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Maritime, Ocean Sector and Ecosystem Sustainability: Fostering Blue Growth in Atlantic Industries

Blue Growth Pathway for Offshore Renewable Energy

Contents

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Executive Summary

The sustainable growth of the offshore renewable energy (ORE) sector has become a critical issue for the development of energy supply in the EU and elsewhere. The development of ORE makes a significant contribution to global warming mitigation efforts but raises other sustainability issues which intensify as the sector continues to grow. This study considers the sector as it is developing in the EU, the Atlantic Area, and Brittany (France). The characteristics of the latter region – Brittany is that the ORE sector is currently at an initial start-up phase and there is a strong willingness to support its developments by regional authorities.

The study also identifies the strategies and the main pieces of regulation that frame the growth of the ORE sector. It outlines the wider context of ORE in Brittany as well as the current technology options. Based on public debates organised with developers and stakeholders on specific projects, the study also summarises the main drivers of sustainable blue growth development for the ORE sector and the risks associated with the strategy to be adopted. Finally, it outlines a number of recommendations that might help to support the short, medium, and long term development of the sector.

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Introduction

Against a backdrop of growing concern about the impacts of climate change and the vast use of fossil fuels by the energy, transport and manufacturing sectors, the development of renewable energy projects involves many companies and utilities worldwide. Under the Paris Agreement of the "Conference of the Parties" COP 21 (12 December 2015), the parties to the United Nations Framework Convention on Climate Change (UNFCCC) presented their national contributions to combat global warming. As a result, a growing number of industry projects focused on climate-neutral production objectives by lowering carbon intensity and prioritizing clean fuel solutions such as hydrogen-powered ships.

In 2019, the EC published the European Green Deal[1] which set the objective of cutting the EU's greenhouse gas emissions by at least 55% by 2030 to achieve climate neutrality by 2050, as part of the EU's contribution to the United Nation's 2030 Agenda for sustainable development[2], published in 2015. The strategies of the EU and its member states must be understood in this context. The situation and the perspective of the ORE sector in the Atlantic Area rely on these strategies but also on the existing state and development of technologies. Brittany provides an interesting example with different technological options available across the ORE sector. This study outlines what these options are, their advantages, and their limits in both economic and environmental terms. It is important to consider that certain decisions have already been taken with regards to these options thus limiting the scope for change or modification.

Lowering carbon intensity and prioritizing clean fuel solutions

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Offshore Renewable Energy and the Atlantic Action Plan

The offshore renewable energy (ORE) sector in the Atlantic Area should be studied with respect to the EU's objectives in terms of renewable energy, as briefly summarised in the AAP. These objectives are motivated by global warming mitigation objectives, the need for energy decarbonisation and by Europe's technological advance in certain key ORE segments.

The ORE sector

The ORE sector is a set of different technologies designed for electricity generation from the exploitation of the physical properties of marine waters and winds.

The main technologies include:

- **Offshore wind turbines** with fixed foundations turbines can only be built in close proximity to the coast thus creating a range of environmental impacts. An increasing number of pilot projects are floating offshore wind turbines (without fixed foundations) for locations over 60-80m in depth.
- **Tidal range energy plants** use estuary or artificial lagoon dams to channel tidal streams toward associated turbines.
- **Tidal stream energy** uses current turbines of diverse types fixed on the seabed that are activated by underwater streams.
- **Wave energy converters** use the motion of surface waves to generate electricity from the moving parts of the device.
- **Ocean thermal energy conversion (OTEC) plants** use the marine thermal gradient between deep and shallow waters, mainly in tropical zones.
- **Osmotic (or salinity gradient) power** is generated through the salinity gradient between seawater and freshwater. Osmotic pressure is exploited using membranes, to generate electricity.

ORE technologies differ by their development stage. The most mature ones, wind power and tidal range energy have now reached the commercial stage. Whilst the former accounts for most current ORE investments worldwide, the latter started developing in the 1960s, but its development was limited by the environmental impacts of large size units. Current turbines have reached an advanced stage towards technological maturity and some pilot projects have been successfully connected to the grid, but their generation cost remains high and no technology appears to be dominating to date. The other technologies are emerging and still at the research stage.

In terms of offshore wind, Europe is a world leader with 75% of the total installed offshore wind capacity in 2019. However, China's annual growth of offshore wind installed capacity has recently become more important than Europe's. The UK is the leading country in Europe. In 2019 the UK, Germany, Denmark, Belgium, and the Netherlands accounted for 99% of the offshore capacity connected in Europe. The North Sea accounts for almost 77% of the cumulative offshore wind capacity in Europe, the Irish Sea almost 13%, the Baltic Sea 10%, and the Atlantic Ocean less than 1% (source: WindEurope). Offshore wind is generally concentrated in the shallow waters of Europe.

Europe is also a leader in the development of floating offshore wind turbines and several prototypes are being installed and operated in the waters of the UK, Portugal, Spain, Sweden, France, and Norway. This technology is an alternative for the Atlantic Area, as fixed-bottom turbines are technically limited to 50-60 metre depths.

The EC's approach to the ORE sector, and the Atlantic Action Plan

Several initiatives have been taken for OREs by the EC in terms of Blue Growth. The EC communication of 2011 on the EU maritime strategy in the Atlantic Area[3] proposed an approach consistent with the 2020 Agenda. Among its main focuses were social cohesion and the search for new job opportunities in coastal zones from sustainable activities. The communication identified five challenges for the Atlantic Area, among which was "reducing Europe's carbon footprint" through the promotion of offshore wind energy and other OREs.

In line with the EC communication on Blue Growth[4], the Atlantic Action Plan (AAP)[5] targeted OREs under Priority 2 "Protect, secure and develop the potential of the Atlantic marine and coastal environment", and formulated the specific objective "Exploitation of the renewable energy potential of the Atlantic area's marine and coastal environment" emphasizing the need to accelerate the sustainable deployment of OREs.

In terms of offshore wind, Europe is a world leader with 75% of the total installed offshore wind capacity in 2019

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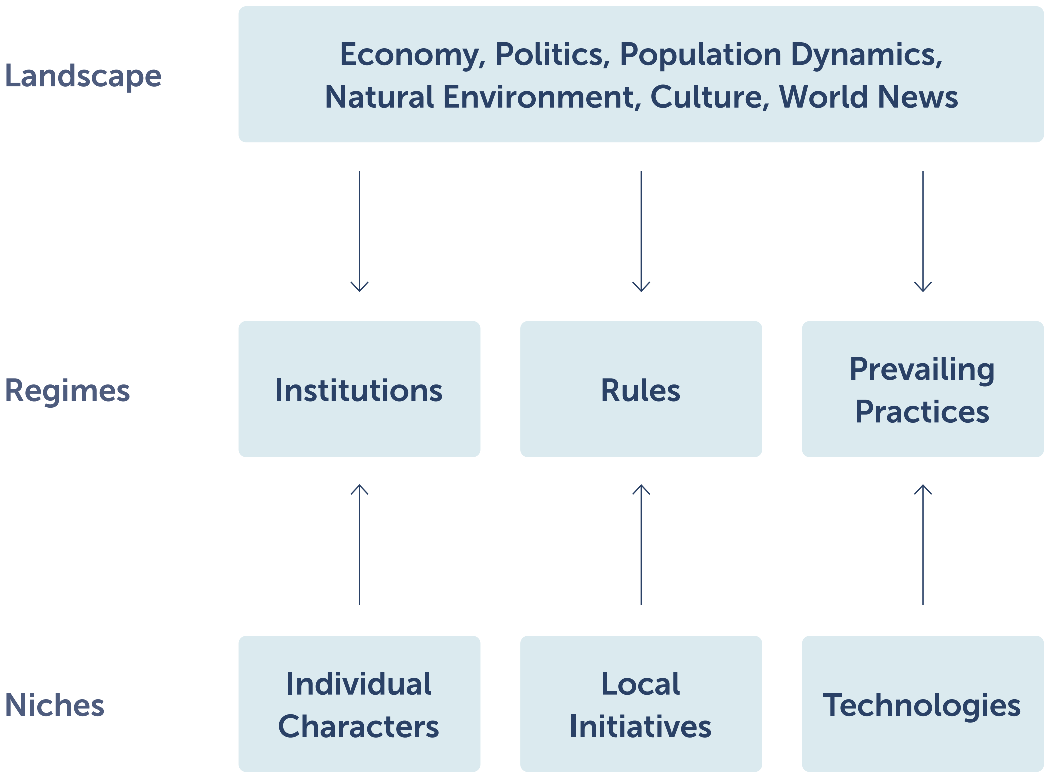
Transition Management

Transition management focuses on coordinating a wide range of actors with the aim of achieving long-term sustainability. It seeks to coordinate these actors through the creation of a shared understanding of a problem and the development of a long-term vision and sustainable pathways through which the problem can be addressed. Sustainable transitions require actors to develop an understanding of the interconnections between the current management regime and the change pressures exerted on it (See Fig 1).

The management regime is the amalgamation of the dominant practices, rules, institutions, and norms that structure activity within a particular policy area. Change pressures can be characterised as landscape pressures and niche practices. Landscape pressures operate at the macro level and include issues such as economic, political, environmental, and demographic dynamics. These dynamics put pressure on the existing regime to change but cannot be directly controlled by the regime. For example, population growth will place pressure on food and energy regimes to scale up production. Niche pressures are micro level innovations that exert pressure for regime change from below. Niches can be the actions of individual actors, the development of alternative technologies, or local management practices that do not conform to established practices and put pressure on the regime to adapt to accommodate them. For example, the development of autonomous vessels will put pressure on port and shipping regimes to accommodate novel navigation systems. Landscape pressures and niches are, therefore, vital seeds for change and are crucial for path-breaking innovations.

The Multi-Level Concept in Transition Studies

Source: Adapted from Geels, 2002[6]



Transition management focuses on the development of sustainable pathways that can overcome barriers and maximize opportunities and can steer innovations to become established within reformed and more sustainable regimes. MOSES has adopted transition management as a broad analytical framework through which to understand existing marine management regimes and to stimulate thinking about how more sustainable regimes may be realized in the future.

> **Transition management focuses on coordinating a wide range of actors with the aim of achieving long-term sustainability**

Creation of a shared understanding of a problem and the development of a long-term vision and sustainable pathways

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Offshore Renewable Energy Management Regime

European management and pressures to change

As highlighted in section 2 of this study, the development of the ORE sector was prioritized in the AAP. However, in terms of EU policy ORE is not only a matter of marine strategy. As part of its 2030-2050 energy and climate objectives and in line with the green deal and social cohesion strategies, the EC published a roadmap[7] in 2020 for public feedback and consultation. The roadmap addressed the future development of OREs in the EU and insisted that the current development pace was "far too slow" to meet carbon neutrality by 2050. It urged a "massive scale-up" to keep up EU's leadership and leverage the potential of OREs in line with the green deal. It also announced the preparation of a European ORE strategy to propose a sustainable development pathway for the industry and to identify actions at both European and regional levels. The EC's ORE strategy[8], published in November 2020, is in keeping with the roadmap. In particular, the strategy sets installed capacity objectives of 60 GW in 2030 and 300 GW in 2050 for offshore wind energy in the EU27 as compared to the current capacity of 12 GW; for ocean energies (such as wave power, tidal stream generators and tidal barrage energy, floating photovoltaic, and algae-based biofuel production) these two objectives are of 1 GW and 40 GW. The delivery of these objectives will require a considerable effort from industry, comprehensive support from public authorities and an overall investment estimated at around EUR 800 billion.

The EC's vision of ORE growth in the near to mid-term future is therefore ambitious both in terms of the necessary amount of funding required but also the required electric power and transmission capacity. Furthermore, it addresses the issue of coastal planning as a major challenge raised by space-consuming OREs. A practical issue raised by the strategy is that most wind farms are assumed to be fixed foundation, so either installed nearby to the shore with inevitable economic and environmental impacts or concentrated in European waters with limited depth where many wind farms have already been installed (see section 2.1). Floating turbines represent an alternative, but more costly technology with a higher LCOE[9], at EUR80 to 100/MWh, as compared to around EUR50/MWh for the former.

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MOSES Offshore Renewable Energy Case Study

The ORE sector in France: sluggish growth and need for transition
France is characterized by early development of ORE. A tidal plant was installed in north Brittany in 1965 on the estuary of the Rance river (240 MW), which significantly impacted the local ecosystem. No other plant of such type and scale was subsequently built on the French coast. In the 2000s and 2010s, the development of ORE was limited to pilot submarine current turbines, operated off the north Brittany coast. No offshore wind capacity has been installed in French waters except for pilot projects.

The law "on energy transition for green growth"[10], enacted on 17 Aug. 2015, a few months before the COP21 Climate Change Conference (Dec. 2015), aimed at, among other things, significantly decreasing greenhouse gas emissions, final energy consumption, and fossil fuel primary energy consumption by 2050. The "Multiannual Energy Programme", a key guidance document aimed at committing support from public authorities is the operational tool to meet these objectives. It was published in 2019 after public debates and was followed by a decree[11] summarising national objectives in terms of energy consumption and supply for the two successive five-year periods of 2019-2023 and 2024-2028. The Multiannual Energy Programme, which is due to be updated every five years outlines a pathway to achieve carbon neutrality by 2050.

In terms of ORE, this programme aims at publishing six calls for tender which include three fixed-bottom farms and three floating farms. These will be issued until 2023 amounting to 3.75 GW and an extension of these farms after 2023 which would equate to around 500 MW per year. It would also lead to a 2.4 MW installed offshore wind capacity in 2023 and between 5.2 and 6.2 MW in 2028. It does not include any new tidal plant project. Submarine current turbines would not reach the commercial stage, the goal being to proceed with pilot projects to further improve and develop the technology.

The Multiannual Energy Programme, which is due to be updated every five years outlines a pathway to achieve carbon neutrality by 2050

Slow growth and high potential of the ORE sector in Brittany

Brittany produces modest amounts of energy as compared to consumption. Its energy balance is in permanent deficit. Owing to potential environmental impacts as well as political reasons, it is difficult to build large size electricity plants in this region. The current state of Brittany's ORE projects is listed in Table 1. Overall, power production is modest but represents a basis for the design of a blue growth scenario.

Table 1. ORE production and projects in Brittany

Developers	Type and size	Power	State of development
EDF (electric utility), Open Hydro (affiliate of Naval Energies)	Submarine current turbine, north coast. 4 units. 40m water depth.	0.5 MW per unit	Pilot farm. Development now stopped after Naval Energies' withdrawal.
Eolfi Offshore France, Naval Energies (Naval Group)	Floating wind farm, south coast. 3 units of 9.5 MW planned. 60m water depth.	28.5 MW	Pilot farm. Construction planned in 2021 and due to start operation in 2022. Followed by a 250MW farm project tendered in 2021 in the same zone and a 500MW farm due to be tendered in 2024.
Sabella D10	Submarine current turbines, west coast. First prototype in a series of 2 planned. 55m water depth.	1 MW	Pilot farm. One unit still in operation. Carbone fiber blades made by CDK Technologies, Brittany.
Ailes marines (affiliate of Iberdrola)	Fixed-bottom wind farm, north coast, 62 turbines, 75 km^2, 16.3 km to the coast.	500 MW	Commercial farm. Construction in 2021. Operation due to start in 2023.
Wattmor project. Fortum (Finland) and Naval Energies (France)	Wave energy converter	1.5 MW	Feasibility study underway for a pilot project on west coast.
Eolink, wih support from Brittany Region and Ifremer	Floating wind turbine. 1/10 scale model. Square base.	5 MW	Feasibility study underway for a full scale 15 MW turbine by 2027 and 20 MW by 2030.
EDF	Tidal range plant, estuary of Rance river, north coast.	240 MW	In operation since 1965.

Two river current turbines have not been listed above, as this table is limited to marine projects.
Source: Bretagne Pole Naval, report to Ifremer on ORE projects in Brittany, 2020

The design of a sustainable pathway for ORE in Brittany requires identifying sustainability conditions based on information available on the projects listed in Table 1. Two of these projects are especially useful to investigate, the floating farm projects of the south coast and the submarine current turbine prototype of the west coast. These two projects raise most of the issues to consider for the development of an ORE sustainable pathway. The debates organised by the National Commission for Public Debates (CNDP)[12] with developers, stakeholders and local communities addressed most environmental issues resulting from the floating farm project. They also helped to identify the main conditions for a blue growth pathway for ORE in Brittany.

Conditions for ORE development in Brittany

This next section uses the cases of floating farms and submarine current turbines to outline the main conditions for a sustainable ORE growth pathway in Brittany. Floating farms are prioritised by the Multiannual Energy Programme and local authorities with the goal of reaching the commercial stage whilst current turbines would remain at the pilot project stage. In terms of the floating farm project, the positive aspect of this technology, as compared to fixed-foundation turbines, is its capacity factor (around 40% to 45%), as well as its locational flexibility, i.e. sufficient distance from the coast that avoids overlaps with marine protected areas and tourist zones (Sections 2 and 4). The selected area of the south Brittany of the farm site lies outside Natura 2000 and other protected zones after discussions with stakeholders including local administrations and fisheries. Cable connections are routed outside ecologically sensitive zones.

To accurately determine the most adapted location of the site inside the selected area, the side-effects from the technology were discussed by stakeholders, locals, and developers during a series of CNDP debates on the project and are summarised below.

a) Impacts of technology

- Connection to the grid and floating farms with semi-submersible foundations, such as those associated with the project. These include a submarine cable linking the set of turbines to an onshore station via the seabed. The generation of magnetic fields impacting marine and human lives concerns coastal populations, although mitigating solutions do exist.
- Anchoring is a system of several anchors which links each floating turbine to the seabed by metallic and synthetic fiber cables.
- Regulated access to waters surrounding floating generators is explained by the anchoring system and submarine cables. It would impact fisheries as a 10km^2 area would be lost in a zone of important stocks, with possible fish sanctuary effects inside the farm zone.
- Navigation would be regulated inside the farm zone in terms of vessel size and speed, distance from generators and prohibition of mooring.
- Possible impacts of the 12,000 tonnes semi-submersible units on waves and coastline.
- Behaviour of turbines and foundations under strong storm, wind, or wave conditions and such issues are usually addressed by engineering solutions.
- Technical and environmental conditions for dismantling.

b) Impacts on environmental assets

- Visual impacts of the 180-meter-high turbines ranging from the shore and boating zones.
- Risk of marine birds flying into direct contact with the turbine blades.

c) Economic impacts

- Impacts on fisheries and boating have an economic dimension.
- Risks of impacts on real estate markets in coastal zones.
- The relevance of funding a floating turbine project with an initial overcost as compared to solar and other alternatives has been questioned.

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Pathway for Sustainable Development of ORE

Research presented in this study allows the framing of a sustainable Blue Growth pathway in terms of ORE in Brittany and the Atlantic Area in general.

- Several decisions have already been made at state and regional levels which are unlikely to be reversed. The Multiannual Energy Programme has been enacted at the state level, and Brittany's regional strategy aims at a 500 MW submarine current turbine capacity and 1,500 MW floating wind power by 2030.

- Indeed, in terms of technology Brittany has few options. Three options have been investigated and debated at state and regional levels and include: fixed foundation wind, floating wind, and submarine current turbines. The LCOE of the latter is still high (EUR 300/MWh or over), and strong current zones are geographically limited. Engineers recommend that it would be feasible to install around 1,500 devices in the west Brittany zone (see tab. 1: Sabella project) to generate an overall 2GW power which is equivalent to four wind farms. Pending a detailed feasibility study on this option, wind farms are the most likely solution in the short term to meet France and its own commitments in line with the EU renewables strategy. Floating turbines can be more easily installed far from the coast, but the technology is constraining for other activities, especially fisheries.

- For the ORE sector, the cost of a sustainable Blue Growth pathway is significant in both environmental and economic terms. Avoiding the most important environmental externalities generates high costs, and floating wind is not the cheapest option. However, worldwide competition is emerging between businesses as well as countries for floating farm technology leadership. This may encourage member states' strategies and accelerate development with the goal of rapidly lowering floating LCOE.

- To verify a sustainable pathway, regular monitoring and evaluation of the economic and environmental impacts would be critical in the short, medium and long term.

In the short term, Brittany will develop a fixed-foundation wind farm off the north coast, a floating pilot project off the south coast, and will continue to test current submarine turbines on the west coast. In the medium term, the two floating farms (250 and 500 MW) off the south coast are likely to be built if funding is available, and acceptance is secured by authorities' willingness to mitigate economic (fisheries) and social (coastal communities) impacts. Before advancing the objectives of the region, monitoring of the impacts created by floating generators will inevitably be required to help better understand the economies of scale, the impacts on biodiversity and waves, as well as issues linked to social acceptance. Under the assumption that the current submarine turbine LCOE can decrease and the region confirms its willingness to develop this technology, the same mechanism applies. This will also require monitoring the impacts created by the development of such generators in terms of cost as well as on local marine currents.

The development of these two technologies will take place as several countries are implementing similar strategies, especially for floating turbines. Such massive development requires research and monitoring of 1) the state of the world market for the basic commodities consumed by the generators, especially metals. A floating wind generator contains around one ton of rare earths, and more than 90% of rare earths are currently supplied by China. At present, tensions also appear in markets of certain battery-critical metals, used for electric cars and wind generators. 2) It also requires monitoring the development of hydrogen technology. At long distance (more than 80 km), an alternating current cable is less efficient to link the farms to the shore. Hydrogen electrolysis represents an alternative considered by several oil companies and may become an important driver in the future evolution of ORE technologies.

Most of these conclusions are applicable across the Atlantic Area in general, as the development of floating farms is also an objective in all Atlantic countries. Likewise, given the considerable current marine capacity potential in Scottish waters, the development of submarine current turbines is an important objective in the UK.

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