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EUROPE'S COMMITMENT TO MARINE RENEWABLE ENERGY

Ocean and Offshore Wind

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1 Introduction

1.1 Objective and Scope

This work is part of the course 'European Economy and Blue Growth', integrated in the Jean Monnet Chair in 'EU Maritime Policy and Blue Growth' granted to the Universidade Nova de Lisboa.

It aims to address the issue of Marine Energy, namely the importance of harnessing European marine resources for the energy sector and its socio-economic implications. Nevertheless, in coherence with the scope of the study, which derives from a curricular unit where a multidisciplinary nature of students predominates, some of the more fundamental technical concepts will be introduced in order to allow a better contextualization of the renewable energy theme.

The paper is structured in 5 chapters and its logical sequence seeks to facilitate the understanding of the document, starting by offering, in the first chapter, a justification for the writing of the document and introduce a general framework to the theme.

The Blue Economy theme is introduced in the follow-up to the previous chapter and the need for European Maritime Policies to address maritime issues in an integrated way is supported.

In the following chapter, a brief description of the state of the art of the different marine energy production technologies is given, followed by an exhibition of some Trends and Statistics on investments in these technologies in Europe.

The Opportunities and Challenges of the Marine Energy Sector are also presented, with the objective of making known, in addition to the projects that are being developed, the difficulties that remain in the application of innovations.

Finally, in the chapter of the Conclusions, a summary of the work is made from a perspective of the economic potential of the Marine Energy sector in Europe.

1.2 Framework: Renewable Energy in Europe

The adverse effects of greenhouse gas (GHG) emissions on the earth's atmosphere have led to an increase in the planet's average temperature, causing extreme weather events to emerge[1].

With the aggravation of climate change comes the need for international communities to reinforce efforts to mitigate their impacts on the environment, particularly in the most relevant sectors[2].

It can be noted that in 2017 the Energy sector, composed of the Energy (28.2%) and Combustion industries (25.8%), was the largest contributor to GHG emissions - with 54% of the total - in the EU-28, followed by the Transport and Agriculture sectors - with 24.6% and 9.8% respectively[3] – Figure 1.1.

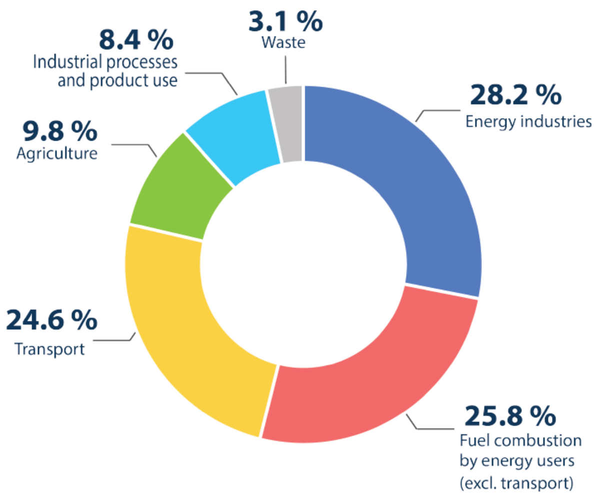

Figure 1.1. GHG emissions by sector consumption, EU-28, 2017 (Adapted from EUROSTAT[3])

In the same year, energy consumption in the European domain was met by around 45% of locally produced energy (European) and 55% of imported energy [3] – Figure 1.2.

Figure 1.2. Energy available in EU-28, 2017

The energy available in the EU-28 results from a mix of various forms of energy[4], of which the three largest parcels stand out: Petroleum Products (41.3%), Natural Gas (21.9%) and Electricity (20.7%)[3] – Figure 1.3. Only 31% of electricity comes from renewable energy sources, compared to 49% from fossil fuels and 25% from nuclear power[3,5].

For electricity production in the EU-28, the fraction obtained through renewables is equivalent to a quarter of the total production[6] – Figure 1.4, of which ocean energy accounts for only 0.06%[6] – Figure 1.5, implying the existence of an untapped potential. The European Commission estimates that by 2050 ocean energy could meet about 10% of the EU-28's energy needs[7].

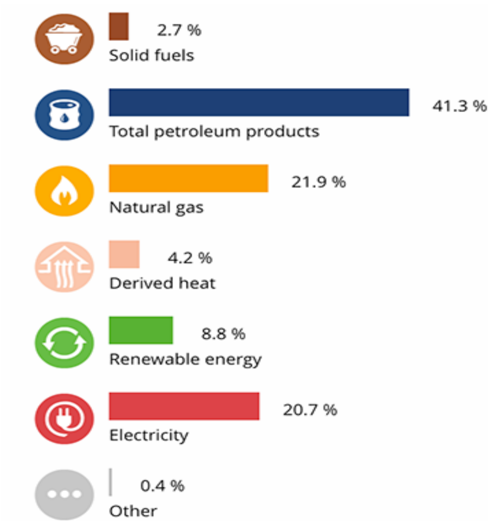

Figure 1.3. Energy consumption in EU-28, 2017 (Adapted from EUROSTAT[3])

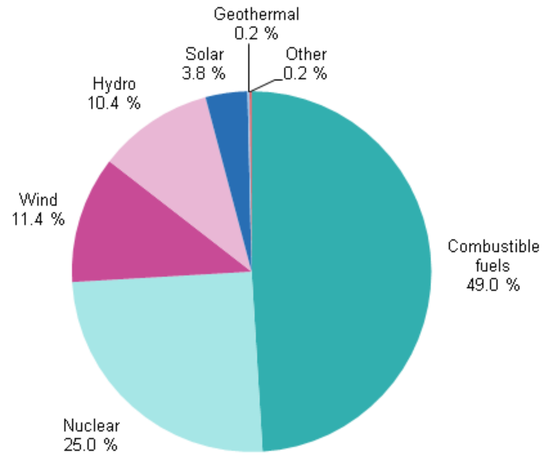

Figure 1.4. EU-28 electricity production, 2017 (Adapted from EUROSTAT [5])

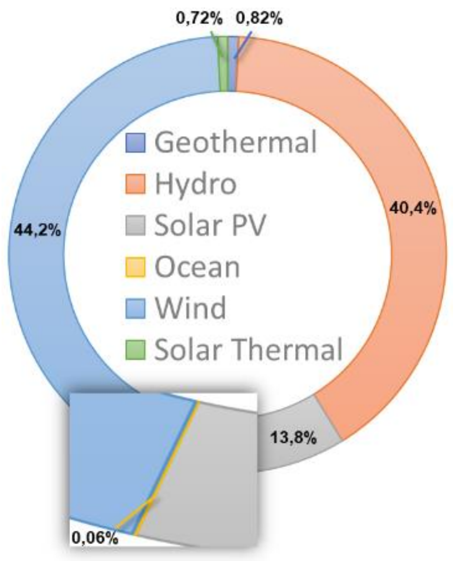

Figure 1.5. Production of electricity from renewable sources in the EU-28, 2017 (Adapted from IEA[6])

2 Blue Economy

As growing energy consumption signals the scarcity of resources such as oil and natural gas, the energy sector is attempting to tackle this problem, at both consumption and production levels, with environmental and economic concerns in mind[1].

Marine resources such as wind, ocean currents, waves, tides and ocean biomass represent a vast source of renewable energy[8] which when properly exploited can secure a significant portion of the electricity supply in many coastal areas of Europe, thus contributing to economic development and job creation in these regions[9].

There is, however, an important constraint on the governance of the European maritime space which interferes with the action of member states in matters of planning: around 60% of the oceanic space is outside the borders of national jurisdiction[10], forcing a shared international responsibility. The United Nations Convention on the Law of the Sea (UNCLOS) establishes an international legal regime governing the ocean[10]. A large number of jurisdictional rights, institutions and specific structures have been created to organise the way States use maritime space[8].

2.1 European Maritime Policies

Over the last decade, the EU has taken a number of measures to mitigate the impacts of its maritime and coastal activities, and a number of EU policy tools and instruments have been put in place to address maritime issues in a holistic manner[11,12] (Figure 2.1).

Figure 2.1. Main instruments of European maritime policy

In February 2015, the European Commission created a strategy for the European Energy Union (EU), based on five interconnected dimensions and designed to foster greater energy security, sustainability and competitiveness[13] – Figure 2.2.

Dimensions	Objectives
Energy security, solidarity and reliability:	Diversifying Europe's energy sources and increasing their efficiency of use in the EU.
Integrated internal energy market:	Use connectors that allow the free flow of energy within the EU, without technical or regulatory constraints, in order to offer sustainable competition at the best prices.
Energy efficiency contributing to moderate demand:	Consume less energy in order to reduce pollution, preserve energy resources and reduce import requirements.
Decarbonization of the economy:	Encourage a global agreement to accommodate climate change and encourage private investment in new infrastructure and technology.
Research, Innovation and Competition:	Support advancements in low carbon technologies through the coordination of research and project funding together with the private sector.

Figure 2.2. Table with dimensions and objectives of the EEU[13]

In order to take advantage of the energy potential contained in the oceans, and following the unification of international efforts to scale up a strategic approach to the energy sector, the Oceans Energy Forum appears in 2014[7]. This initiative, which took the form of open meetings, workshops and conferences, in which promoters, experts and public authorities participated, culminates in 2016 in the Strategic Ocean Energy Roadmap, a document which aims to identify priority actions for the development of the ocean energy sector in Europe[7].

A strategy was later developed at EU level to boost sustainable blue growth and take advantage of the EU - the European Green Pact [14,15]. The latter takes account of blue economy considerations in external policies, particularly as regards natural resources, energy, trade, development and security.

The European Green Deal highlights the key role that marine renewable energy forms, notably offshore wind energy, can play in the transition to a low-carbon economy[15].

Given that the Blue Economy is expected to play a crucial role in the achievement of greenhouse gas emissions and biodiversity targets[14,16], it is expected that there will be enhanced EU investment support.

In 2019, the European Investment Bank (EIB) unveiled a new ambition for climate and environmental sustainability and an energy lending policy that will affect all sectors, including the Blue Economy[16,17]. The central objective would be to discontinue funding of inactive fossil fuel energy projects (including natural gas) by the end of 2021[17]. In this way, the energy transition will be accompanied, in a similar way, by a migration in investments.

The EIB expects to invest around 1 trillion euros in climate action and environmental sustainability projects in the period 2021-2030[17], stipulating a gradual increase in this investment to achieve 50% of its operations by 2025[17].

In February 2020, a cooperation between the European Investment Fund (EIF) and the European Commission announced the Blue Invest Fund which intends to provide 75 million euros - including up to 22 million euros in 2019 and 20 million euros in 2020 - of funding for action funds that have a strategic objective and support the Blue Economy in activities related to oceans, seas and coastal areas[14,16,18,19] (Figure 2.3).

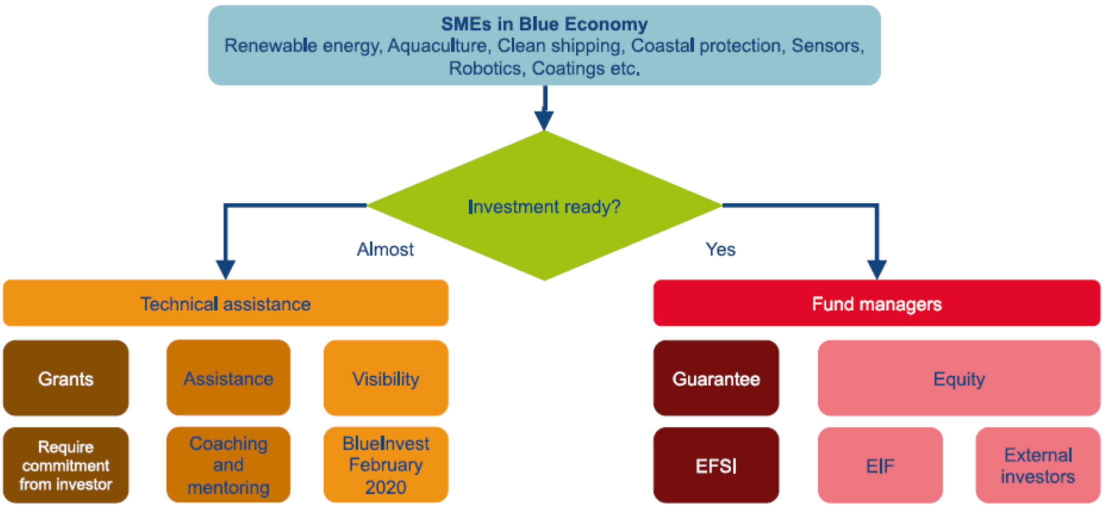

Figure 2.3. Blue Invest Fund Structure[14]

3 State of the Art

Europe's coastal waters offer a source of opportunities for marine renewable energy production facilities, including: offshore wind, ocean energy, floating photovoltaics and offshore hydrogen (as an energy carrier)[14,18,20] – Figure 3.1. These production technologies take advantage of the most diverse phenomena and resources of the marine biome and are currently at different stages of maturity.

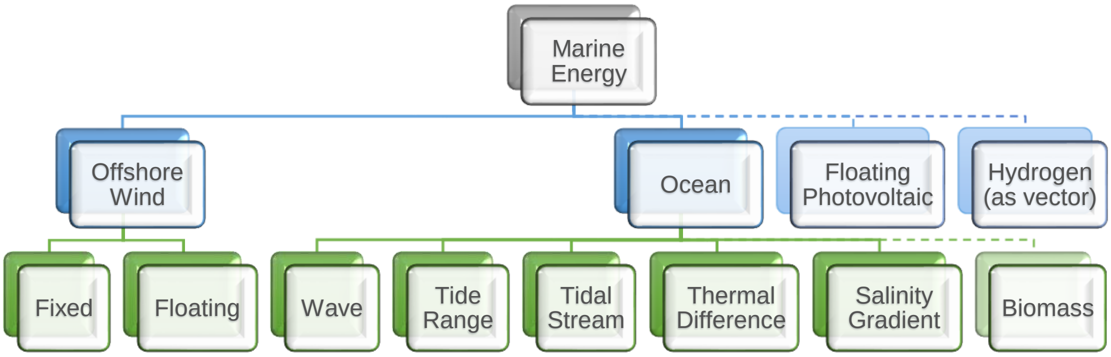

Figure 3.1. Marine energy production technologies

3.1 *Offshore Wind*

Offshore wind is the most commercially and technologically developed marine renewable energy sub-sector in the world and is rapidly achieving electricity supplier status [21].

The EU-28 has over 90% of the world's total installed offshore wind capacity [22]. Offshore wind market activity is currently concentrated in the Atlantic Ocean, and the Baltic and North Sea basins. The innovations are relevant for the Atlantic and Baltic basins, where offshore wind is commercially established and more mature[23].

3.2 Ocean

Ocean Energy has advantages at many levels in comparison to other renewable energy sources and is therefore considered a viable option in the search for a sustainable future. According to Ocean Energy Europe, the added value of this form of energy is supported by six key points[24]:

- Unexplored Potential

By 2050, it will be able to generate enough electricity to meet 10% of Europe's energy needs.

- Energy Security and Independence

Ocean Energy, due to its inherent and infinite potential, is capable of reducing dependence on imports of fossil fuels and reducing the associated bill by 226 billion euros annually.

- Export Opportunity to Europe

It is estimated that Europe will be able to dominate about 53 billion euros of the global market annually.

- Environmentally Responsible Solution

Approximately 234 million tonnes of CO_2 could be avoided.

- Ideal complement

The production of energy at different times from Solar and Wind allows the system of electricity demand and supply to be harmonized.

- New European Industry

The installed capacity of 100GW of ocean energy by 2050 in Europe will create an immense economic contribution, revitalising coastal areas, creating new opportunities for traditional maritime industries, and generating close to 400,000 new jobs[18].

Waves[7]

Wave energy converters derive energy from wave motion and can be flexibly located - on the coast, near shore or at sea at depths greater than 100 m - to harness available energy more efficiently. A variety of full-scale prototypes have already been deployed, but further development and research of these technologies is needed before they can be implemented on an industrial scale.

Tide Range[7]

Tidal technologies use the differences in sea level (between high and low tides) to create energy. Tidal stream technology uses the same principles as hydropower and requires a barrier to capture a large body of water, propelling turbines that generate electricity. Tidal stream energy technologies are the most well-established forms of ocean energy, with several projects around the world.

Tidal Stream[7]

Tidal stream turbines take advantage of the flow of sea currents to produce electricity and can be fixed directly to the sea bottom or floating, anchored to the sea bottom.

Ocean Thermal Energy Conversion (OTEC)[7]

Ocean Thermal Energy Conversion (OTEC) uses heat exchangers to explore temperature differences, between cold waters on the ocean floor and "warm" waters on the surface.

Salinity Gradient[7]

Salinity gradient power generation uses the difference in salt content between fresh and salt water, found in areas such as deltas or *fjords*, to provide a constant flow of electricity by reverse electrodialysis - RED - or by delayed pressure osmosis - PRO. The potential for deployment is significant across Europe. However, further technology development is needed to bring the salinity gradient to maturity

Ocean Biomass[25]

Marine algae are highly suitable for the production of biofuels. Between 85 and 90% of algae are water, which means that algae can undergo biofuel production processes such as anaerobic digestion to produce biogas, and fermentation to produce ethanol.

3.3 Floating Photovoltaic

Floating Photovoltaic (FPV) installations consist of a floating structure on which regular solar panels are installed. To date, most FPV structures have been installed on lakes and in the vicinity of water reservoirs, with offshore FPV being predominantly in the Research and Development (R&D) and demonstration phase.

Projects are underway to validate the technology to prove its efficiency, conversion and durability under adverse conditions in the Netherlands (Oceans of Energy, TNO) and France (HelioRec). The 17 kW system (50 kW in the future) designed by Oceans of Energy, has withstood different storms with waves over 5 m high.

3.4 Offshore Hydrogen

The production of hydrogen by electrolysis from renewable sources, in particular from marine sources, can help overcome various challenges and provide alternatives for storing excess electricity produced at sea that is not immediately delivered to the grid. Once produced, hydrogen could be used in the production of electricity (in fuel cells) or as fuel for cars and ships.

4 Trends and Statistics

Europe has already implemented its own marine energy sector, with a higher incidence of ocean energy in the North Sea and the Atlantic Ocean, and offshore wind energy in the southern Baltic Sea region[23] – Figure 4.1.

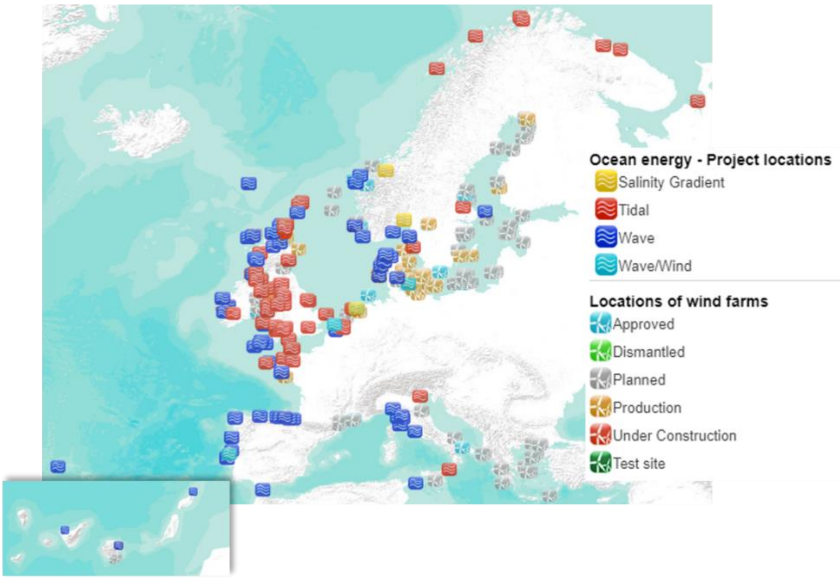

Figure 4.1. Distribution of European Marine Energy Projects, 2020 (Adapted from European Commission[23])

4.1 *Offshore Wind*

Among marine renewable energy production technologies, the most commonly deployed to date is offshore wind. It is a widely known technology because of its similarities to energy production in onshore wind farms, so it is not surprising that there is a large flow of investment in this area of renewables. Within the European domain alone, there is already an installed capacity of 183 GW onshore and 22 GW offshore (Figure 4.2), spread over 110 wind farms and over 5,000 turbines in 12 European countries (including the United Kingdom).

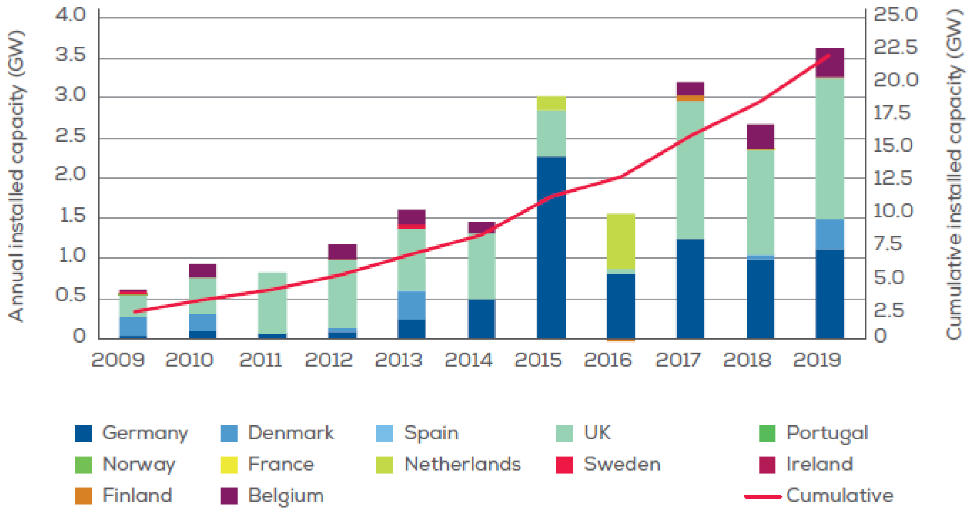

Figure 4.2. Installed and cumulative offshore wind power in Europe by country[26]

In the last year alone, Europe installed a net offshore wind capacity of 3,623 MW, setting a record in annual offshore installations [26]. The countries responsible for this increase were the United Kingdom (1,764 MW), Denmark (374 MW), Belgium (370 MW), Germany (1,111 MW) and Portugal (8 MW), where the first three also set annual installed capacity records[26] (Figure 4.2). The North Sea accounts for 77% of installed capacity, followed by the Irish Sea with 13% and the Baltic Sea with 10%. (Figure 4.3).

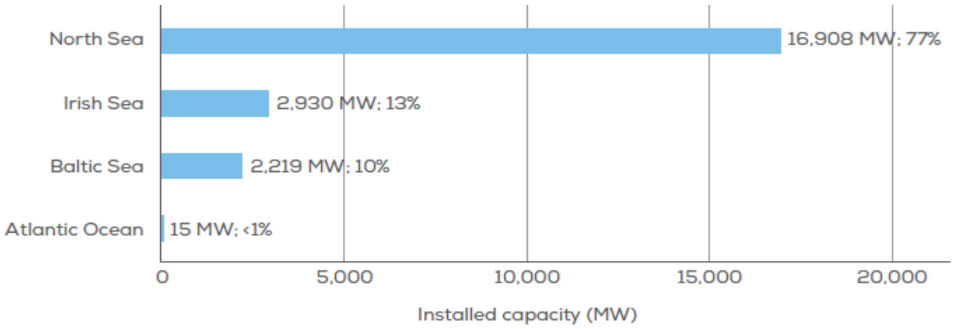

Figure 4.3. Installed capacity per sea basin[26]

4.1.1 Offshore Wind Investments

Investments in offshore wind projects are traditionally dominated by project finance, making use of investment funds, due to the tendency for offshore wind farms to occupy large areas and there being a limited number of developers able to finance the high capital requirements.

Between 2012 and 2016, there was a significant increase in investment in these technologies, with a sharp drop after the maximum of 18.2bn euros in 2016. In 2017, investment in offshore wind power generation was 7.5bn euros, having remained in the same range of values (10.3bn and 6bn euros) for the following years[26] (Figure 4.4).

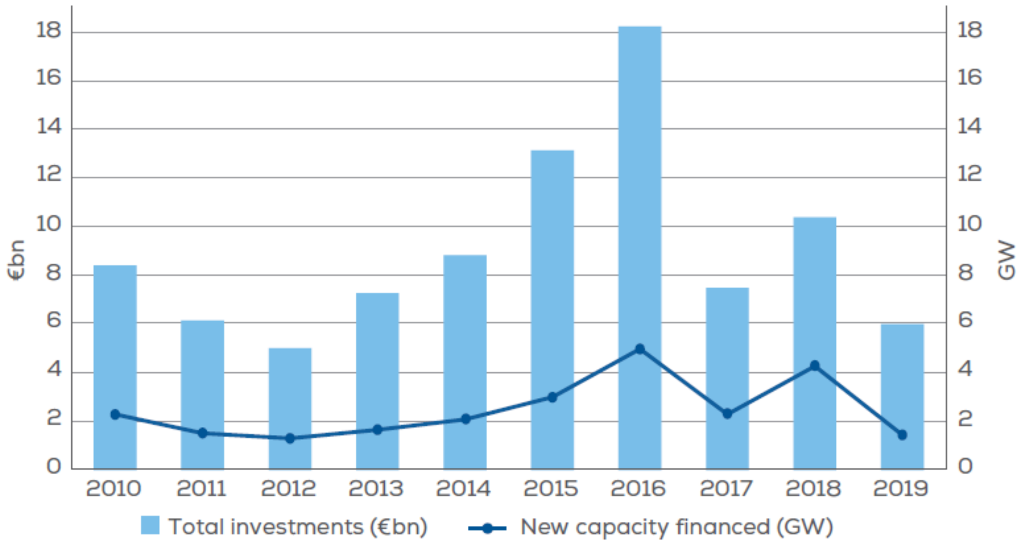

Figure 4.4. New funding for Offshore Wind Technology in EU-28, 2019[26]

Given the amounts invested in onshore wind production technologies, which have proved much more stable by comparison, the peak in investment in offshore wind in 2016 is indicative not only of an increase in the valorisation of this technology, but also of the reduced degree of confidence in its state of the art. On the contrary, a product such as onshore wind that has already proven itself profitable in the energy market, displays a typical investment for its state of maturity (Figure 4.5).

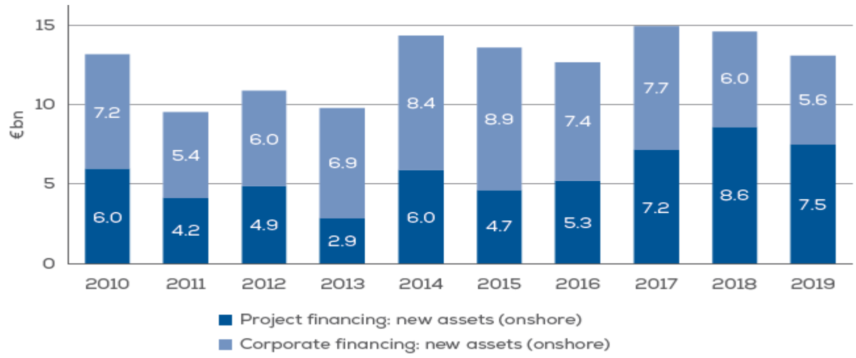

Figure 4.5. Financing of onshore wind generation technologies in the EU-28, 2019[17]

While the EU ranks as the largest patent holder for marine renewable energy technologies, the implementation of these technologies, with the exception of offshore wind, is still under-exploited due to lack of investor confidence.

4.2 Ocean

Ocean energy is of particular relevance in the European context under tidal stream and wave energy technologies. According to Ocean Energy Europe data for 2019, about 39.5 MW of ocean energy have been installed since 2010, with 11.9 MW still in the operating phase and the remaining 27.6 MW decommissioned after the tests have been successfully completed[24].

4.2.1 Tidal Stream

Tidal stream production technology capacity in Europe in 2019 was 1.52 MW, with a decrease of almost 60% since 2018 (Figure 4.6). In the decade 2010-2019, there were 27.7 MW of tidal stream technology implemented, with 10.4 MW currently in operation[24].

The countries that encouraged the deployment of tidal energy technologies were France and the United Kingdom, largely due to the existence of competitive test facilities offering grid connection and the potential for expansion (Figure 4.7).

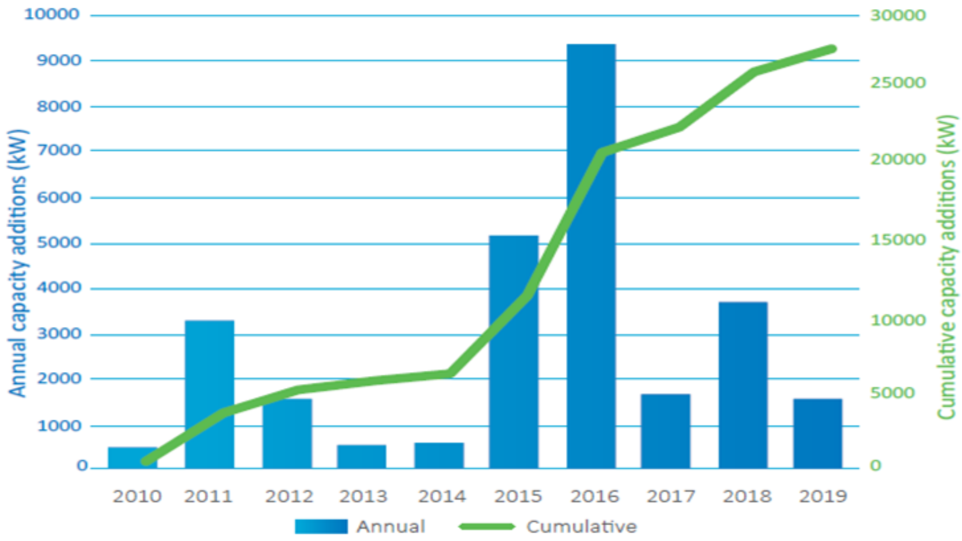

Figure 4.6. Annual and Cumulative Tidal Current Capacity in Europe [24]

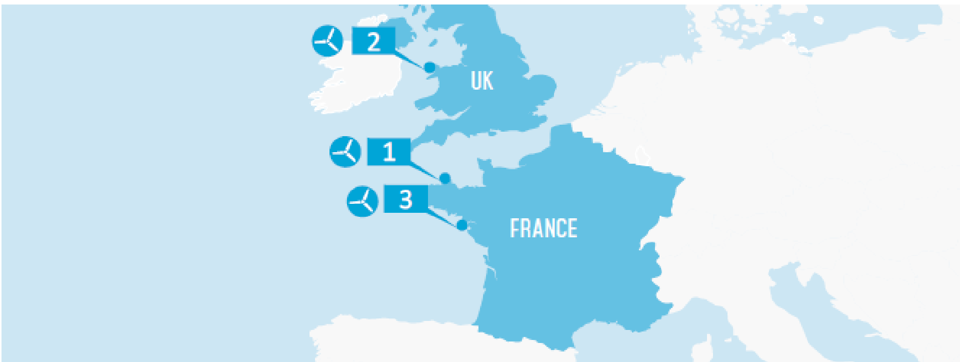

Figure 4.7. Location of tidal power generation projects in 2019[24]

4.2.2 Wave

The capacity of wave production technologies installed in Europe in 2019 was 603 kW, with an increase of around 25% since 2018 (Figure 4.8). In the decade 2010-2019, there were 11.8 MW of wave technology implemented, with 1.5 MW currently in operation.

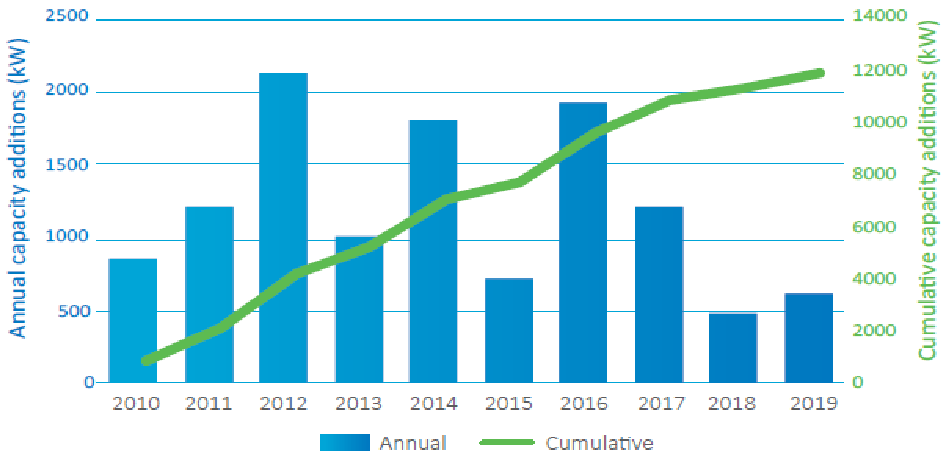

Figure 4.8. Annual and Cumulative Wave Capacity in Europe[24]

Six nations stand out in the implementation of wave energy technologies in 2019, namely Portugal, France, Belgium, Italy, England and Scotland – Figure 4.9. In a similar way to tidal production, the motivations for giving preference to these countries were the existence of competitive testing facilities as well as investment funds.

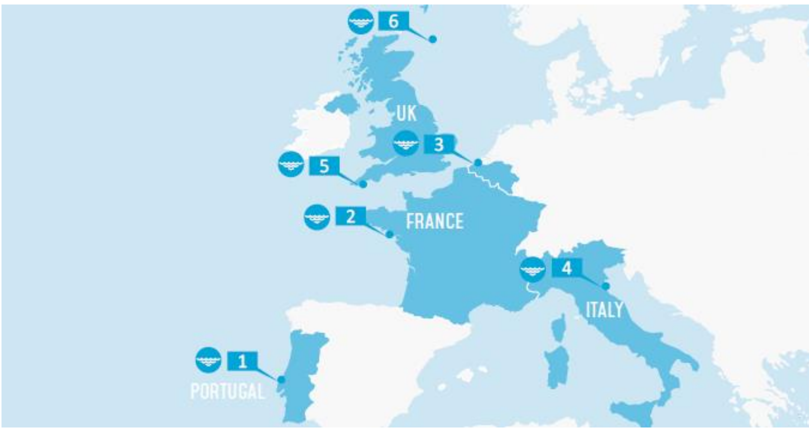

Figure 4.9. Location of projects for wave energy production in 2019[24]

4.2.3 Wave Investments

As a whole, Europe remains the world leader in ocean energy, but the lack of support for national revenues and the increased foreign activity is putting this leadership under pressure[18].

The European Commission estimates that more than 5 billion euros of private funds were invested in ocean energy worldwide between 1978 and 2017; and in the last 10 years, more than 400 million euros will have gone to R&D[14] (Figure 4.10). In terms of R&I, the Member States' budget increased from an average of € 5 million per year (1995-2008) to an average of € 48 million per year (2009-2015), as all phases of development benefit from R&I.

The various forms of ocean energy, such as wave and tidal energy, continue to be developed and the sector already employs around 2,250 individuals[14].

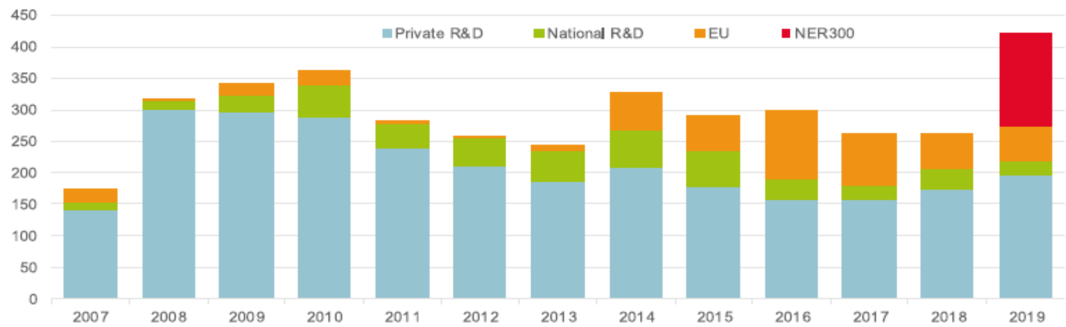

Figure 4.10. EU R&D expenditure on wave and tidal energy in millions of euros[14]

5 Challenges and Opportunities

5.1 Investment opportunities

5.1.1 Offshore Wind

In total, 15 offshore wind farms in 6 countries had work underway last year, 10 of which have connected turbines to the grid, and 5 wind farms have simply installed the foundations[26] – Figure 5.1.

COUNTRY	WIND FARM	FOUNDATIONS INSTALLED IN 2019	TOTAL NUMBER OF FOUNDATIONS	TURBINE MODEL	TYPE OF FOUNDATION
Germany	EnBW Albatros	16	16	SWT-7.0-154 (SGRE)	Monopile
Netherlands	Borssele 3&4	30	77	V164-9.5 MW (MHI Vestas)	Monopile
Belgium	Northwester 2	23	23	V164-9.5 MW (MHI Vestas)	Monopile
	Mermaid	28	28	SG 8.4-167 DD (SGRE)	Monopile
	Seastar	30	30	SG 8.4-167 DD (SGRE)	Monopile

Figure 5.1. Wind farms not yet connected to the grid in 2019[26]

The European Commission considers that in order to meet renewable energy targets and manage maritime spatial planning (MSP), alternatives to fixed wind power generation structures should be considered[26]. Although there is limited economic data on this subject, several Member States are carrying out tests to find the most suitable materials for floating structures (economically efficient and less harmful to the environment) – Figure 5.2.

Project	Country	First Power	Capacity (MW)	Floating substructure
Hywind Scotland	UK	2017 (operational)	30	Spar-buoy
Floatgen Project[1]	FR	2018 (operational)	2	Barge
WindFloat Atlantic (WFA)[2]	PT	2019 (partly operational)	25	Semi-Submersible
Kincardine Offshore Windfarm Project	UK	2020	50	Semi-Submersible
BALEA[2]	ES	Earliest 2021 (2024)	26	
Nautilus Demonstration	ES	Earliest 2021	5	Semi-Submersible
DemoSATH - BIMEP	ES	2021	2	Semi-Submersible
SeaTwirl S2[3] (VAWT)	NO	2021	1	Spar-buoy
EolMed[4]	FR	2021	25	Barge
Seawind 6 demonstrator	UK	2021	6	Semi-Submersible
FWT Groix & Belle-Île	FR	2022	24	Semi-Submersible
FWT Provence Grand Large/VERTIMED[2]	FR	2022	25	Tension-leg platform
FWT Golfe du Lion	FR	2022	24	Semi-Submersible
Katanes Floating Energy Park - Pilot[5]	UK	2022	8	Semi-Submersible
Hywind Tampen	NO	2022	88	Spar-buoy
Seawind 12 demonstrator	UK	2024	12	Semi-Submersible
FLOCAN 5[2]	ES	2024	25	Semi-Submersible

Figure 5.2. Floating offshore wind projects, 2019[14]

5.1.2 Ocean

EU-28 plans to implement up to 3.4 MW of tidal energy, and 3 MW of wave energy in 2020[24]. Several new devices will be tested in Denmark, the UK and Spain, supported by the DEMO Ocean project, and sponsored by the EU. Much of the installed wave power will come from large capacity devices, and on a large scale[24].

5.2 Challenges

There are numerous obstacles to the development and deployment of marine energy production technologies, and they extend across the subsystems of the Blue Economy. These impediments, which are typical of the technology or the stages of development in which they are found, most often overlap and fall within the technological, socio-economic, political and environmental fields.

At the technological level, two key factors that constrain investment in Research, Development and Innovation (R&D&I) stand out. On the one hand, the lack of electrical grid connections is a substantial barrier to the development of marine energy, as it contributes to the increase of overall costs; on the other hand, the scarce information about these technologies inhibits possible investors who, in turn, do not foster R&D&I projects.

With the industrial deployment, the potential for conflict with other stakeholders regarding access to marine resources, aesthetics and visual amenity, noise and other factors will require special consideration.

Different Member States and regions will have interests in different marine energy technologies, depending on their natural resources and the state of their industry. The development of a common understanding of the technological, political and financial needs of the sector at the different stages of development will facilitate dialogue and cooperation.

From the perspective of environmental protection, the study of the environmental impacts associated with new and emerging technologies helps decision-makers and stakeholders to have the best and most up-to-date information. A key component will be the establishment of a common strategic environmental research programme to address the main consent issues and knowledge gaps.

Conclusions

The energy sector is the largest contributor to greenhouse gas emissions, and it is therefore necessary to find renewable alternatives to the fossil energy sources currently used.

Marine resources have a wide range of renewable energy sources, recognised globally, and in particular by the EU-28, as it has 90% of the world's total installed offshore wind capacity. Nevertheless, the energy potential of the seas and oceans is far from being fully exploited.

This requires policy instruments that govern joint action at international level and benefit communities, notably the European ones such as the European Energy Union, the European Green Deal, and the Blue Invest Fund. These instruments make it possible to find consensus on objectives and methods of action.

In general, marine energy production technologies are in primary stages of maturity, with the exception of offshore wind whose technical characteristics derive closely from onshore wind farms and are therefore the most exploited.

Currently, the EU-28 hosts the implementation of 22 GW of offshore wind power and 11.9 MW of ocean power. This discrepancy in capacity, although tending to increase in the overall picture, is mirrored in the capital invested, with values in the order of billions for offshore wind energy, and in the order of millions for ocean energy.

Although projects for marine energy production technologies are planned for Europe in the near future, there are still many challenges related to the technological, socio-economic, political and environmental components.

Due to the limitations established in the elaboration of this work, a number of issues in the theme of European Marine Renewable Energy have been left unmentioned, particularly the framing of European data in the global context. This document aims to summarise the wide range of information available from the various authorities and stakeholders, with emphasis on the European Commission itself, and to make known part of the work that has been done for the European community.

References

1. EUSTAT. Greenhouse gas emission statistics - emission inventories. *Eurostat*. 2018;63(3):175-180.

2. APA. Roteiro Nacional de Baixo Carbono 2050 - Análise técnica das opções de transição para uma economia de baixo carbono competitiva em 2050. *Alterações Climáticas*. 2012:122.

3. Eurostat. Shedding light on renewable energy in the EU. 2019:1-28. doi:10.2785/555325

4. EU. Blue Energy - IMPACT ASSESSMENT. 2014;(2013):1-8.

5. Eurostat. Electricity production, consumption and market overview. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_production,_consumption_and_market_overview. Published 2019.

6. IEA. Renewables Information 2018: Overview. *IEA Stat*. 2018:497.

7. Ocean Energy Forum. Ocean Energy Strategic Roadmap: Building Ocean Energy for Europe. 2016:74. https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1036.

8. Borthwick AGL. Marine Renewable Energy Seascape. *Engineering*. 2016;2(1):69-78. doi:10.1016/J.ENG.2016.01.011

9. Johnson K, Dalton G, Masters I. *Building Industries at Sea: “Blue Growth” and the New Maritime Economy*.; 2018. doi:10.13052/rp-9788793609259

10. IUCN. GOVERNING AREAS BEYOND NATIONAL JURISDICTION. 2015;(November):21-22.

11. Yates KL, Bradshaw CJA. Offshore energy and marine spatial planning. *Offshore Energy Mar Spat Plan*. 2017:1-300. doi:10.4324/9781315666877

12. European Commission. An Integrated Maritime Policy for the European Union (JOIN(2016) 21 final). 2016:1-17. http://www.eeas.europa.eu/arctic_region/docs/160427_joint-communication-an-integrated-european-union-policy-for-the-arctic_en.pdf

13. Comissão Europeia. Uma estratégia-quadro para uma União da Energia resiliente. 2015.

14. European Commission. The EU Blue Economy Report 2020.

15. Comissão Europeia. Pacto Ecológico Europeu. *Comissão Eur*. 2019. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_pt.

16. European Commission. *The EU Blue Economy Report 2019*.; 2019. doi:10.2771/21854

17. WindEurope. Financing and investment trends. 2020:48.

18. José Luis Villate, Pablo Ruiz-Minguela, Joannès Berque, Lotta Pirttimaa, Donagh Cagney, Charlotte Cochrane HJ. Strategic Research and Innovation Agenda (SRIA) for ocean energy. 2020;(826033).

19. DGMare, EIF, PwC. Introducing the BlueInvest Fund : Sustainable financing for the Blue Economy. 2020;(May).

20. Koh SLC. *The Maritime Dimension of Sustainable Energy Security*. Vol 15.; 2019. doi:10.1080/19480881.2019.1581519

21. Hoegh-Guldberg O, Caldeira K, Chopin T, et al. The Ocean as a Solution to Climate Change: Five Opportunities for Action. 2019:116. http://www.oceanpanel.org/climate.

22. Schiffer H-W. World Energy Resources 2016. *World Energy Counc 2016*. 2016:6-46. https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources_SummaryReport_2016.10.03.pdf

23. EMODnet, European Commission. European Atlas of the Sea. https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/#lang=EN;p=w;bkgd=15;theme=88:0.75,89:0.75;c=-125355.78503082693,7521102.976680031;z=3.

24. Amy Parsons RG. Ocean Energy - Key trends and statistics 2019. *Lect Notes Energy*. 2020;3(March):215-243. doi:10.1007/978-1-4471-4385-7_11

25. Pinto D. Gamma Radiation applied to the Pretreatment of Macroalgae Biomass for Biofuel Production. 2020.

26. Walsh C. Offshore wind in Europe - Key trends and statistics 2019. *Refocus*. 2019;3(2):14-17. doi:10.1016/s1471-0846(02)80021-x