate Change Act 2008 put in place a system of carbon budgets, aiming at maintaining UK companies below a GHG emission threshold over 5 years (The Scottish Parliament, 2016; Department for Business, Energy & Industrial Strategy, 2016).

In 2011, the Government published its roadmap to reach the 15% target of energy generation from renewable sources (Department of Energy & Climate Change, 2013). This legislation, created in partnership with actors of the renewable industry, states the measures and targets the country will implement throughout the years for each type of renewable energy, including offshore wind, tidal and wave power (Department of Energy & Climate Change, 2013). The government updated the document in 2013, with a summary of the industry's performances and the new objectives, rendered possible by the sector's improvements (Department of Energy & Climate Change, 2013). In parallel to that roadmap, the UK needed to deliver a national action plan, the National Renewable Energy Action Plan for the United Kingdom, as required by the European Commission, presenting the framework for reaching the objectives set by the EU (European Commission, n.d.). The difference between the two documents lies in the strict requirements in content established for the national action plan.

Furthermore, the Energy Act 2013 enabled the UK to make an important progress towards reduction of GHG emissions with the implementation of the Electricity Market Reform (EMR) (The Scottish Parliament, 2016). This reform aimed at addressing the "energy trilemma" between the energy cost, GHG emission and security of supply by increasing renewable energies in the energy-mix, improving security of supply and reducing consumers' cost (The Scottish Parliament, 2016). In order to achieve the aforementioned objectives, the government put in place four main schemes (Zeniewski, 2017):

- the Capacity Market
- Contracts for Difference (CfDs)
- Feed in Tariff Scheme (FiTS)
- Levy Control Framework

The Capacity Market ensures energy security when the system is tight through regular payments to suppliers (The Scottish Parliament, 2016). This scheme, orientated towards reliable suppliers, is a way to attract investments and therefore improve the current infrastructures and develop MRE (The Scottish Parliament, 2016; Department for Business, Energy & Industrial Strategy, 2016).

The Feed in Tariff Scheme promotes the development of renewable energies of small-scale infrastructures (<=5MW) by granting subsidies to companies or individuals generating their own electricity (Department for Business, Energy & Industrial Strategy, 2018).

The Levy Control Framework targets the cost component of the “energy trilemma” by shifting the burden of funding from consumers through taxation, to energy companies (The Scottish Parliament, 2016). In that regard, according to the projected costs for low-carbon developments, the government sets an annual limit for schemes funded via taxation, including CfDs, RO and FiTS to limit imposition on consumers (Department for Business, Energy & Industrial Strategy, 2016). Projected costs for the period 2020/2021 rose to £8.4 billion end of 2016, an increase of £800 million compared to previous forecasts due to the rapid technological development of renewable energies (Department for Business, Energy & Industrial Strategy, 2016).

Among other relevant piece of legislations concerning MRE development directly or indirectly are (Department for Business, Energy & Industrial Strategy, 2016):

- the Energy Act 2008, the Planning Act 2008 and the Marine and Coastal Access Act 2009 setting a framework for MRE
- the Coastal Access Bill 2008 fosters a sustainable usage of the sea by its various users
- the Birds Directive (2009/147/EC) protects birds from users of the seas and set guidelines to follow for developments, for instance concerning offshore wind farms
- the Habitats Directive (92/43/EEC) protects animals and plants by setting a number of requirements to developers
- the Marine Strategy Framework Directive of 2008 that “aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend”
- DECC Offshore Energy Plan structures the 2020 objectives in English and Welsh territorial waters in terms of offshore wind power (25 GW)

2.6.5. Scottish Legislation

Scotland also developed its own legislation, in response to the EU targets and to fix more challenging objectives (Zeniewski, 2017):

- the Climate Change (Scotland) Act 2009, among the first documents to set general targets for reduction of GHG emissions, with an 80% decrease compared to 1990 levels and an interim level of 42% by 2020 (Scottish Government, 2009). (Scottish

Government, 2017). Moreover, this binding Act set a path for transition to low-carbon energies with a current objective of 100% electricity consumption coming from renewable sources (Scottish Government, 2009). In 2017, the country was on track to meet both of its targets (McGreevy, 2017)

- the Renewables Obligation, a scheme working identically to the RO in the UK (Scottish Government, n.d.)
- the Low Carbon Economic Strategy created in 2010 to help move the economy to a low-carbon state and meet the EU and national targets (Scottish Government, 2010)
- the 2020 Routemap for Renewable Energy, updated several times since 2011 (The Scottish Parliament, 2016). This document makes a summary of the progress realized in the renewable energy sector and the measures needed (The Scottish Parliament, 2016)
- Electricity Generation Policy Statement 2013, as required by the Climate Change (Scotland) Act 2009 with key measures to unlock Scotland potential and meet energy targets (Scottish Government, 2013)
- the Scottish Government Community Energy Policy Statement of 2015, to engage communities in the whole process of renewable energies (Scottish Government, 2015)
- Scotland's Energy Strategy, created in 2017 to set the roadmap of the government for its energy sector in the long-term (Scottish Government, n.d.). This document underlines the necessity to foster and attract investments, improve the renewable sector, secure energy availability for the consumers at a competitive price, enhance energy efficiency, and promote community engagement in the whole energy process (Scottish Government, n.d.)

2.6.6. Conclusion

Climate change partially led to the development of MREs to replace carbon generating techniques. In order to foster and improve the production of marine devices, the EU, the UK and members of the Kingdom set some targets for the upcoming decades (Figure 34). Currently, the UK is not on track to meet its renewable objective, despite a strong offshore wind sector and a growing tidal and wave sector (Climate Action Network Europe, 2016). Moreover, the UK and Scotland set more ambitious national targets than the one fixed by the EU and consequently produced several legal documents and schemes to structure the route to reach them. Furthermore, the latest Intergovernmental Panel on Climate Change (IPCC) report in October 2018 gave crucial measures to take in order to keep temperatures rising below 1.5°C pre-industrial levels with the necessity of having 85% of the electricity coming from renewable sources by 2050 (McGrath, 2018). The report also states the need for governments to improve their legislations to cut GHG emission to preserve the planet from environmental catastrophes.

	% reduction in emissions from 1990 levels		% of electricity generated from renewables	% of heat to be generated from renewables
	By 2020	By 2050	By 2020	By 2020
Scotland[2]	42	80	100	11
UK	34	80	30	12
EU[3]	20	80-95	20 (of all energy)	20 (of all energy)

Figure 34. Targets for Scotland, the UK and the EU (The Scottish Parliament, 2016)

2.7. Brexit

2.7.1. What is Brexit?

The 23rd of June 2016, the UK held a referendum to decide on the future of the UK in the EU (Hunt et al., 2018). 51.9% of the voters chose to leave the organization against 48.1% who voted to stay in the EU (Hunt et al., 2018). To engage in the process of leaving the EU, the government needed to trigger Article 50 of Lisbon Treaty (Hunt et al., 2018). This article, invoked the 29th of March 2017 by Prime Minister Theresa May, gave the UK two years to withdraw from the Union (Villanacci, 2016). Therefore, by the 29th of March 2019, the UK will no longer be part of the EU, assuming that state members refuse to extend the deadline

(Hunt et al., 2018). As recently as December 2018, no agreement had been accepted by the Members of Parliament (MPs), increasing the chances of a "no-deal" Brexit.

2.7.2. The Rationales for Brexit

There are three main reasons why the majority of the UK population voted in favour of Brexit. Firstly, being in the EU reduces the country's sovereignty over its policies and legislation (Hepburn et al., 2017; Baldock et al., 2016). The UK citizens desired more freedom for their country in its political actions and targets, and less constraints regarding the EU's ambitions. Secondly, according to pro-Brexit groups, the EU hampered the UK to respond to the consequences of the 2008 global financial crisis with lingering impacts still occurring (Mauldin, 2018). Finally, pro-Brexit voters wanted better control over its frontiers, threatened and undermined by the latest EU migration policies (Lee, 2016).

2.7.3. The Types of Brexit

Prior to withdrawal from the EU, the UK and the EU need to determine what principles and practices will underscore their new relationship (Froggatt et al., 2016). In this regard, five main models have been discussed that will determine the type of Brexit to come:

- the "Norwegian model"
- the Energy Community model
- the "Swiss model"
- the "Canadian model" or free trade agreement model
- the World Trade Organization (WTO) model or "no-deal" model

The "Norwegian Model"

In order to keep a close relationship with the EU, the UK can aim for the "Norwegian model", labelled "soft-Brexit". In that scenario, the country will remain in the European Economic Area (EEA) and thus in the Internal Market, enabling the UK to maintain multiple advantages such as the free movement of people, goods, services and capital, in a favourable environment (Burns et al. 2018). The UK will also integrate into the European Free Trade Association (EFTA) (like Iceland, Switzerland, Norway and Liechtenstein) with the possibility of signing agreements with third parties and implementing national custom tariffs

(State Secretariat for Economic Affairs SECO, n.d.). In that regard, all the European environmental laws and directives, apart from the Bird Directives and Habitat Directives, will regulate the UK, and have binding targets for GHG emission (Burns et al. 2018). Moreover, despite being a member of the EEA, the UK's influence over policies will be limited (Pye et al. 2017). Joining the "Norwegian model" is fundamental for the UK MRE sector and for its investors, as it will decrease the uncertainty for the future (Reid, 2016). Finally, in this scenario, the UK will still contribute to the EU budget and therefore receive funding for various MRE projects (Villanacci, 2016). All in all, this "soft-Brexit" provides the country with economic advantages, however the country would lose its influence on the EU's decisions while being tied to European legislation (Reid, 2016). Figure 35 provides a summary of the main outcomes of the "Norwegian Model".

Norway

- Membership of EFTA and EEA
- Fully integrated in EU single market
- Adopts vast majority of EU energy legislation, but with significantly less influence over its contents and with no formal voting power
- Contributor to EU budget

Figure 35. Main outcomes of the "Norwegian model" (Froggatt et al., 2016)

Energy Community Model

The second option for the UK is to join the Energy Community, with similar advantages as the "Norwegian model". The Energy Community groups the current 28 EU member States and eight surrounding countries in order to attract investment, foster renewable energy development or integrate non-EU members into the Internal Energy Market (IEM) (Energy Community, n.d.). Under that scenario, the UK will benefit from the same level of market access as the EU member States (Froggatt et al., 2016). Yet again, the EU's environmental legislation, grouped under the *acquis communautaire*, will shape the UK's policies and targets (Reid, 2016). Similarly, to the "Norwegian model", the UK will not influence EU policies or standards and will have to comply to the organization's rules (Reid, 2016). Moreover, in that scenario, the certainty provided by the agreements will secure the UK's access to investments, similar to the "Norwegian model" (Froggatt et al., 2016). Staying close to the EU will reassure investors in their decision of supporting the energy sector and therefore the MRE industry. Also, the UK will reduce its contribution to the EU budget, allowing the country to reallocate this money (Froggatt et al., 2016). Consequently, the funding available for the UK will decrease substantially (Froggatt et al., 2016). Figure 36 displays the main outcomes of Energy Community participation.

Energy Community	• Adopts the *acquis communautaire* relating to energy • Access to single energy market • No formal or limited opportunity to shape EU energy and climate legislation • No contribution to EU budget

Figure 36. Main outcomes of Energy Community participation (Froggatt et al., 2016)

The "Swiss Model"

The third possible type of Brexit is the system adopted by Switzerland. In this scenario, the UK will integrate the EFTA (European Free Trade Association) and be excluded from the EEA. One of the main advantages for the country will be the increased freedom and sovereignty over its environmental policies and legislations (Froggatt et al., 2016). While the UK will lose its influence over EU policies and targets, it will shape its own environmental targets according to the importance the post-Brexit government gives to climate change issues. Concerning funding, in the "Swiss model" the EU requires little contribution, determined by bilateral agreements, however in return, the money allocated to state-members significantly decreases (Froggatt et al., 2016). Despite advantages coming from the EU withdrawal, the UK's MRE industry will face numerous challenges. One of the main issues relates to the uncertainty among investors (Pye et al. 2017). Switzerland signed the main core of its agreements after 12 years of discussion with the EU, and the UK will need to undertake similar negotiations after Brexit, raising uncertainty for the future among investors (Villanacci, 2016). Moreover, leaving the EEA will automatically exclude the UK from the IEM (Villanacci, 2016). This model will require the UK to rapidly secure agreements with the EU in order to decrease uncertainty and allow the MRE industry to keep developing. Figure 37 shows a summary of the main outcomes of the "Swiss model".

Switzerland	• Membership of EFTA, but not of EEA • Sector-specific bilateral agreements with the EU • Small contribution to EU budget • Participant in EU energy market; some harmonization of rules and standards required

Figure 37. Main outcomes of the "Swiss model" (Froggatt et al., 2016)

The "Canadian Model"

The fourth possible scenario for the UK compares to the situation of Canada with the EU. Canada's agreement with the EU concerns trade and is labelled CETA (Comprehensive Economic and Trade Agreement). One of the main advantage of this plan is the removal of tariffs on goods, to notably facilitate trade relative to renewable energies (Froggatt et al., 2016). However, the country now faces regulatory constraints relating to movements of goods and services and cannot influence any policies or standards set by the EU (Froggatt et al., 2016). Labelled "hard-Brexit", the "Canadian model" addresses some issues pro-Brexit groups put forward during the campaign. It returns sovereignty to the UK over product standards, environmental policies and/or climate change targets (Froggatt et al., 2016). In this scenario, the UK will leave the single market and sign an agreement similar to the Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada (Burns et al. 2018). The advantage of this agreement lies in the freedom of the UK to undertake trade deals with any country while having access to the EU internal market and control over the movement of people (depending on the agreement) (Burns et al. 2018). Concerning environmental policies, this agreement fosters the development of MRE through the elimination of trade barriers (Froggatt et al., 2016). However, this model brings uncertainty, in the short to medium-term, concerning future relationships with EU countries. Therefore, following Brexit, the UK will need to sign agreements to secure a stable environment. Moreover, the country will lose its influence over EU policies and decisions regarding environmental questions (Froggatt et al., 2016). Finally, under the "Canadian model", the UK will not contribute to EU funding, allowing the country to reallocate the money according to the government's priorities (Froggatt et al., 2016). Yet again, this situation could either boost or hamper the development of MRE, depending on the government's vision of climate change targets and investments in renewable energy. Figure 38 illustrates the main outcomes the UK will face in case of the "Canadian model".

Free trade agreement/ Canada	• Comprehensive free trade agreement with the EU allowing access to internal market for goods, and to a lesser extent services • Conditional market access • No access to EU energy-related finance programmes • No contribution to EU budget

Figure 38. Main outcomes of the "Canadian model" (Froggatt et al., 2016)

The WTO or "No-Deal" Model

Finally, the last model will arise in case the EU and the UK do not find any common ground: the WTO or "no-deal" model. This type of Brexit is similar to the "Canadian model" and mainly differs on trade mechanisms (Reid, 2016). Indeed, the UK will operate under the WTO rules for trade with the freedom to sign agreements with third parties (Burns et al. 2018; Froggatt et al., 2016). Under this scenario, the UK leaves the EU without pre-arranged agreements, creating uncertainty for the future concerning the single market's participation and investments (Burns et al. 2018; Froggatt et al., 2016). Similarly to the "Canadian model", without any deal, the UK will not contribute to the EU funding mechanism letting the country reallocate the money (Froggatt et al., 2016). Moreover, concerning environmental issues, the UK will address climate change independently from the EU and set its national target for renewable energies (Froggatt et al., 2016). The WTO model provides the UK with more freedom and gives back the country its sovereignty, a key feature in the pro Brexit campaign. However, being excluded from the European market and from its different funding arrangements could hamper MRE developments. At the end of October 2018, the UK and the EU failed to find an agreement, increasing the likelihood of a "no-deal" scenario (Sandhu, 2018). Figure 39 displays the different outcomes linked to a "no-deal"/WTO model.

No deal/WTO	• No agreement; trade regulated under WTO rules • Conditional market access • No access to EU energy-related finance programmes • No contribution to EU budget

Figure 39. Main outcomes of the "no-deal"/WTO model (Froggatt et al., 2016)

2.7.4. Conclusion

The UK will leave the EU the 29th of March 2019, and prior to this date, both parties need to settle the basis of their upcoming relationship. In that regard, five main types of Brexit models have been explored. Figure 40 shows a summary of the main consequences of each scenario for the UK. All the aforementioned scenarios present advantages and disadvantages for the UK and will impact three main areas of MRE development:

- legislation and regulations in the UK
- funding and investment
- the UK supply chain

The impacts' intensity on each area will depend on the type of Brexit chosen by the UK and the EU, further discussed in the following three sections.

Model	Key Elements
Norway	• Membership of EFTA and EEA • Fully integrated in EU single market • Adopts vast majority of EU energy legislation, but with significantly less influence over its contents and with no formal voting power • Contributor to EU budget
Energy Community	• Adopts the acquis communautaire relating to energy • Access to single energy market • No formal or limited opportunity to shape EU energy and climate legislation • No contribution to EU budget
Switzerland	• Membership of EFTA, but not of EEA • Sector-specific bilateral agreements with the EU • Small contribution to EU budget • Participant in EU energy market; some harmonization of rules and standards required
Free trade agreement/Canada	• Comprehensive free trade agreement with the EU allowing access to internal market for goods, and to a lesser extent services • Conditional market access • No access to EU energy-related finance programmes • No contribution to EU budget
No deal/WTO	• No agreement; trade regulated under WTO rules • Conditional market access • No access to EU energy-related finance programmes • No contribution to EU budget

Figure 40. Main outcomes for the UK for each Brexit scenario (Reid, 2016)

3. Methodology

3.1. Introduction

Given the context of Brexit, there is uncertainty how the MRE sector in the UK will be impacted and respond to changes. To understand and address the research question "how will the MRE industry be impacted by Brexit in the UK?", an in-depth analysis of the MRE sector in the UK was required. Content analysis was the method employed to explore this impact. This chapter reviews the methods employed to develop insight into impacts to MRE from Brexit.

3.2. The Content Analysis

The impact of Brexit on the MRE sector was analysed through content analysis. Content analysis is a tool used by researchers in order to understand and explain certain phenomena occurring in our societies (Renz et al., 2018). Hsieh et al. (2005) distinguished three different types of content analysis:

- Conventional Content Analysis
- Directed Content Analysis
- Summative Content Analysis

In this thesis, only conventional and summative content analysis were selected, followed by a quantitative approach. After extensive investigation relating to Brexit and the MRE sector in the UK, 62 documents were selected, having relevant information.

3.2.1. Conventional Content Analysis

Conventional content analysis aims at describing a specific event without preconceived ideas of themes and categories (Renz et al., 2018). In this regard, the researcher can undertake qualitative research through interviews or total immersion in the documents analysed (Hsieh et al., 2005). If the researcher chooses to review documents to support the research, there are multiple steps required to support a rigorous approach. This type of method has been used many times for end-of-life research (Hsieh et al., 2005). For instance, conventional content analysis will analyse how patient reacts emotionally to their life in the hospice (Hsieh et al., 2005). Patients who experience life in a hospice for the first time react differently concerning social obligations (finding someone to take care of the cat) compared to patients who are familiar with living in a hospice (Hsieh et al., 2005). The researcher will therefore create different categories according to the various emotional reactions (Hsieh et al., 2005).

For this research, the following steps were taken in developing a content analysis:

- online research was done to identify relevant key MRE and Brexit related documents by using key words such as "Marine Renewable Energies", "UK", "Brexit"
- the numerous documents (>100) were read multiple times to develop full understanding of the issues/concepts
- key MRE documents providing relevant information were selected
- key words and ideas were identified that emerged from the documents
- key words/concepts raised in the documents were grouped into similar categories
- concepts that were similar or connected were grouped into broad thematic categories
- thematic categories were refined into sub-themes

One of the main advantages of conventional content analysis is the absence of preconceived ideas on a phenomenon, avoiding a certain bias (Hsieh et al., 2005). However, a critique of this approach suggests that key categories can be omitted due to inaccurate understanding of the phenomenon (Hsieh et al., 2005).

3.2.2. Summative Content Analysis

Summative content analysis is described by Hsieh et al. (2005) as the process of *"identifying and quantifying certain words or content in text with the purpose of understanding the contextual use of the words or content".* As opposed to the quantitative approach aiming at counting the number of occurrences of certain words, this type of analysis goes deeper and identifies an alternative word or idea to another word or idea (Hsieh et al., 2005; Rapport 2010). This method is labelled as latent content analysis (Sharif, n.d.). Also, one of the main advantages of summative content analysis is to enable the researcher to study a phenomenon where the consequences and the outcomes are not yet determined (Rapport, 2010). In the example of end-of life-research, researchers would find alternative words to "death", and check with the participants of the study the meaning they give to certain words or ideas related to “death” (Hsieh et al., 2005).

In this thesis, summative content analysis was used following conventional content analysis. Indeed, after undertaking the exploratory research and identifying main themes and ideas, the objective was to review the same documents to find alternative key words. For instance, once “sterling” was grouped in the “Trade” subsection, alternative words were sought, such as “pound”. This method allowed to reduce potential omissions of key terms and ideas in the 62 documents analysed.

Through both content and summative analysis of 62 documents, three dominant themes emerged with 14 sub-themes supported by 45 key words. (Figure 41).

Sections	Subsections	Key Words and Ideas
Legislation and Regulations in the UK	Great Repeal Bill	Great Repeal Bill
	Environmental Policies	Environmental policies, environmental regulations, environmental legislation
	Environmental Targets	Environmental targets, renewables targets
	Modification of Standards	Standards, requirements, norms
	Government's Disinterest Towards MRE	Disinterest, folding of departments, Brexit's main concerns, decarbonization with nuclear
	Renewable Energy Guarantees of Origin	Renewable Energy Guarantees of Origin
Funding and Investment	Support Schemes from the EU	EU funding schemes, European Investment Bank (EIB), European Fund for Strategic Investments (EFSI), European Structural and Investment Funds (ESIF), Horizon 2020, NRE 300, EU funded projects
	Research Development and Innovation	Research, development, innovation, funding
	Uncertainty for Investors	Uncertainty
	State Aid Rules	State Aid Rules
UK Supply chain	Trade	Volatility of currencies and products, sterling/pound, taxes, standards, trade barriers, goods and services, imports, exchange rate, tariffs, uncertainty
	Labour Mobility	Workers mobility, migration, immigration, workers movement, free movement
	Carbon Release Mitigation	EU Energy Trading System (ETS), carbon price floor
	Interconnectors	Interconnectors

Figure 41. Sections, subsections and their relevant key words and ideas

Following the conventional and summative content analysis, the number of documents with key words were counted and added for each subsection (Figure 42). This allowed to understand the importance of the impact according to specialists.

Sections	Subsections	Number of occurrences throughout the 62 Brexit related documents
Legislation and Regulations in the UK	Great Repeal Bill	5
	Environmental Policies	18
	Environmental Targets	33
	Modification of Standards	15
	Government's Disinterest Towards MRE	6
	Renewable Energy Guarantees of Origin	7
Funding and Investment	Support Schemes from the EU	28
	Research Development and Innovation	13
	Uncertainty for Investors	30
	State Aid Rules	18
UK Supply chain	Trade	51
	Labour Mobility	19
	Carbon Release Mitigation	26
	Interconnectors	24

Figure 42. Number of documents with related key words and ideas

The number of each type of documents were calculated per sections in order to assess the relevance of the consequences and the validity of the information (Figure 43). This quantitative approach allowed to gain an understanding on the amount of information delivered by each source and to identify the gaps in knowledge to put the focus on for future research.

Types of Document	Number of Types of Document	Number of Occurrences of a Document in Each Section		
		Legislation and Regulation in the UK	Funding and Investment	UK Supply Chain
Article	4	7	9	14
Blog	1	1	4	3
Briefing Paper	4	5	5	9
Government Guidance	1	1		
Governmental Note	1			1
Interview Transcript	1	2	4	4
Online Article - Consultanting Group	4	6	9	10
Online Article - Law Firm	1	3		
Online Article - Magazine	3	3	1	4
Online Article - Media	5	2	3	5
Online Article - Newspaper	7	6	1	7
Online Article - No Category	10	12	11	16
Online Article - World Trade Organization	1			1
Online Article - European Commission	2		1	2
Report	9	17	23	32
Research Paper	5	15	14	22
Review	1	2	3	2
University Blog	1	1	1	2
Workshop Summary	1	1		3

Figure 43. Number of occurrences of a type of document per section

3.3. Trustworthiness

According to Guba (1981), in order for a qualitative study to reach a good level of trustworthiness, it should incorporate four elements:

- credibility
- transferability
- confirmability
- dependability

Credibility will determine how realistic the results are compared to reality and will depend on the variety of the data (Shenton, 2004). In order to increase the degree of credibility within a study, the researcher can use triangulation (Stumpfegger, 2017). Triangulation refers to the use of multiple sources of information (data triangulation), of various types of methods (methodological triangulation), of numerous researchers (investigator triangulation) or of many theories (theoretical triangulation) (Stumpfegger, 2017; Shenton, 2004). For this thesis, the first two types of triangulation were used to improve the credibility of the study. Indeed, among the 62 documents, 19 different types were identified as relevant data source (data triangulation). Figure 44 shows that online articles from law firms, consultancy groups or newspapers, cover information relating to the three sections, in the same way as governmental guidance, scholars' articles or research papers. Moreover, after analysis of the information, the authors predict similar consequences for the MRE sector in the UK throughout the various documents. This consistency in the information shows the credibility of the expected consequences for the UK MRE industry. Also, both qualitative and quantitative approaches were selected in order to support the results (methodological approach).

Furthermore, trustworthiness will depend on transferability which is the possibility to apply the results of the study to another situation (Stumpfegger, 2017). According to Bassey (1981), "*if practitioners believe their situations to be similar to that described in the study, they may relate the findings to their own positions*". Therefore, according to this theory, a country sharing similar characteristics with the UK regarding its MRE sector, and facing a EU withdrawal, would risk comparable outcomes as the ones discussed in this paper.

Confirmability relates to the researcher's objectivity during the study (Shenton, 2004). It must be assured that the findings result from thorough and unbiased research rather than from the researcher's beliefs. In order to reduce or eliminate bias, triangulation is a powerful tool (Shenton, 2004). During the thesis, the data analysis on the consequences of Brexit on the MRE industry in the UK drove the study, and the researcher's opinion on the referendum was set aside.

The last component for a trustworthy study is dependability (Stumpfegger, 2017). According to this term, "*if the work were repeated, in the same context, with the same methods and with the same participants, similar results would be obtained*" (Shenton, 2004). Therefore, the research design needs to be detailed and explained for researchers to undertake the same approach. In this thesis, the whole process surrounding the collection of data to the analysis was described and would enable academics to repeat this study.

3.4. Limitation to Methodology

This thesis explores impacts of Brexit on the UK MRE sector broadly. It does not focus on specific sectors but is inclusive of all the broad sectors of MRE in the UK. While depth is provided in the sense that most facets of the MRE industry were explored, the research does not explore each sector in significant depth as this was not the ultimate purpose of the research. Future studies may explore specific sectors in depth.

As Brexit is a recent phenomenon, information relating to the consequences for the MRE industry remains incomplete and uncertain. Indeed, as the type of Brexit has not yet been agreed upon by the UK and the EU, the uncertainty of the future makes it difficult to accurately assess the impact on the MRE industry. For this reason, in the following months, more research will be required in order to identify more thoroughly the impact.

4. Analysis and Discussion

The purpose of this study was to assess the MRE industry in the UK and the consequences of Brexit on the sector. The objectives include:

- To develop a state of knowledge review on the involvement of the UK in the development of MRE
- To assess the impact of Brexit for the UK concerning MRE

The negative impacts of Brexit on the MRE industry will be explored in this chapter based on the content analysis.

The chapter is divided into two parts. In part one, key themes and sub-themes from the content analysis are highlighted through a series of tables. The analysis of key articles and their content provides the foundation for part two of this chapter where key themes emerging from the content analysis are explored. These are:

- legislation and regulations in the UK
- funding and investment
- the UK supply chain

4.1. The Analysis of Brexit's Impact

During the content analysis, the number of documents with key words and ideas in each subsection was quantified and their meaning for the thesis was analysed.

4.1.1. Key Words and Ideas

The content analysis revealed that Brexit will impact many interconnected areas relating to the MRE industry. Indeed, 3 sections were identified including 14 subsections overall (Figure 44). Within those subsections, 45 different key words or ideas were extracted from the documents during the exploratory research, and their heterogeneity illustrate that Brexit's impact will not remain confined to a specific area (Figure 44). The consequences of Brexit will encompass all the UK participants involved in the national MRE sector, such as developers, workers or investors. For instance, key words and ideas such as "volatility of currencies", "workers' mobility" or "tariffs" illustrate the global nature of the impact, for the industry but also for the EU (Figure 44). The interconnectedness of the three sections raises the issue of a snowball effect. For instance, a decrease of targets for electricity coming from renewable sources would diminish the importance of the MRE sector in the UK and reduce funding availabilities for developers. Consequently, the UK supply chain would suffer from this decision and with it, the UK's expertise and leadership in the industry. All in all, this example demonstrates that most of the areas hit by Brexit are linked together, and that an impact on one sector can have severe repercussions on another one.

Sections	Subsections	Key Words and Ideas
Legislation and Regulations in the UK	Great Repeal Bill	Great Repeal Bill
	Environmental Policies	Environmental policies, environmental regulations, environmental legislation
	Environmental Targets	Environmental targets, renewables targets
	Modification of Standards	Standards, requirements, norms
	Government's Disinterest Towards MRE	Disinterest, folding of departments, Brexit's main concerns, decarbonization with nuclear
	Renewable Energy Guarantees of Origin	Renewable Energy Guarantees of Origin
Funding and Investment	Support Schemes from the EU	EU funding schemes, European Investment Bank (EIB), European Fund for Strategic Investments (EFSI), European Structural and Investment Funds (ESIF), Horizon 2020, NRE 300, EU funded projects
	Research Development and Innovation	Research, development, innovation, funding
	Uncertainty for Investors	Uncertainty
	State Aid Rules	State Aid Rules
UK Supply chain	Trade	Volatility of currencies and products, sterling/pound, taxes, standards, trade barriers, goods and services, imports, exchange rate, tariffs, uncertainty
	Labour Mobility	Workers mobility, migration, immigration, workers movement, free movement
	Carbon Release Mitigation	EU Energy Trading System (ETS), carbon price floor
	Interconnectors	Interconnectors

Figure 44. The global range of Brexit's impact illustrated by the variety of key words and ideas and negative wording connotation

Finally, the "UK Supply Chain" section also displays key words and ideas with negative connotations such as "taxes", "barriers", "tariffs", and similarly to the other two sections, the main themes discussed by authors of articles, reports or other types of document, relate to undesirable effects on the MRE sector. For example, the free movement of people could be hampered and trade could suffer from Brexit with a devaluation of the sterling. All in all, the key words and ideas identified during the exploratory research exhibit the undesirability of Brexit for most of the specialists of the energy and MRE sector, and the need to negotiate a "Norwegian model" in order to reduce the possible negative consequences. In that regard, leaving the EU will require the UK to realize trade-offs without the possibility to keep the same advantages.

4.1.2. Number of Occurrences Throughout the 62 Brexit Related Documents

Furthermore, content analysis also allowed to assess the concerns relating to the impact on the UK MRE industry. Out of the 14 subsections and 62 documents, only three subsections had key words and ideas occurring less than 10 times, and the others ranged between 13 and 51 times (Figure 45). Concerning the "Legislation and Regulations in the UK" section, the distribution was more heterogeneous than for the other two sections. Indeed, the environmental targets were mentioned throughout 33 documents whereas the Great Repeal Bill was discussed in only 5 documents (Figure 45). On the contrary, "Funding and Investment" and "the UK Supply Chain" sections displayed less heterogeneity in the occurrences. Between 13 and 30 incidences were identified for the former section and 19 to 51 for the latter one (Figure 45). According to the number of documents with key words and ideas, the "UK Supply Chain" raises the most concerns. Indeed, throughout the 62 documents, they were mentioned 120 times compared to the two other sections where it appeared 84 and 89 times (Figure 45). As for the subsections, the apprehension orientates towards two areas:

1. the future of trade between the EU and the UK with 51 occurrences
2. the decision regarding environmental targets with 33 occurrences

The substantial number of incidences of most of the key words and ideas advocates for a significant concern over the future of legislation, funding and of the supply chain in the UK.

Sections	Subsections	Number of occurrences throughout the 62 Brexit related documents
Legislation and Regulations in the UK	Great Repeal Bill	5
	Environmental Policies	18
	Environmental Targets	33
	Modification of Standards	15
	Government's Disinterest Towards MRE	6
	Renewable Energy Guarantees of Origin	7
Funding and Investment	Support Schemes from the EU	28
	Research Development and Innovation	13
	Uncertainty for Investors	30
	State Aid Rules	18
UK Supply chain	Trade	51
	Labour Mobility	19
	Carbon Release Mitigation	26
	Interconnectors	24

Figure 45. The concerns over Brexit's Impact for each section, illustrated by the number of occurrences of documents per subsection with relevant key words

4.2. Legislation and Regulations in the UK

4.2.1. Great Repeal Bill

Shortly after Brexit vote, Theresa May announced the UK will repeal the 1972 European Communities Act (ECA), labelled the Great Repeal Bill (Sheftel, 2016). This Act gives priority to EU law over national laws, and jurisdiction to the European Court of Justice on national territories (BBC News, 2017). The Great Repeal Bill aims to simplify a smooth transfer of EU legislation into UK legislation (Sheftel, 2016). In that regard, all Directives and Regulations passed before the 29th of March 2019 will be transferred into domestic law (Sheftel, 2016). Following Brexit, the Parliament will then decide on the laws to keep and delete from the statute book according to their relevance (Pye et al., 2017). Indeed, depending on the type of Brexit some piece of legislation will be annulled (BBC News, 2017). For instance, in case of a "no-deal" model, a regulation requiring the European Commission to verify EIA's are done correctly will not apply anymore as the UK will not be bound to the European Commission.

4.2.2. Environmental Policies

If the UK leaves the EEA, it will lose its influence on policy making, while maintaining sovereignty over national policies (Russell, 2016). Throughout the years the UK helped shape the EU's policies, influencing the organization's decisions (PWC, 2017). On the one hand, leaving the EU will undermine this influential power and on the other hand, withdrawing from the organization will enable the country to have sovereignty on its environmental and energy policies (Froggatt, 2016). Therefore, as shown in Figure 46, the type of Brexit sets a trade-off for the UK between more control over national policies and less influence over EU's environmental decisions. The "Canadian model" and the "no-deal" scenario display complete freedom for the UK to control its own policies without any influence on EU's decisions. The "Norwegian model" and the Energy Community model, on the contrary, gives more power to the UK over EU's policy making while abiding to the organization's environmental legislation.

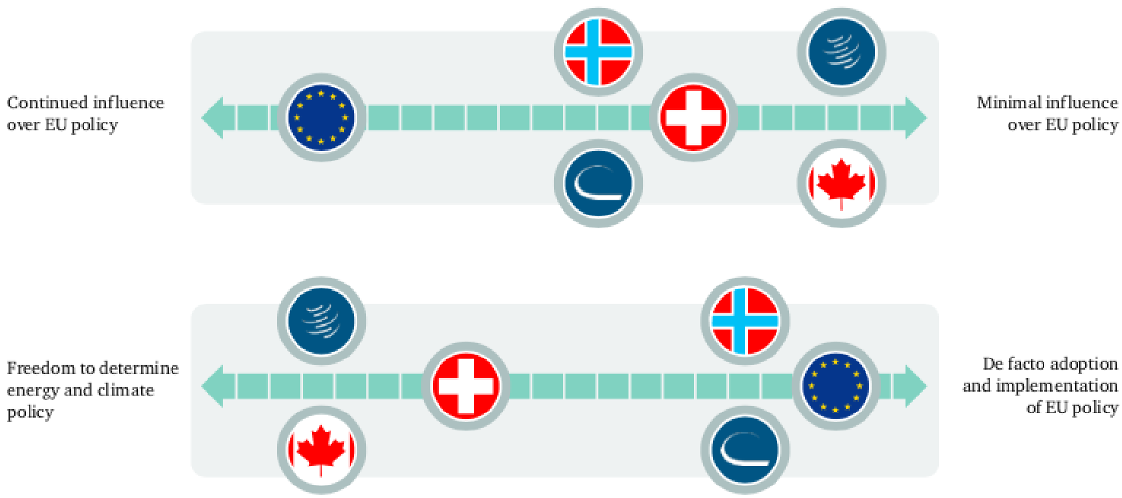


Figure 46. Spectrums of influence over EU policies and freedom to set own national policies (Froggatt et al., 2016)

4.2.3. Environmental Targets

The trade-off between more influence on EU policy shaping and less independence regarding national policies can impact UK's environmental targets. Depending on the Brexit scenario, the UK will face two possible outcomes regarding European renewable energy targets (Norton Rose Fulbright, 2018). In the first scenario, the UK stays in the EEA and adopts the "Norwegian model" or implement the Energy Community model, keeping a close relationship with the EU (Norton Rose Fulbright, 2018). In the second model, the UK would maintain all the binding renewable targets set by the EU of 15% of energy coming from renewable sources by 2020 and maintain the status quo (Kristensen, 2016).

In the second scenario, the UK withdraws from the EEA and will most likely adopt either the "Swiss model", the "Canadian model" or the WTO model (Norton Rose Fulbright, 2018). These scenarios bring uncertainty to the future of the MRE sector as it is unsure whether the UK will maintain the same national renewable targets (Antonas, 2016). Being in the EU obliges countries to abide by the rules due to potential heavy fines, if they do not meet the targets (Hilson, 2018). Therefore, MRE industry stakeholders fear that leaving the EU impacts the decarbonisation process in the government and therefore jeopardise the future of the industry and its long-term viability (Mongoose Energy, 2016)

However, the likelihood the UK government will change its renewable energy targets in the short-term remains slim due to the long-term strategy set until 2050 (Grubb et al., 2016; LawCareers.Net, 2016). The UK's national targets, more ambitious than the EU's, are embedded in the Climate Change Act of 2008 (LawCareers.Net, 2017). Moreover, in its Clean Growth Strategy delivered in October 2017, the government stated that departure from the EU "*will not affect our statutory commitments under our own domestic Climate Change Act and indeed our domestic binding emissions reduction targets are more ambitious than those set by EU legislation*" (Department for Business, Energy & Industrial Strategy, 2017). Furthermore, by 2050, through the Climate Change Act, the UK is required to decrease by 80% its GHG emissions compared to 1990 levels, and therefore, leaving the EU will have no impact on the aforementioned targets (Froggatt et al., 2016). Also, in July 2016, the UK announced its 5th Carbon Budget establishing objectives to reach the 2050's targets (57% decrease in GHG emissions compared to 1990 levels) (LawCareers.Net, 2016). Moreover, MRE developments are also closely linked to economic development and even with a decrease in renewable targets, the UK would still support the MRE industry (Department of Energy & Climate Change, 2016). In the medium-term, though, depending on the type of government, some modifications regarding renewable targets might occur and hamper MRE developments (Grubb et al., 2016). Substantial amounts of EU policies regulate the UK, and leaving Brexit could eliminate the most inefficient ones obstructing MRE developments to implement new directives (Hepburn et al., 2017).

4.2.4. Modification of Standards

Planning consents delivered to projects, and more specifically EIAs undertaken by developers is a key consequence of Brexit (Marsh et al., 2016). The intensity of the impact depends upon the UK's ongoing and future relationship with the EU and will vary from the short-term to the long-term (Fallows et al., n.d.). Following Brexit, the Great Repeal Bill will transfer European law onto the UK statute book and all the relevant environmental regulations required by the EU will still apply, such as the Environmental Impact Assessment Directive for MREs (Marsh et al., 2016). After March 2019, the situation will evolve and depend on the type of Brexit the UK and the EU have agreed upon and therefore the type of relationship it wants to keep (Fallows et al., n.d.). Under the "Norwegian model" or the Energy Community model, all existing pieces of UK environmental legislation will apply to the UK a part from the Habitats Directive 1992 and Birds Directive 2009 (Fallows et al., n.d; Marsh et al., 2016). These directives protect birds and natural habitats by requiring developers to undertake specific EIA to assess the impact of MRE development on the site (Marsh et al., 2016). If the UK chooses the "Swiss model", the "Canadian model" or the WTO model, the UK will benefit from more freedom to shape its environmental regime and therefore diminish pressure put on MRE developers via EIAs (Marsh et al., 2016; Fallows et al., n.d).

Therefore, after the 29th of March 2019, the UK could modify EIA requirements and therefore set higher or lower standards for MRE developers (Pace, 2017). Under the first scenario (i.e., higher standards), companies will more likely switch their focus to other countries where environmental regulations are less restrictive (Pace, 2017). In the second scenario (i.e., lower standards), these international companies will maintain the same level of involvement in UK waters (Pace, 2017). If the UK decides to change its standards, the government will have to determine if these modifications impact ongoing and future MRE developments (Pace, 2017). However, according to the current government's position, EIA's standards will remain the same, independent from the type of Brexit strategy (Pace, 2017). MRE development will benefit from stability in EIA standards.

4.2.5. Government's Disinterest Towards MRE

Since the referendum, the UK government displayed the little concern it gave to renewable energies and thus MREs (Gardiner, 2017). Firstly, in 2016, it eliminated the Department of Energy and Climate Change (DECC) subsuming it within the Department of Industry, Business and Skills to create the newly Department for Business, Energy and Industrial Strategy (Antonas, 2016). Theresa May made this decision within 24 hours as Prime Minister, raising concern among politicians and environmentalists (Gardiner, 2017). Addressing climate change issues requires a dedicated Department in order to have an impact, and folding this concern into a global Department could undermine representatives' voice (Gardiner, 2017). Secondly, according to Shakespeare Martineau's report (2017), the UK aims to decarbonize the country with a focus on nuclear power rather than renewable energies. Lack of investment in tidal and wave energy pushed the government to support more reliable source of energy such as nuclear (Shakespeare Martineau, 2017). Finally, the numerous concerns raised by Brexit such as the Irish border or the rights of expatriates, might push MRE's issue at the bottom of the to-do list (Pollitt, 2017; Fraser, 2017). However, according to green energy supporters, grouping the DECC into an influential Department will help the government address climate change issues with an improved policy coordination (Gardiner, 2017). Furthermore, Theresa May declared in early 2018 the importance to develop offshore wind to solve GHG emission's issues, and the intention of supporting this industry (Foxwell, 2018).

4.2.6. Renewable Energy Guarantees of Origin

Finally, the last main impact concerning legislation and regulations relates to low-carbon certificates. Currently, in the EU, in order to track the source of electricity and prove its "green" origin, companies comply to the Renewable Energy Guarantees of Origin system (Norton Rose Fulbright, 2018). This certificate delivers transparent information on the source of energy origin such as the date of production, the country producing the electricity or the source's type (offshore wind, tide…) (Association of Issuing Bodies, n.d.). A "no-deal" situation would annul the guarantees' legitimacy in the EU, and therefore compromise contracts between the UK and the state members' generators and traders (Department for Business, Energy & Industrial Strategy, 2018). The WTO model would therefore curtail MRE's development by reducing the amount of electricity exported abroad. Moreover, this situation brings uncertainty to investors and could prevent international companies from developing MRE projects in the UK.

4.2.7. Conclusion

After the 29th of March 2019, the UK will repeal the ECA and incorporate relevant EU environmental regulations into UK policies. Following this event, the government will decide on the regulations and policies to keep and to erase from its law. The decision on what EU policies the UK will adopt depends upon the type of Brexit the UK and the EU choose, and the objectives of the country in terms of renewable energies. The UK government confirmed the importance of this sector for the country; however, certain decisions raised concern for the future of the MRE industry. Yet again, the impact on the industry will vary according to the Brexit model. The UK government faces an intricate situation, having to choose between freedom and influence on EU's resolutions.

4.3. Funding and Investment

4.3.1. Support Mechanisms from the EU

Brexit will impact funding mechanisms available from the EU for the UK, depending on the scenario. Consequently, research, development and innovation will also suffer from this event, endangering the future of the MRE industry in the UK. Among the main support mechanisms available to the UK, Brexit will particularly jeopardize five:

- the European Investment Bank (EIB)
- the European Fund for Strategic Investments (EFSI)
- the European Structural and Investment Funds (ESIF)
- Horizon 2020
- NRE 300

The UK's renewable energy sector including the MRE industry, largely benefited from EIB funding for project development, including deployment, construction, research and innovation (Gardiner, 2017). For instance, MeyGen 1B and the Sound of Islay in Scotland, received more than €37 million from the organization and the 588 MW Beatrice offshore wind farm was granted a £525 million loan for its development (Zeniewski, 2017). Moreover, other developments such as the London Array (870 MW) and Thanet (640 MW) also benefited from EIB support (Grant, 2016; Norton Rose Fulbright, 2018). Overall, since 2007, the UK received £5.6 billion worth of loans for renewable energy projects, accounting for 24% of the EU's financial support (Mongoose Energy, 2016; Burns et al., 2018). Also, during the same period, Scotland benefited from £4 billion of the aforementioned funding (Grant, 2016). Since the referendum, multiple sectors, including the renewable industry, felt the EIB's reluctance to provide funding to the UK, with a decrease of €5.72 billion in support between 2016 and 2017 (Cuff, 2018).

Brexit's effect on MRE undertakings will vary according to the model of departure the UK and the EU choose (Reid, 2016). Currently, countries outside the EU receive only 12% of EIB's total funding (Mongoose Energy, 2016). The UK relies on this bank to fund projects as the EIB granted almost one quarter of its budget to the country between 2007 and 2016 (Antonas, 2016). Therefore, leaving the EU will substantially reduce this financial support (Antonas, 2016). Another issue relates to MRE ongoing developments receiving financial loans from the organization (Norton Rose Fulbright, 2018). Indeed, depending on the terms of the contract between the EU and the companies, these projects could lose the support. (Allen & Overy, 2016). Furthermore, depending on the choice of the UK to remain in the single market, the cost of production will increase accordingly (Grant, 2016). This market allows goods and services to move freely within the EU, and without any agreements, taxes and tariffs on European imports could rise for the UK following Brexit (Zeniewski, 2017). All in all, with a loss of support from the EIB, the MRE sector in the UK will face an intricate situation with less European funding available (Norton Rose Fulbright, 2018).

Apart from the EIB, the EU provides state members with financial support through other schemes, mentioned previously. The direct impact of Brexit on the availability of these funds remains unclear (Froggatt et al., 2016). However, yet again, remaining in the EEA will allow the UK to benefit from more options than choosing the "Canadian model", the "Swiss model" or the "no-deal" model (Froggatt et al., 2016). The UK strongly relies on EU funding mechanisms and will significantly suffer from a "hard-Brexit" (Hepburn et al., 2017).

4.3.2. Research, Development and Innovation

In order to create a competitive advantage and maintain leadership in a sector, countries must rely on strong research and development (R&D) activities. During the COP21, countries raised the concern of funding in research, and the need of more support for low-carbon projects (Hepburn et al., 2017). Indeed, according to certain models *"substantial increases in innovation funding are needed today and, because innovation is cumulative, delaying support today will be extremely costly in the future"* (Hepburn et al., 2017). For this reason, the Mission Innovation programme was created, including the UK, in order to double the funding available to research and development for the period 2016-2021 (Hepburn et al., 2017).

After Brexit, the UK will lose some of its access to funding for research and development, hampering innovation (Burns et al., 2018). The UK depends on EU funding to improve its MRE technologies and maintain its global leadership. The country greatly benefited from Horizon 2020, a R&D funding mechanism operating between 2014 and 2020 (Koeppel, 2016). Moreover, during the period 2014 to mid-2017, the UK became "lead coordinators" and received a €380 million funding for energy, including MREs (Zeniewski, 2017). Norway's participation in Horizon 2020, albeit not being a EU member state, brings hope for the industry to preserve this funding source (Zeniewski, 2017). However, the UK stands among the two largest recipients from the plan and in comparison, Norway is 9^{th} (Zeniewski, 2017). Therefore, even if the UK stays in the EEA and adopts the "Norwegian model", its support will significantly decline (Zeniewski, 2017). Tidal and wave energy especially depend on EU funding to improve efficiency as they are currently too risky for many investors; therefore, Brexit could bring the industry to a delicate situation (Koeppel, 2016).

Not only will loss of funding affect MRE project developments, it will also negatively impact connectivity between countries for research cooperation (Hogg et al., n.d.). The UK coordinates projects, and benefits from exchange of knowledge and information from state members, allowing it to maintain its leadership in the MRE industry (Koeppel, 2016). This status enables the UK to influence the EU's agenda in terms of R&D, and therefore

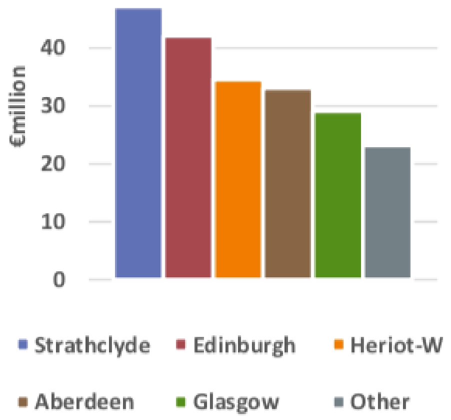


Figure 47. Partnership's valued by Scottish University since 2013 for R&D related to energy and climate (Zeniewski, 2017)

orientating the organization's decisions for its benefit (Koeppel, 2016). Moreover, cooperation between preeminent European research organizations enables the EU and its state members to gain competitive advantages over other countries in the MRE sector (Zeniewski, 2017). For instance, Scottish universities partners in Horizon 2020 valued the importance of the network-building opportunity for R&D related to energy and climate, since 2014 (Figure 47) (Zeniewski, 2017).

4.3.3. Uncertainty for Investors

The uncertainty concerning the Brexit model raises uncertainty for post-Brexit legislation and the involvement of the EIB and EU funding schemes, affecting private investors' decision in funding MRE projects (Lowe, 2017; Reid, 2016). Consequently, this vagueness pushes investors to request higher returns on investments or higher interest rates for their loans (Allen & Overy, 2016). This will ultimately impact the customers, charged with higher prices for electricity (Allen & Overy, 2016). However, the UK can avoid this situation if it stays within the EU energy market by maintaining steady prices (Allen & Overy, 2016). Uncertainty is a main factor of delays in project developments and the MRE industry, reliant on funding, will suffer from investor's indecision (Hepburn et al., 2017; PWC, 2017). The "Norwegian model" or the Energy Community model will decrease uncertainty in the short-term and in the medium term, with continuity in energy investments and will encourage agreements between the UK and the EU (Figure 48) (Froggatt et al., 2016).

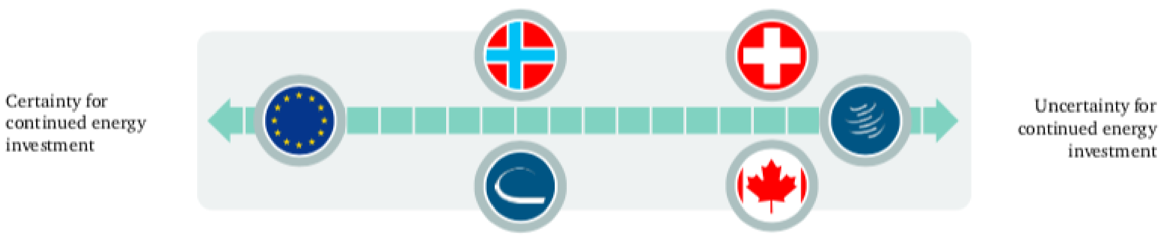


Figure 48. Outcome of Brexit models on energy investments in the UK (Froggatt et al., 2016)

Prior to the referendum, foreign companies investing and operating in MRE developments in the UK threatened legal action if MRE activities were impacted by Brexit (Zeniewski, 2017). However, since the result, many companies like Siemens, a German company manufacturing blades in Hull, or the Swedish wave company, CorPower Ocean, have announced their continued support of the MRE industry in the UK (Zeniewski, 2017; Gardiner, 2017). Moreover, DONG Energy, the global leader in offshore wind development, declared it will maintain its £6 billion investment in the UK (LawCareers.Net, 2017). The UK benefits from important geographic opportunities for offshore wind, tidal and wave development, and even with uncertainty, investors remain better off maintaining their support given the MRE resources available in the UK (Zeniewski, 2017).

4.3.4. State Aid Rules

The EU state aid rules prohibits EU members' government from providing financial support to companies, in order to prevent market distortions and to disadvantage competitors (European Commission, n.d.). In that regard, the UK government is restricted from providing direct funding to a MRE company. However, this form of funding is allowed by the European Commission if it supports the economic development of the country (European Commission, n.d.). For instance, the Renewables Obligation and the Contracts for Difference resulted from this European law (Marsh et al., 2016). Therefore and because of this rule, the EU shapes most of the UK's funding scheme for MRE (Kristensen, 2016).

The type of Brexit chosen by the UK and the EU will determine the future of this law in the UK (Froggatt et al., 2016). Under the "Norwegian model" or the Energy Community model, the state aid rules would still apply and the UK will have no discretion in influencing it (Froggatt et al., 2016). Under the three other scenarios, the rule would not apply and the UK could support any company by providing them with funding (Froggatt et al., 2016). However, the government declared it will transfer all EU existing laws into its national statute book, including state aid rules, and will decide following departure from the organization the laws to erase and to maintain (Norton Rose Fulbright, 2018). Therefore, even after Brexit occurs, the law will still apply in the UK (Norton Rose Fulbright).

4.3.5. Conclusion

MRE funding in the UK will be impacted both negatively and positively by Brexit through decreased financial support for research, development and innovation. Most of the EU funding strategies available will disappear and curtail research and development activities in the UK. Moreover, the loss of funding raises concerns for investors and for the future of the MRE industry and could delay further investments. However, if the UK decides to erase the state aid rules from the statute book, the government will be able to support projects and companies according to their climate change strategy. Also, it could be enhanced by the reduction in the contribution to the EU's budget. Finally, uncertainty raises concerns for investors.

4.4. Supply Chain

Brexit's impact on the supply chain will vary according to the model agreed upon by the EU and the UK. However, as long as the country stays in the EEA, the impact will be minimized (UK in a Changing Europe, n.d.). On the contrary, under the "Swiss model", the "Canadian model" and the "no-deal" model, the impact's intensity will increase and could severely affect the UK supply chain (UK in a Changing Europe, n.d.). Four main areas will particularly suffer from Brexit:

- trade
- labour mobility
- carbon release mitigation
- interconnectors

4.4.1. Trade

Brexit will impact negatively and positively the UK supply chain through various factors, and among the most important one is the country's ability to trade with others (Grubb et al., 2016). Following EU's departure, the UK can potentially face trade barriers, currently absent, due to the European Single Market (ESM) (Zeniewski, 2017). Indeed, the ESM allows goods and services to move freely inside the EU, without constraining measures such as import taxes (Energy Policy Research Group, 2016). Therefore, the choice of Brexit model is decisive as it could raise the costs on imports, an essential component of the MRE supply chain in the UK (Zeniewski, 2017). For instance, countries operating under the WTO model pay between 0% and 4% tax for electrical components (Zeniewski, 2017). Moreover, under the scenario of an EEA withdrawal, the EU could set standards for products used for electricity production and transmission, such as cables (Pace, 2017). If the UK wants to stay in the Single Market, it will have to comply to the EU's standards for products, while having no influence in setting them (Froggatt et al., 2016). Nonetheless, the country will have the possibility to determine higher standards for manufacturers to thus prevents the risks of non-compliance to EU criterions (Froggatt et al., 2016). Also, in 2001, the WTO engaged in a process of negotiation to eliminate the barriers for "environmental goods" in order to foster renewable energy developments (Zeniewski, 2017; World Trade Organization, n.d.).

Trade will both suffer and benefit from the depreciation of currencies (Froggatt et al., 2016). Following the referendum's result, the value of the sterling lost 10% against the dollar, and despite its resilience, uncertainty surrounding the form of Brexit and its consequences put the British currency in a delicate position (Treanor et al., 2016). Although the sterling partially recovered from the drop, the MRE supply chain still suffered from the effects, as not all the offshore wind, tidal or wave pieces are produced on UK territory (Zeniewski, 2017). The increase price of production could curtail MRE developments and especially tidal and wave projects. However, international companies will more likely develop MRE projects in the UK as their currency now has an edge over the sterling (PWC, 2017). Consequently, with a supply chain more competitive, national production will increase and boost the industry's economy.

Trade will also suffer from uncertainty with potential reduced support by investors. Similarly to funding, uncertainty will rise among investors, impacting the UK supply chain and therefore trade (Reid, 2016). Indeed, despite progress concerning Brexit's negotiation between the UK and the EU at the end of December 2018, the situation remains still unclear with political disagreements between UK parties and UK countries (BBC News, 2018). As the industry highly depends on foreign investments to operate and increase its production, Brexit could severely hamper its development as long as no political stability appeases the tensions. Ultimately, this would lead to a focus on more secure and reliable piece of technologies such as offshore wind, and a disinterest in more risky devices such as tidal and wave energy.

4.4.2. Labour Mobility

Brexit could reduce the freedom of movement from the EU to the UK for European workers (Froggatt et al., 2016). Yet again, it will depend on the Brexit strategy agreed upon by the two parties. The "Norwegian model" and the Energy Community model will not modify the current status of EU workers as the country would remain in the EEA and have the same advantages (Froggatt et al., 2016). However, the other three models would set barriers to their freedom of movement, and their mobility will depend on the agreements found between the UK and the EU (Froggatt et al., 2016). With a "Canadian model", a "Swiss model" or a "no-deal" model, the industry could suffer more important drawbacks due to (PWC, 2017; Elgot et al., 2018):

- higher costs of hiring
- loss of attractiveness to come to the UK
- loss of access to EU centres and facilities

Indeed, the UK is dependent on a foreign workforce for certain industries, including the MRE sector (Pollitt, 2017). Therefore, the free movement of people is an essential element for Brexit and the future of the MRE industry.

Brexit could increase administrative costs for the UK supply chain and with it, decrease the attractiveness of hiring European workers (White, 2018). Indeed, the UK government will require foreign workers to obtain a visa to work in the country, adding more time to the hiring process and therefore more administrative costs for developers (White, 2018). Other reasons will restrain European workers for applying in UK companies such as the decreased purchasing power of the sterling or the reduced possibility for subsidies or other governmental supports (UK in a Changing Europe, n.d.). Concerning the loss of access to EU centres and facilities, the UK would lose crucial support for MRE developments (PWC, 2017). In that regard, the MRE industry will suffer from a hard-Brexit as the country relies on the external workforce and the partnership it has with the EU. However, Theresa May declared the UK will grant preferential access to high skilled workers such as engineers or doctors over low skilled workers (Elgot et al., 2018). Therefore, this controlled migration could reduce the pressure put on developers and maintain the country's attractiveness for European workers.

4.4.3. Carbon Release Mitigation

Brexit also threatens the participation in the EU Energy Trading System (ETS) and its national carbon price floor (Norton Rose Fulbright, 2018; Kristensen, 2016). The objective of the ETS is to reduce the amount of CO2 emission by setting a cap on its production (European Commission, 2017). Companies surpassing this threshold pay a fine determined by the price of carbon fixed by the EU and the amount of carbon produced in excess (European Commission, 2017; HM Revenue & Customs, 2014). Every year, the cap decreases, allowing a global reduction in carbon emission (European Commission, 2017). This system therefore indirectly decreases the relative price of investing in renewable energies compared to the coal industry, and foster the development of the MRE sector (European Commission, 2017). Remaining in the ETS will depend upon the Brexit model and whether the UK stays in the single market or not (PWC, 2017). In conjunction with the EU ETS, the UK developed a carbon price floor, setting a minimum price for carbon emission in the country, in order to underpin the European system (HM Revenue & Customs, 2014). After Brexit, this tax will still apply to UK companies and its future will depend on the government's objectives concerning climate actions (Hirst, 2018). Hence, if the UK leaves the EU ETS, the increased price of MRE developments will curtail hazardous undertakings such as wave and energy projects, to favour more advanced technologies such as offshore wind. This will eventually have repercussions on the national MRE supply chain and on its importance worldwide.

4.4.4. Interconnectors

Interconnectors allow countries to share electricity via underwater cables in order to secure the supply of electricity at an affordable price (Nemo Link, n.d.). Indeed, with the exchange of electricity and market competition (the possibility to obtain electricity at the lowest cost), prices decrease (Vella, 2015). It represents also an optimal way for countries to supply partners when it has a surplus of electricity produced by offshore wind farms and tidal or wave devices (Nemo Link, n.d.). Currently, the UK has 4 GW of capacity, and connections with France, the Netherlands, Northern Ireland and the Republic of Ireland, and plans to increase it to 10 GW by 2022 (The Crow Estate, 2018; Froggatt et al., 2016).

Participants of the Internal Energy Market (IEM) benefit from market coupling, a system that automatically adjusts the price difference between countries and allow each of them to sell their electricity (Whiddington et al., n.d.). Brexit could impact UK's interconnection with the EU if the country leaves the IEM, and exclude the UK from market coupling (Miller, 2018; Whiddington et al., n.d.). In that regard, the UK could lose demand for its electricity coming from sustainable sources, such as MRE, due to higher prices in the country, and lose its access to cheaper and reliable electricity (Miller, 2018; Whiddington et al., n.d.). Therefore, a reduced demand could curtail MRE development and switch the focus to more stable sources of electricity such as coal.

4.4.5. Conclusion

Two models of Brexit, the "Norwegian model" and the Energy Community model could better support the relevant MRE supply chain in both the UK and EU in the context of Brexit. The other three Brexit strategies, the "Swiss model", the "Canadian model" and the WTO model, however, could curtail the MRE's supply chain as discussed in this section. Evidently, a "hard-Brexit" would substantially impact the MRE industry via its supply chain and could jeopardize the UK's worldwide leadership.

5. Conclusion and Recommendations

5.1. Key Insights

The 29th of March 2019, the UK will no longer be a EU state member and the type of relationship will be decided prior to departure. However, beginning of January 2019, no agreement had been accepted by MPs and the perspective of a dramatic “no-deal” scenario became more realistic. For most industries including the MRE sector, such a scenario would be catastrophic given the level of uncertainty and lack of confidence for investing in research and development in the sector. Through content analysis it was determined that three main areas in the UK will be impacted by Brexit:

- legislation and regulations
- funding and investment
- the supply chain

For the UK and its MRE industry, maintaining its relationship with the EU would be the best option to support existing and ongoing legislation and regulations. Indeed, agreeing on a “Norwegian model” would allow the UK to maintain a certain influence on the EU’s decisions regarding environmental issues. For example, this model would provide the context for ongoing collaborative EU and UK efforts to address climate change’s impacts. A hard-Brexit model would provide the UK more control over its environmental legislation and regulations and could see the UK setting even higher standards with respect to emission and renewable energy targets. However, a soft Brexit would allow the UK to maintain its influence on EU decisions and on the EU’s organization’s roadmap in terms of renewable targets.

Funding will also require a close partnership with the EU for multiple reasons. First, the UK is the biggest recipient of the EU’s funding mechanisms and by leaving the organization, the country will lose a substantial amount of funding. Second, uncertainty in the Brexit model casts a shadow on MRE development as investors could decrease their support for the industry. Finally, the repercussions on research and innovation, one of the core components of MRE development, will suffer from the loss of funding. Indeed, Brexit will likely jeopardize the UK's current overall leadership position in the MRE sector.

The last area to suffer from Brexit will be the UK supply chain. MRE developers rely on certain components of their technology on foreign expertise and Brexit could increase the cost of imports. Also, labour mobility may be curtailed and yet again, price of foreign expertise could increase. Finally, if the UK leaves the internal energy market (IEM), price of electricity coming from renewable sources will increase compare to the EU. Consequently, foreign demand will decrease.

5.2. Recommendations

The content analysis identified the key impacts related to Brexit for the MRE industry in the UK. Based on these insights, a set of recommendations are highlighted to guide the ongoing development of MRE in light of Brexit.

5.2.1. The Type of Brexit

Before the 29th of March 2019, the UK and the EU will have to settle on the type of relationship both parties want to have following departure. As discussed, five different types of Brexit models exist that provide a series of trade-offs for the UK concerning its freedom, certainty and support from its EU partners. From the documents analysed, it is clear that a hard-Brexit would severely hamper the MRE industry in the UK and curtail MRE development due notably to a lack of funding, higher costs and uncertainty. For this reason, the UK should agree on a model closest to the statu quo, thus the "Norwegian model" would be preferable as it would provide the greatest certainty for ongoing MRE research and development in the UK.

5.2.2. Environmental Policies and Targets

The current predictions related to climate change and CO2 emissions are alarming and countries must act rapidly. In that regard, environmental policies should promote the development of MRE technologies and set even more ambitious targets. Currently the EU aims for 27% of energy coming from renewable sources by 2030 and a 40% decrease of GHG emission by 2030 compared to 1990 levels. With pressing issues, the EU should modify its priorities and allocate more funding to renewable energy development in order to set more ambitious emission and renewable targets. By 2030, in order to reverse the effect of climate change, the EU should aim for 40% of energy coming from renewable sources and by 2050, increase this to 100%. Also, the UK should increase its current national targets to EU levels, too low to reverse climate change's impacts.

5.2.3. Modification of Standards

Regardless of the model chosen, all environmental regulations will be transferred into the UK's statute book, apart from the Habitats Directive 1992 and Birds Directive 2009. In order to address climate change's issues and encourage MRE development, the EU should revise relevant regulations, and new pieces of legislation should be ratified in order to accelerate the MRE development process. For instance, EIAs undertaken by developers can hamper a project and in some cases, stop its development. For this reason, in order to accelerate the transition to clean energy, under certain circumstances, the precautionary principle should not apply. Also, by setting lower standards and requirements, the MRE industry's attractiveness will increase along with the number of projects in the UK and in the EU.

5.2.4. Government's Disinterest Towards MRE

Integrating the Department of Energy and Climate Change (DECC) with the Department of Industry, Business and Skills to create the newly Department for Business, Energy and Industrial Strategy raised concerns regarding the priorities of the UK government and its indifference towards the MRE sector. Despite major apprehensions raised by Brexit for the MRE sector and the disagreements between the UK and the EU concerning Brexit, the UK government should take into account the future of the MRE industry when agreeing on the type of Brexit.

5.2.5. Renewable Energy Guarantees of Origin

The Renewable Energy Guarantees of Origin would suffer in the case of a no-deal scenario. Therefore, the UK government should avoid this situation and aim for a close partnership with the EU with a "Norwegian model". In the case the UK and the EU agrees on the WTO model ("no-deal" model), the guarantees' legitimacy will be annulled and the country will need to develop a similar certificate in order to ensure trade between the two parties.

5.2.6. Support Mechanisms from the EU

The UK MRE sector heavily relies on EU funding for development and leaving the EU could curtail this support. The UK population contributes to the EU budget that is reallocated to the country through financial support for MRE and other projects. Leaving the EU without an agreement would provide more freedom to the UK concerning the allocation of funding for certain types of development. However, depending on the priorities of the government, this could severely reduce the amount available for MRE developers. For this reason, the UK should maintain a close relationship with the EU.

Following Brexit, the EU should continue to support MRE development in the UK given its geographical potential for certain types of MRE development like tidal energy. The EU should therefore deliver a larger share of the budget than it currently does or create a special fund for tidal devices. This will enable the development of the technology and ultimately facilitate its commercialization by reducing the overall cost.

5.2.7. Research, Development and Innovation

In order to produce cheaper devices and improve their efficiency, the MRE industry needs to undertake more research and development. For this reason, the EU created funding programmes such as Mission Innovation. However, this fund will stop in 2021 and will need to be maintained or replaced. Along with Mission Innovation, other schemes need to be developed for the MRE industry as a whole.

Independently from the model chosen by the EU and the UK, the country will lose access to some research and development schemes and facilities. Also, the collaborative research and development connectivity that exist between the UK and the other EU state members will deteriorate and reduce the UK's influence on EU's research objectives. The intensity of the impact will vary according to the level of independence from the EU, therefore maintaining a close relationship will allow the UK to preserve most of its advantages. For this reason, the UK should negotiate for a "Norwegian model". Under this scenario, the UK would still have to develop research facilities of its own and start negotiating access to EU funding and facilities. Furthermore, the EU would benefit from UK's experience as the country leads the MRE industry in Europe.

5.2.8. Uncertainty for Investors

One of the most disastrous consequences of Brexit is the uncertainty for investors. Therefore, in order to reduce the uncertainty, the government needs to choose a scenario with the least uncertain outcomes in the short-term and in the long-term. The "Norwegian model" fulfils the requirements as it will bring stability to the industry, and will therefore maintain a good level of investments.

5.2.9. State Aid Rules

The creation of state aid rules by the EU had two aims: to prevent market distortions and to protect companies from arbitrary governmental support. This rule does not apply when it supports the economic development of the country (CfDs). In order to facilitate the creation of supporting mechanisms, the EU should reduce the restrictions set by the state aid rules for MRE undertakings, and foster their development.

5.2.10. Trade

In order to maintain a similar level of overall cost for MRE developments, the UK government needs to maintain its participation in the European Single Market (ESM). Being part of the ESM allows the UK to buy goods and services without taxes. In the case of a harder Brexit, the MRE sector would be impacted by increased taxes on imports and the UK government would need to negotiate agreements with the EU.

5.2.11. Labour Mobility

In case of a hard Brexit, both the EU and the UK would suffer the consequences as free movement between the two countries will be hampered due to higher costs of hiring, potential visa applications and a depreciated sterling. Therefore, both parties would benefit from a soft-Brexit, thus a "Norwegian model". In the case of a no-deal Brexit, the UK government should maintain the same level of protection regarding labour mobility as the MRE industry relies on an external workforce.

5.2.12. Carbon Release Mitigation

In order to maintain the dynamics of MRE price reduction, the UK should stay in the EU ETS. This would benefit both the UK and EU, especially concerning less advanced technologies such as tidal and wave power. Also, the EU should accelerate the transition to low-carbon technologies by reducing more drastically the CO2 production cap. In addition, the EU should increase the fines' prices of companies producing more CO2 than the cap allows. In parallel, the UK's carbon price floor should be maintained or increased, to foster renewable energy developments. This could allow the country to reach more ambitious renewable targets.

5.2.13. Interconnectors

Participating in the IEM is crucial for the UK as it allows the country to sell its electricity at an affordable price. Without access to the this market, higher prices in the UK market will not compete with EU prices. For this reason, the UK needs to maintain its participation in the IEM and develop more interconnectors with EU countries. This would promote investments in MRE technologies in the UK.

5.2.14. Recommendations Summary

Sections	Recommendations for the UK	Recommendations for the EU
Legislation and Regulations in the UK	"Norwegian Model" Increase national targets to EU levels Maintain high priority for MRE (pre-Brexit and post-Brexit) Develop certificate in case of a "no-deal" Brexit	Increase targets to 40% by 2030 Increase targets to 100% by 2050 Establish lower environmental standards
Funding and Investment	"Norwegian Model"	Increase support to tidal energy
	Increase support to tidal energy	Develop new funds
	Develop own research facilities	Increase support to research and development
	Negotiate access to EU funding and facilities	Negotiate UK's access to research facilities
		Reduce state aid rules restrictions
UK Supply Chain	"Norwegian Model" Agreements with the EU if hard Brexit No barriers to entry for workers Increase carbon price floor Build more interconnectors	No barriers to entry for workers More drastic reduction of the cap Increase fines' price

Table 2. Summary of the recommendations for the UK concerning pre-Brexit and post-Brexit situations

5.3. Future Research

The scope of this study is broad and the consequences of Brexit while explored in depth warrant ongoing consideration. This thesis identified the main impacts and their significance on the UK MRE industry from Brexit. However, while this study provided a comprehensive overview of these impacts, each area could be explored on its own in significantly more depth. Doing a complete and in-depth assessment of a political event such as Brexit, and on an industry as complicated as MREs requires more time and a longitudinal approach to explore the impacts pre and post Brexit. Therefore, future research should focus on one aspect of Brexit, as more detailed findings might be revealed to support more specific policy adjustments. Indeed, each three main themes identified in this study could be explored in a separate research study. For instance, the “legislation and regulations” section comprises many nuances and complex situations, that a single paper could discuss.

Furthermore, in order to assess the impact of Brexit on the MRE industry in the UK, future research post-Brexit will be required concerning the three main areas discussed (legislation and regulation, funding and investment and the supply chain). Based on the findings, new recommendations could suggest methods to support and maintain a vibrant and dynamic MRE sector. Also interviews with key stakeholders of the MRE sector would help gain understanding on Brexit’s consequences and the obstacles the industry and government encounter. Finally, research would be needed to quantify and understand the consequences on the EU and its MRE industry. Indeed, the organization depends on the UK in some aspects and the departure from the EU could also curtail undertakings within the EU.

Further research can certainly provide more depth to a range of areas impacted by Brexit. However, the research presented in this thesis provide a significant start to understanding the range of impacts from Brexit and also highlights recommendations for the MRE sector and its UK and EU stakeholders.

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Appendix A

Háskólasetur Vestfjarða
University Centre of the Westfjords

Research ethics training and clearance

University Centre of the Westfjords
Suðurgata 12
400 Ísafjörður, Iceland
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This letter certifies that **Florian Billarant** has completed the following modules of:

(X) Basic ethics in research
(X) Human subjects research
(X) Animal subjects research

Furthermore, the Master's Program Committee has determined that the proposed masters research entitled **The Impact of Brexit on the Marine Renewable Energy Industry in the UK** meets the ethics and research integrity standards of the University Centre of the Westfjords. Throughout the course of his or her research, the student has the continued responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

University Centre of the Westfjords ethics training certification and research ethics clearance is valid for one year past the date of issue.

Effective Date: 15 June 2018
Expiration Date: 15 June 2019

Prior to making substantive changes to the scope of research, research tools, or methods, the student is required to contact the Masters Program Committee to determine whether or not additional review is required.

Appendix B

Table B1. Offshore wind development in the UK (Eunomia, 2018)

Site Name	Technology Type	Installed Capacity (MWelec)	Turbine Capacity (MW)	No. of Turbines	Height of Turbines (m)	Development Status	Development Status (short)
London Array Phase 2	Wind Offshore	240.0	2.93	341		Abandoned	Abandoned
Cromer	Wind Offshore	108.0	4.00	30		Abandoned	Abandoned
London Array Phase 1	Wind Offshore	630.0	3.60	175		Operational	Operational
Gwynt y Mor	Wind Offshore	576.0	3.60	160		Operational	Operational
Greater Gabbard Wind Farm	Wind Offshore	504.0	3.60	140		Operational	Operational
Dudgeon East	Wind Offshore	402.0	6.00	67		Operational	Operational
Rampion Offshore Wind Farm (Hastings Zone)	Wind Offshore	400.0	5.00	116	140	Operational	Operational
West of Duddon Sands	Wind Offshore	389.0	3.60	108		Operational	Operational
Galloper Wind Farm	Wind Offshore	353.0	6.30	56		Operational	Operational
Sheringham Shoal	Wind Offshore	317.0	3.60	88		Operational	Operational
Thanet	Wind Offshore	300.0	3.00	100		Operational	Operational
Race Bank (Phase 1)	Wind Offshore	286.5	6.00	46	154	Operational	Operational
Race Bank (Phase 2)	Wind Offshore	286.5	6.00	45	154	Operational	Operational
Centrica (Lincs)	Wind Offshore	270.0	3.60	75		Operational	Operational
Burbo Bank Extension (Burbo Bank 2)	Wind Offshore	258.0	8.00	32		Operational	Operational
Humber Gateway A	Wind Offshore	219.0	3.00	73		Operational	Operational
Westermost Rough A	Wind Offshore	210.0	6.00	35		Operational	Operational
Walney 1	Wind Offshore	183.6	3.60	51		Operational	Operational
Walney 2	Wind Offshore	183.6	3.60	51		Operational	Operational
Ormonde Offshore	Wind Offshore	150.0	5.00	30		Operational	Operational
Gunfleet Sands Offshore Wind Scheme	Wind Offshore	108.0	3.60	30		Operational	Operational
Inner Dowsing	Wind Offshore	97.2	3.60	27		Operational	Operational
Lynn	Wind Offshore	97.2	3.60	27		Operational	Operational
Burbo Bank	Wind Offshore	90.0	3.60	25		Operational	Operational
Kentish Flats	Wind Offshore	90.0	3.00	30		Operational	Operational
Rhyl Flats	Wind Offshore	90.0	3.60	25		Operational	Operational
Robin Rigg East	Wind Offshore	90.0	3.00	30		Operational	Operational
Barrow	Wind Offshore	90.0	3.00	30		Operational	Operational
Robin Rigg West	Wind Offshore	84.0	3.00	28		Operational	Operational
Gunfleet Sands II	Wind Offshore	64.8	3.60	18		Operational	Operational
Teeside Offshore Wind Farm	Wind Offshore	62.1	2.30	27		Operational	Operational
North Hoyle	Wind Offshore	60.0	2.00	30		Operational	Operational
Scroby Sands	Wind Offshore	60.0	2.00	30		Operational	Operational
Kentish Flats 2	Wind Offshore	49.5	3.30	15		Operational	Operational
Blyth Offshore Wind Test Site	Wind Offshore	41.5	8.30	5		Operational	Operational
Hywind Scotland Pilot Park (Hywind 2) Demonstrator	Wind Offshore	30.0	6.00	5		Operational	Operational
Gunfleet Sands - (Demo) Extension	Wind Offshore	12.0	6.00	2		Operational	Operational
Beatrice Demonstrator	Wind Offshore	10.0	5.00	2		Operational	Operational
Levenmouth demonstration turbine (Fife Energy Par	Wind Offshore	7.0	6.00	1		Operational	Operational
Blyth Offshore	Wind Offshore	4.0	2.00	2		Operational	Operational
The East Anglia Array - Norfolk Vanguard	Wind Offshore	1 800.0	5.00	360	145	Planning Application Submitted	Application Submitted
Hornsea Project Three	Wind Offshore	1 200.0	5.00	171		Planning Application Submitted	Application Submitted
Moray Firth 2 (West)	Wind Offshore	750.0	12.00	50		Planning Application Submitted	Application Submitted
Neart na Gaoithe (Resubmission)	Wind Offshore	450.0	7.00	54	208	Planning Application Submitted	Application Submitted
Thanet (extension)	Wind Offshore	340.0	10.00	34	210	Planning Application Submitted	Application Submitted
Atlantic Array One - Bristol Channel Zone	Wind Offshore	1 200.0	5.00	240		Planning Application Withdrawn	Application Withdrawn
Cirrus Shell Flat Array	Wind Offshore	284.0	3.15	90		Planning Application Withdrawn	Application Withdrawn
Scarweather Sands	Wind Offshore	108.0	3.00	30		Planning Application Withdrawn	Application Withdrawn
Dogger Bank Creyke Beck A & B	Wind Offshore	2 400.0	5.00	360		Planning Permission Granted	Awaiting Construction
Hornsea Project Two - Optimus and Breesea	Wind Offshore	1 400.0	8.48	165		Planning Permission Granted	Awaiting Construction
East Anglia 3	Wind Offshore	1 200.0	7.00	172	247	Planning Permission Granted	Awaiting Construction
Dogger Bank Teesside A	Wind Offshore	1 200.0	5.00	480		Planning Permission Granted	Awaiting Construction
Sofia (Dogger Bank Teesside B)	Wind Offshore	1 200.0	5.00	480		Planning Permission Granted	Awaiting Construction
Triton Knoll	Wind Offshore	860.0	9.50	90		Planning Permission Granted	Awaiting Construction
Inch Cape	Wind Offshore	784.0	7.12	110	186	Planning Permission Granted	Awaiting Construction
Seagreen Alpha	Wind Offshore	525.0	7.00	75		Planning Permission Granted	Awaiting Construction
Seagreen Bravo	Wind Offshore	525.0	7.00	75		Planning Permission Granted	Awaiting Construction
Neart na Gaoithe	Wind Offshore	450.0	7.00	64		Planning Permission Granted	Awaiting Construction
MacColl Offshore Windfarm (Moray Firth)	Wind Offshore	317.0	6.00	62		Planning Permission Granted	Awaiting Construction
Telford Offshore Windfarm (Moray Firth)	Wind Offshore	317.0	6.00	62		Planning Permission Granted	Awaiting Construction
Stevenson Offshore Windfarm (Moray Firth)	Wind Offshore	316.0	6.00	62		Planning Permission Granted	Awaiting Construction
Kincardine Offshore Windfarm	Wind Offshore	50.0	6.00	8	176	Planning Permission Granted	Awaiting Construction
Forth of Firth (Methil)	Wind Offshore	12.0	6.00	2	121	Planning Permission Granted	Awaiting Construction
Dounreay Tri Floating Wind Demonstration	Wind Offshore	10.0	5.00	2	201	Planning Permission Granted	Awaiting Construction
Navitus Bay	Wind Offshore	970.0	5.00	121		Planning Permission Refused	Application Refused
Docking Shoal A	Wind Offshore	540.0	5.00	108		Planning Permission Refused	Application Refused
Hornsea Project One - Heron & Njord	Wind Offshore	1 200.0	7.00	174		Under Construction	Under Construction
East Anglia 1 (EA 1)	Wind Offshore	714.0	5.00	100		Under Construction	Under Construction
Walney 3	Wind Offshore	660.0	6.00	110	222	Under Construction	Under Construction
Beatrice	Wind Offshore	588.0	7.00	84		Under Construction	Under Construction
European Offshore Wind Deployment Centre (EOWD	Wind Offshore	93.2	8.40	11		Under Construction	Under Construction

Table B2. Shoreline wave development in the UK (Eunomia, 2018)

Site Name	Technology Type	Installed Capacity (MWelec)	Turbine Capacity (MW)	No. of Turbines	Height of Turbines (m)	Development Status	Development Status (short)
Siadar Wave Energy Generating Scheme	Shoreline Wave	4.0				Abandoned	Abandoned
Seatricity Turbine (Billia Croo - EMEC)	Shoreline Wave	1.0				Decommissioned	Decommissioned
Hayle Wave Hub (Test Site)	Shoreline Wave	23.0				Operational	Operational
Wello Penguin Device (Billia Croo - EMEC)	Shoreline Wave	1.0				Operational	Operational
Milford Haven Wave Dragon Pre-Commercial Demor	Shoreline Wave	7.0				Planning Application Submitted	Application Submitted
WestWave	Shoreline Wave	3.0	4.00	1		Planning Application Withdrawn	Application Withdrawn
Lewis Oyster Wave Array	Shoreline Wave	50.0				Planning Permission Granted	Awaiting Construction

Table B3. Tidal energy development in the UK (Eunomia, 2018)

Site Name	Technology Type	Installed Capacity (MWelec)	Turbine Capacity (MW)	No. of Turbines	Height of Turbines (m)	Development Status	Development Status (short)
SeaGen Wales Tidal Farm	Tidal Barrage and Tidal Stream	10.0	2.00	5		Abandoned	Abandoned
AR-1000 (FoW - EMEC)	Tidal Barrage and Tidal Stream	1.0				Decommissioned	Decommissioned
TGL (FoW - EMEC)	Tidal Barrage and Tidal Stream	1.0				Decommissioned	Decommissioned
Voith (FoW - EMEC)	Tidal Barrage and Tidal Stream	1.0				Decommissioned	Decommissioned
Kawasaki (FoW - EMEC)	Tidal Barrage and Tidal Stream	1.0				Decommissioned	Decommissioned
Hammerfest (FoW - EMEC)	Tidal Barrage and Tidal Stream	1.0				Decommissioned	Decommissioned
Inner Sound Phase 1A (MeyGen)	Tidal Barrage and Tidal Stream	6.0	1.50	4		Operational	Operational
SR-2000 (FoW - EMEC)	Tidal Barrage and Tidal Stream	2.0				Operational	Operational
Floating Energy Generation Platform - ATIR	Tidal Barrage and Tidal Stream	2.0	n/a	n/a	n/a	Operational	Operational
SeaGen Tidal Farm	Tidal Barrage and Tidal Stream	1.2				Operational	Operational
Brims Tidal Array (Cantick Head)	Tidal Barrage and Tidal Stream	200.0	n/a	n/a	n/a	Planning Application Submitted	Application Submitted
Fair Head	Tidal Barrage and Tidal Stream	100.0	n/a	n/a	n/a	Planning Application Submitted	Application Submitted
Kyle Rhea Tidal Stream Array	Tidal Barrage and Tidal Stream	8.0				Planning Application Withdrawn	Application Withdrawn
Kylerhea	Tidal Barrage and Tidal Stream	1.2				Planning Application Withdrawn	Application Withdrawn
Swansea Bay Tidal Lagoon	Tidal Barrage and Tidal Stream	320.0				Planning Permission Granted	Awaiting Construction
Inner Sound Phase 1B/1C (MeyGen)	Tidal Barrage and Tidal Stream	80.0	1.70	46		Planning Permission Granted	Awaiting Construction
West Islay Tidal Array	Tidal Barrage and Tidal Stream	30.0				Planning Permission Granted	Awaiting Construction
Sound of Islay	Tidal Barrage and Tidal Stream	10.0				Planning Permission Granted	Awaiting Construction
Mull of Kintyre	Tidal Barrage and Tidal Stream	3.0				Planning Permission Granted	Awaiting Construction
Open Centre Turbines (FoW - EMEC)	Tidal Barrage and Tidal Stream	2.5	n/a	n/a	n/a	Planning Permission Granted	Awaiting Construction
The Fall of Warness Tidal Scheme, (FoW - EMEC)	Tidal Barrage and Tidal Stream	2.0				Planning Permission Granted	Awaiting Construction
Wootton Bridge	Tidal Barrage and Tidal Stream	2.0				Planning Permission Granted	Awaiting Construction
Magallanes (FoW - EMEC)	Tidal Barrage and Tidal Stream	2.0	n/a	n/a	n/a	Planning Permission Granted	Awaiting Construction
Shetland Tidal Array	Tidal Barrage and Tidal Stream	2.0	n/a	n/a	n/a	Planning Permission Granted	Awaiting Construction
Lynmouth Tidal Demo	Tidal Barrage and Tidal Stream	1.2				Planning Permission Granted	Awaiting Construction
St. Catherine's Race	Tidal Barrage and Tidal Stream	30.0				Secretary of State - Granted	Awaiting Construction

Appendix C

Theme	Reference
Birds	Grecian WJ, Lane JV, Michelot T, Wade HM & Hamer KC (2018). Understanding the ontogeny of foraging behaviour: insights from combining marine predator bio-logging with satellite-derived oceanography in hidden Markov models. J. R. Soc. Interface 15: 20180084. http://dx.doi.org/10.1098/rsif.2018.0084.
Birds	Langston R & Teuten (2018). Ranging behaviour of northern gannets. British Birds 111: 131-143.
Birds	Thaxter CB, Ross-Smith VH, Bouten W, Masden EA, Clark NA, Conway GJ, Barber L, Clewley GD & Burton NHK (2018). Dodging the blades: new insights into three dimensional space use of offshore wind farms by lesser black-backed gulls Larus fuscus. Marine Ecology Progress Series 587: 247–253.
Birds	Thaxter CB (2017). Chapter 15: Tracking and telemetry of marine birds. In: Perrow, M. (ed.) Wildlife and Wind Farms: Offshore Volume 2: Conflicts and Solutions. Conservation Handbooks. Pelagic Publishing.
Birds	Shamoun-Baranes J, van Gasteren H & Ross-Smith V (2017). Sharing the Aerosphere: Conflicts and Potential Solutions. In: Chilson P, Frick W, Kelly J & Liechti F (eds) Aeroecology. Springer, Cham, pp.465-497.
Birds	Thaxter CB, Clark NA, Ross-Smith VH, Conway GJ, Bouten W & Burton NHK (2017). Sample size required to characterise area use of tracked seabirds. Journal of Wildlife Management 81: 1098-1109.
Birds	Ross-Smith V, Thaxter C, Clark N, Shamoun-Baranes J, Bouten W & Burton N (2016). GPS telemetry reveals differences in the foraging ecology of breeding lesser black- backed gulls between three Special Protection Area colonies. BOU Proceedings – Birds in time and space: avian tracking and remote sensing.
Birds	Ross-Smith V, Thaxter CB, Masden EA, Shamoun-Baranes J, Burton NHK, Wright LJ, Rehfisch MM & Johnston A (2016). Modelling flight heights of lesser black-backed gulls and great skuas from GPS: a Bayesian approach. Journal of Applied Ecology 53: 1635- 1891.
Birds	Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Masden EA, Wade HM, Leat EHK, Gear SC, Marsh M, Booth C, Furness RW, Votier SC & Burton NHK (2016). Contrasting effects of GPS device and harness attachment on adult survival of lesser black-backed gulls Larus fuscus and great skuas Stercorarius skua. Ibis doi: 0.1111/ibi.12340.
Birds	Cleasby IR, Wakefield ED, Bearhop S, Bodey TW, Votier SC & Hamer KC (2015). Three-dimensional tracking of a wide-ranging marine predator: flight heights and vulnerability to offshore wind farms. Journal of Applied Ecology 52: 1474-1482.
Birds	Thaxter CB, Ross-Smith VH, Bouten W, Clark NA, Conway GJ, Rehfisch MM & Burton NHK (2015). Seabird-wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull Larus fuscus in the UK. Biological Conservation 186: 347-358.
Birds	Thaxter CB, Ross-Smith VH, Clark NA, Bouten W & Burton NHK (2015). GPS telemetry reveals within-wind farm behavior of lesser black-backed gulls during the breeding season. In: Köppel J & Schuster E (eds.) Book of Abstracts (page 65). Conference on Wind energy and Wildlife impacts (CWW 2015), March 10-12, 2015. Berlin, Germany.
Birds	Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Marsh M, Leat EHK & Burton NHK (2014). A trial of three harness attachment methods and their suitability for long-term use on lesser black-backed gulls and great skuas. Ringing & Migration 29: 65- 76.
Birds	Wade HM, Masden EA, Jackson AC, Thaxter CB, Burton NHK, Bouten W & Furness RW (2014). Great skua (Stercorarius skua) movements at sea in relation to marine renewable energy developments. Marine Environmental Research 101: 69-80.
Birds	Thaxter C, Ross-Smith V, Burton N, Wade H, Masden E & Bouten W (2013). Connectivity between seabird features of protected sites and offshore wind farms: lesser black-backed gulls and great skuas through breeding, migration and non-breeding seasons. BOU proceedings – Marine Renewables and Birds.
Birds	Wakefield ED, Bodey TW, Bearhop S, Blackburn J, Colhoun K, Davies R, Dwyer RG, Green J, Grémillet D, Jackson AL, Jessopp MJ, Kane A, Langston RHW, Lescroël A, Murray S, Le Nuz M, Patrick SC, Péron C, Soanes L, Wanless S, Votier SC & Hamer KC (2013). Space partitioning without territoriality in gannets. Science 341: 68-70.

Figure C1. Research within SEA's scope (Department for Business, Energy & Industrial Strategy, 2018)

Theme	Reference
Marine Mammals	Arso Civil M, Quick N Cheney B Pirotta E, Thompson P & Hammond P (submitted). Changing distribution of the east coast of Scotland bottlenose dolphin population and the challenges of area-based management. Aquatic Conservation: Marine and Freshwater Ecosystems.
Marine Mammals	Sparling C, Lonergan M & McConnell B (2017). Harbour seals (Phoca vitulina) around an operational tidal turbine in Strangford Narrows: no barrier effect but small changes in transit behaviour. Aquatic Conservation: Marine and Freshwater Ecosystems 28:194- 204.
Marine Mammals	Graham IM, Pirotta E, Merchant ND, Farcas A, Barton TB, Cheney B, Hastie GD & Thompson PM (2017). Responses of bottlenose dolphins and harbour porpoises to variations in piling noise during harbour construction. Ecosphere 8: 1-16.
Marine Mammals	Quick NJ, Cheney B, Thompson PM & Hammond PS (2017). Can the camera lie? A non-permanent nick in a bottlenose dolphin (Tursiops truncatus). Aquatic Mammals 43: 156-161.
Marine Mammals	Jones EL, Sparling CE, McConnell BJ, Morris CD & Smout S (2017). Fine-scale harbour seal usage for informed marine spatial planning. Scientific Reports 7: 11581.
Marine Mammals	Farcas A, Thompson PM & Merchant ND (2016). Underwater noise modelling for environmental impact assessment. Environmental Impact Assessment Review 57: 114- 122.
Marine Mammals	Hastie GD, Russell DJF, McConnell BJ, Thompson D & Janik VM (2016). Multiple-pulse sounds and seals: results of a harbour seal (Phoca vitulina) telemetry study during windfarm construction. Advances in Experimental Medicine and Biology 875: 425-430.
Marine Mammals	Lucke K, Hastie GD, Jurczynski K, McConnell B, Moss S, Russell DJF, Weber H & Janik VM (2016). Aerial low frequency hearing in captive and free-ranging harbour seals (Phoca vitulina) using auditory brainstem responses. Journal of Comparative Physiology A 202: 859-868.
Marine Mammals	Russell DJF, Hastie GD, Thompson D, Janik VM, Hammond PS, Scott-Hayward LAS, Matthiopoulos J, Jones EL & McConnell BJ (2016). Avoidance of wind farms by harbour seals is limited to pile driving activities. Journal of Applied Ecology 53: 1642-1652.
Marine Mammals	Hastie GD, Russell DJF, McConnell B, Moss S, Thompson D & Janik VM (2015). Sound exposure in harbour seals during the installation of an offshore wind farm: predictions of auditory damage. Journal of Animal Ecology 52: 631–640.
Marine Mammals	Jones EL, McConnell BJ, Smout S, Hammond PS, Duck CD, Morris CD, Thompson D, Russell DJF, Vincent C, Cronin M, Sharples RJ & Matthiopoulos J (2015). Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. Marine Ecology Progress Series 534: 235–249.
Marine Mammals	Russell DJF, McClintock BT, Matthiopoulos J, Thompson PM, Thompson D, Hammond PS, Jones EL, MacKenzie ML, Moss S & McConnell BJ (2015). Intrinsic and extrinsic drivers of activity budgets in sympatric grey and harbour seals. Oikos 124: 1462-1472.
Marine Mammals	Cheney B, Corkrey R, Durban JW, Grellier K, Hammond PS, Isals-Villanueva V, Janik VM, Lusseau SM, Parsons KM, Quick NJ, Wilson B & Thompson PM (2014). Long-term trends in the use of a protected area by small cetaceans in relation to changes in population status. Global Ecology and Conservation 2: 118-128.
Marine Mammals	Hastie GD, Donovan C, Götz T & Janik VM (2014). Behavioral responses by grey seals (Halichoerus grypus) to high frequency sonar. Marine Pollution Bulletin 79: 205-210.
Marine Mammals	Russell DJF, Brasseur SMJM, Thompson D, Hastie G, Janik VM, Aarts G, McClintock BT, Matthiopoulos J, Moss SEW & McConnell B (2014). Marine mammals trace anthropogenic structures at sea. Current Biology 24: 638-639.
Marine Mammals	Silva MA, Jonsen I, Russell DJF, Prieto R, Thompson D & Baumgartner MF (2014). Assessing performance of Bayesian state-space models fit to Argos satellite telemetry locations processed with Kalman filtering. PLoS ONE 9(3): e92277.
Marine Mammals	McClintock BT, Russell DJF, Matthiopoulos J & King R (2013). Combining individual animal movement and ancillary biotelemetry data to investigate population-level activity budgets. Ecology 94: 838-849.
Marine Mammals	Russell DJ, McConnell BJ, Thompson D, Duck CD, Morris C, Harwood, J & Matthiopoulos J (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. Journal of Applied Ecology 50: 499-509.

Figure C2. Research within SEA's scope (Department for Business, Energy & Industrial Strategy, 2018)

Theme	Reference
Seabed and Water Column	Wasson B & de Blauwe H (2014). Two new records of cheilostome Bryozoa from British waters. Marine Biodiversity Records 7: e123.
Seabed and Water Column	Gafeira J, Long D & Diaz-Doce D (2012). Semi-automated characterisation of seabed pockmarks in the central North Sea. Near Surface Geophysics 10: 303-314.
Seabed and Water Column	Howell KL, Davies JS & Narayanaswamy BE (2010). Identifying deep-sea megafaunal epibenthic assemblages for use in habitat mapping and marine protected area network design. Journal of the Marine Biological Association of the United Kingdom 90: 33–68.
Seabed and Water Column	Oliver PG, Holmes AM, Killeen IJ & Turner JA (2010). Marine bivalve shells of the British Isles (Mollusca: Bivalvia). Amgueddfa Cymru - National Museum Wales.
Seabed and Water Column	Hastie LC, Pierce GJ, Wang J, Bruno I, Moreno A, Piatkowski U & Robin JP (2009). Cephalopods in the north-eastern Atlantic: species, biogeography, ecology, exploitation and conservation. Oceanography and Marine Biology: An Annual Review 47: 111-190.

Figure C3. Research within SEA's scope (Department for Business, Energy & Industrial Strategy, 2018)

Appendix D

Name of the Document	Types of Document	Number of Occurrences of a Document in Each Section		
		Legislation and Regulation in the UK	Funding and Investment	UK Supply Chain
Impact of Brexit on UK Energy Security	Article		3	4
The Economic Consequences of Brexit: Energy	Article	2	2	3
The energy sector implications of Brexit	Article	2	4	5
The impact of Brexit on the environment: exploring the dynamics of a complex relationship	Article	3		2
The impact of Brexit on Scotland's Energy Strategy	Blog	1	4	3
Brexit: implications for climate change commitments	Briefing Paper	1	1	2
Carbon Price Floor (CPF) and the price support mechanism	Briefing Paper			1
Investing in the Future: How the UK can replace EU Funding for Low Carbon Infrastructure	Briefing Paper	2	2	3
Meeting Carbon Budgets – Implications of Brexit for UK climate policy	Briefing Paper	2	2	3
Generating low- carbon electricity if there's no Brexit deal	Government Guidance	1		
Carbon price floor- Reform and other technical amendments	Governmental Note			1
The Potential Implications of Brexit on Energy and Climate Change Policy	Interview Transcript	2	4	4
Brexit's Impact On R&D Funding	Online Article - Consultanting Group		3	2
Impact of Brexit on the energy sector	Online Article - Consultanting Group	3	3	5
RCG launches multi-client study to assess the impact of a "Brexit" on the offshore renewables	Online Article - Consultanting Group	1		
UK offshore wind: What impact is Brexit likely to have on the UK's offshore wind industry?	Online Article - Consultanting Group	2	3	3
Brexit: Implications for Planning and Environment	Online Article - Law Firm	3		
Impact of Brexit on the UK and European Marine Energy Sector	Online Article - Magazine	1	1	2
Marine group fires renewables Brexit impact warning shot at government	Online Article - Magazine			1
One Year on from the EU Referendum	Online Article - Magazine	2		1
Confederation of British Industry warns of Brexit threat to energy	Online Article - Media			2
Government urged to issue post-Brexit stimulus package for green energy sector	Online Article - Media		2	1
No-Deal Brexit Leaves Renewables Exposed	Online Article - Media	1	1	1
MPs warned on Brexit RE impact	Online Article - Media			1
Industry gives qualified backing to May speech	Online Article - Media	1		
Brexit and energy: does 'taking back control' mean losing power?	Online Article - Newspaper	1		3
EU Withdrawal Bill: A guide to the Brexit repeal legislation	Online Article - Newspaper	1		
For Renewable Energy, Brexit Spurs Mixed Prospects	Online Article - Newspaper	1	1	3
Labour vows to boost British renewable energy firms	Online Article - Newspaper	1		
May says EU immigrants will lose priority status after Brexit	Online Article - Newspaper			1
Reality Check: Brexit withdrawal agreement - what it all means	Online Article - Newspaper	1		
The real Brexit challenges facing the UK in 2018	Online Article - Newspaper	1		

Figure D1. 62 documents used for content anaylsis

Name of the Document	Types of Document	Number of Occurrences of a Document in Each Section		
		Legislation and Regulation in the UK	Funding and Investment	UK Supply Chain
Brexit: A Hard or Soft Landing for Renewables?	Online Article - No Category	2	3	3
Brexit: Implications for the energy market	Online Article - No Category	1	1	3
How will Brexit affect the UK's renewables sector?	Online Article - No Category	1	2	4
Implications of Brexit on UK renewable energy	Online Article - No Category	2	3	2
OMM warn of Brexit woes	Online Article - No Category	1		1
Prime Minister supports clean energy and innovation in keynote Brexit speech	Online Article - No Category	1	1	
Renewable Energy Guarantees of Origin	Online Article - No Category	1		
What effect would Brexit have on free movement?	Online Article - No Category			1
What Would Brexit Mean for UK Renewables?	Online Article - No Category	2	1	
WindEurope: Brexit will cast a shadow over UK Investments	Online Article - No Category	1		2
Eliminating trade barriers on environmental goods and services	Online Article - World Trade Organization			1
EU Emissions Trading System (EU ETS)	Online Article (European Commission)			1
State aid control	Online Article (European Commission)		1	1
Brexit – the Implications for UK Environmental Policy and	Report	3	1	3
Brexit and energy: Time to make some hard choices	Report	1	4	4
Brexit Monitor: The impact on the energy sector	Report	2	2	5
Brexit- Energy Policy	Report	2	4	4
Impact of Brexit on the UK energy system – A statement from Durham Energy Institute	Report	2	3	3
The impact of Brexit on the UK energy sector	Report	1	1	3
The potential impact of Brexit on Scotland's renewable electricity ambitions	Report	3	4	4
UK Environmental Policy Post-Brexit/ A Risk Analysis	Report	3	3	4
National Grid Impact of Brexit on the UK energy system	Report		1	2
Brexit Insights – The Impact of Brexit on the Energy Sector	Research Paper	3	3	5
The implications of Brexit for UK energy	Research Paper	3	3	5
Brexit and Energy: Cost, Security and Climate Policy Implications	Research Paper	4	2	4
Energy and Climate Policy After Brexit	Research Paper	2	2	3
UK Unplugged? The Impacts of Brexit on Energy and Climate	Research Paper	3	4	5
Climate change policy after Brexit	Review	2	3	2
How might Brexit affect supply of energy in Scotland?	University Blog	1	1	2
Implications of Brexit for UK and EU Energy and Climate Policy	Workshop Summary	1		3
Total		**84**	**89**	**137**

Figure D2. 62 documents used for content anaylsis

Háskólasetur
Vestfjarða
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