

Non-technical Challenges in Developing Offshore Renewable Energy Projects

North Sea Solutions for Innovation
in Corrosion for Energy

June
2018





The NeSSIE project (2017-2019) seeks to deliver new business and investment opportunities in corrosion solutions and new materials for offshore energy installations. The project aims to draw on North Sea regional expertise in traditional offshore sectors (i.e. oil and gas, shipbuilding) in order to develop solutions for emerging opportunities in offshore renewable energy sources (wave, tidal and offshore wind energy).

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1 Acronyms

ACS	Anti-corrosion solution
CAPEX	Capital expenditure
GWEC	Global Wind Energy Council
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre
LCOE	Levelised Cost of Energy
MSP	Marine Spatial Plan
NREAP	National Renewable Energy Action Plan
O&M	Operation and Maintenance
OEM	Original equipment manufacturers
OPEX	Operating expenditure
ORE	Offshore renewable energy
OWT	Offshore wind turbine
RES	Renewable energy source
SME	Small to Medium size Enterprise
TEC	Tidal energy converter
WEC	Wave energy converter
WP	Work Package

2 Executive Summary

This report supports the aim of NeSSIE to develop Offshore Renewable Energy (ORE) demonstration projects related to corrosion issues through the identification of the current landscape. An overview of the market, finance, infrastructure and regulatory status regarding ORE in Europe, specifically for the North Sea basin countries, followed by the challenges encountered in these areas for the development of ORE towards commercialisation.

In terms of market deployment, wave and tidal energy are at a relatively early stage, followed by floating offshore wind, whereas fixed offshore wind has reached commercialisation. It is expected for marine energy generation to move towards industrial roll-out by 2030. Market challenges for ORE to reach their deployment potential are varied and specifically the combination of technical and non-technical challenges. These include affordability, performance, standardisation, reliability, survivability, installability and environmental considerations.

Due to the early stage of marine energy, project development comes with high risks, resulting in difficulties in securing funding. For these early stage ORE technologies to move towards commercialisation, financial support throughout the complete trajectory towards commercialisation is required to avoid technologies disappearing in the 'valley of death' between demonstration and commercial status. To ensure sufficient and appropriate funding sources, the need for coordination is expressed.

Both hard and soft infrastructure aspects are of relevance to the ORE sector. Hard infrastructure refers to the tangible facilities such as ports, vessels, transport, power, manufacturing facilities, etc. required to facilitate the ORE roll-out. Soft infrastructure encompasses the health and safety regulations and legislation, personnel training, design/manufacturing standards and offshore environmental impact assessments required. Identified infrastructure challenges are a conflict of marine space, the lack of skilled workers and an insufficient grid capacity for these renewable energy sources to be connected.

Within the European Union and the Member States, there are different legal instruments, with different levels of enforcement power that are of importance to the implementation of the demonstration projects in the North Sea basin.

Regulatory challenges encountered in the ORE sector are found to be related to the uncertainties in consenting and the uncertainties of the environmental impact. In addition, the need for a clear and encompassing certification process is indicated.

The findings of this report feed in to the NeSSIE Roadmap (Deliverable D3.4), which aims to provide a pathway to the reduction of lifetime costs of ORE components through the use of anti-corrosion solutions (ACSs) by identifying and prioritising the key challenges associated with ACS in the ORE sector.

3 Introduction

This report seeks to research the non-technological challenges inherent in the larger construction of the NeSSIE **Roadmap** and **Investment Plan** to apply anti-corrosion solutions (ACSs) in the offshore renewable energy (ORE) sector. ACSs refer to corrosion mitigation, management, monitoring as well as novel materials usage.

NeSSIE builds on the partnerships formed in the Vanguard Initiative Energy Pilot to build robust, high-integrity manufacturing value chains for marine offshore energy applications by identifying common areas of expertise, identifying common challenges and developing networks to support innovative technology/service developments. A key identified technology challenge considered was corrosion in water and corrosion protection for marine operating devices, which have been traditionally made using steel which is highly susceptible to corrosion in salt water. The ultimate aim is to reduce the lifetime costs of offshore renewable energy technology components, and make devices cheaper to construct, install and operate – thus lowering their levelised cost of electricity (LCOE) generation. Anti-corrosion systems will lead to maintaining and potentially increasing the energy conversion efficiency, availability, survivability and reliability, whilst at the same time significantly affecting operation costs (OPEX) associated with operation and maintenance (O&M) activities for wave energy converters (WECs), tidal energy converters (TECs) and offshore wind turbines (OWTs).

NeSSIE seeks to research the optimum method for translating original equipment manufacturer (OEM) expertise and their value chains across to marine energy device construction and operations to:

- Deliver three sustainable, investable short-term demonstration projects in the North Sea region;
- Create and establish new cross-sectoral supply chains in the medium to long term;
- Build a long-term North Sea strategic specialisation partnership with wider EU regions.

This report, Deliverable 3.1 (D3.1) in the NeSSIE project, undertakes a strategic analysis of the non-technology deployment/commercial challenges and barriers to developing ORE demonstration projects and supply chains. This report and the work on the state of the art of anti-corrosion solutions from WP2 are used in the development of the Roadmap (D3.4); as portrayed in Figure 1.

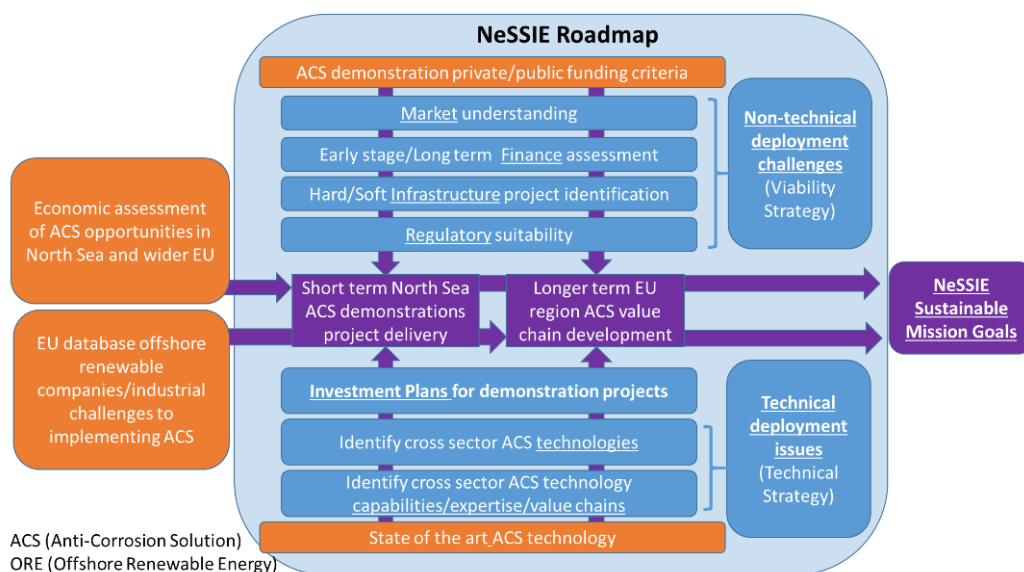


Figure 1 – Integration of WP2 and WP3 deliverables to produce final Roadmap and NeSSIE mission goals

The chapters of this report are broken down into key areas focusing on a North Sea basin pilot in the short-term demonstration window and a medium/longer term future perspective:

- **Market:** Current development and prospects of the ORE sector.
- **Finance:** Early stage financing for ORE demonstration projects with the aim to translate this to ACS innovation/new materials demonstration projects. Long-term finance strategy for post demonstration projects and supply chains.
- **Infrastructure:** Hard (facilities, availability, etc.) and soft (skills, health and safety, etc.) factors affecting small to medium enterprise's (SME) ability to test and deliver projects.
- **Regulation:** Identification and suitability of environmental and consenting legislation to ACS testing and delivery.

4 Market development

When analysing non-technological market challenges for ACSs, it is relevant to investigate the expected ORE evolution and the driving market segments. In the case of ACSs for offshore renewable energy, this challenge is especially complex as this potential evolution depends on the success of several different markets in, again, different levels of technological maturity. These are wave energy, tidal stream and offshore wind, the latter also depending on if installation takes place in shallow or deep waters (by means of floating platforms). The first sections of this chapter gather insights on how these different offshore renewable energy sources are expected to evolve and their key challenges. This is followed by the role of ACSs to tackle offshore renewable challenges. This will help to identify the best targets for the three demonstration projects, which constitute the final objective of NeSSIE.

As mentioned, the three considered ORE alternatives are at different stages of technology readiness:

- In **wave energy**, although a range of full-scale prototypes has been deployed, more design divergence and further technology development is required prior to commercialisation and roll-out.
- Several **tidal stream** power developers are testing full-scale prototypes in offshore environments, mainly converging to a dominant technology concept (i.e. horizontal axis). It is worth highlighting the MeyGen project, the world's largest tidal-stream endeavour under construction, located between the Scottish mainland and Orkney Islands, with a first phase consisting of four 1.5MW turbines (adding up to 6MW) and a final aim of 398MW [1].
- **Offshore wind** is by far the most developed market of the ORE technologies, with more than 12GW installed in Europe. However, the floating option for deep waters has not reached commercialisation. There are several demonstrators, which are being tested but with no dominant concept yet.

Figure 2 is a summarized timeline for the expected development of OREs considered for the demonstration projects of NeSSIE (based on the ORECCA project [2] and the Ocean Energy Strategic Roadmap [3]). It is organized in five different stages, as suggested by Ocean Energy Europe: R&D, Prototype, Demonstration, Pre-Commercial and Industrial Roll-Out.

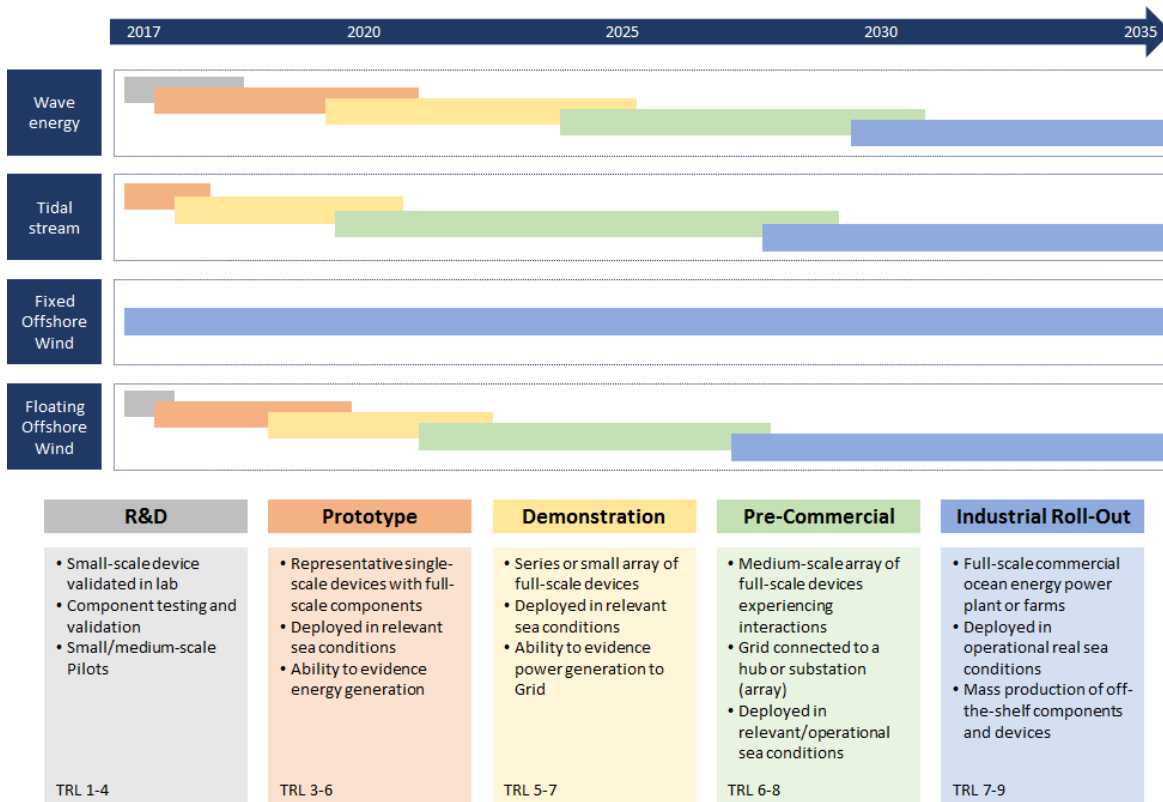


Figure 2 – Expected development of marine energies, based on [3]

In the following sections, an overview of the current deployment and expected evolution for each offshore generation technology is discussed, with a special focus on its market potential in the North Sea basin.

4.1 Market Wave and Tidal energy

4.1.1 Market status and prospects

According to the Annual Report of the IEA OES, ‘An overview of activities in 2017’ [4] the global wave energy deployment has increased to approximately 8 MW in 2017, however not all of this capacity is still installed as these deployments have been demonstration projects, and thus often in the water for a limited time span. Examples of wave energy demonstration projects in operation in 2017 in the North Sea basin are displayed in Table 1.

Project	Country, Location	Device Developer	Device	Capacity
Isle of Muck	UK, Isle of Muck	Albatern	WaveNET/SQUID	22 kW
WaveEL	Norway, Runde	Waves4Power	WaveEL	1x 200kW
CEFOW	UK, Orkney Billia Croo	Wello Oy	Penguin	1x 500kW

Table 1 – Examples of wave energy projects in operation in 2017 in the North Sea basin, based on [4]

The number of projects located in North Sea basin countries is coherent with the distribution of wave resource throughout Europe, as can be seen in Figure 3.

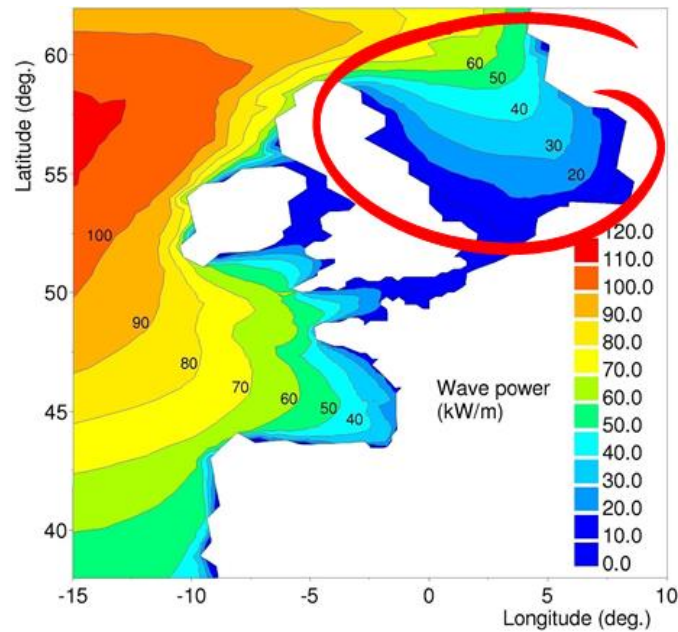


Figure 3 – Map of wave energy resource in Europe [5]

It is worth noting that for wave energy technology convergence has not yet taken place. Technological drawbacks have reduced the confidence of investors in wave energy technology. Current initiatives (such as the ones shown in the Table 1) are aimed at ensuring a more thorough assessment of wave energy technology throughout the various testing and development phases.

In contrast with wave energy, tidal current technologies have made significant progress towards industrialization in the past years with pre-commercial installed devices converging towards one technology class, i.e. horizontal axis turbines. At the same time, some other alternatives are being tested (e.g. tidal kites). For this technology, the path to commercialization is focusing on two main areas: large devices over 1MW, and smaller turbines for niche markets. Examples of the tidal energy projects in the North Sea basin in operation in 2017 can be found in Table 2.

Project	Country, Location	Device Developer	Device	Capacity
Shetland Tidal Array	UK, Shetland Bluemull Sound	Nova Innovation Ltd.	M100	3x 100kW
MeyGen	UK, Scotland Pentland Firth	Atlantis Resources Ltd.	AR1500	4x 1.5MW
Eastern Scheldt	Netherlands, Eastern Scheldt	Tocado Internatiol B.V.	T2	5x 250kW
FloTEC	UK, Orkney	Scotrenewables Tidal Power Ltd	SR2000	1x 2MW

Table 2 – Examples of tidal current projects in operation in 2017 in the North Sea basin based on [4]

Global tidal current energy deployment surpassed 17MW in 2017. Similarly to the installed wave energy projects, due to the demonstration nature of these projects and the associated time limit not all of the 17 is currently installed [4].

According to the JRC Ocean Energy Status Report 2016 Edition, the majority of worldwide tidal projects occur in Europe, specifically in the North Sea basin [6]. This predominance of tidal projects in the North Sea basin, specifically in the UK, is related to the available resources, as shown in Figure 4. The projects in the Netherlands are located at the storm surge barriers, creating an increased tidal flow.



Figure 4 – Map of tidal current resource in Europe [7]

Ocean Energy Europe, the industry association, estimates a combined 100 GW of wave and tidal energy capacity can be deployed in Europe by 2050 [8]. The global market for ocean energy could see 337 GW of installed capacity by 2050 [9]. It should be noted that this capacity roll-out will largely depend on the funds assigned to R&D and on the ability to converge to a successful technology with competitive LCOE.

4.1.2 LCOE status and prospects

The emerging state of wave and tidal energy, as it is still in the prototype or pre-commercial stage, adds a complexity in identifying LCOE levels. Latest estimations indicate that tidal energy has costs around €350/MWh, with higher costs for wave energy at about €450/MWh [10].

For Europe, the ORE market presents a potential progress towards a resource-efficient economy, with high projections in terms of economic growth and job creation. However, the forecasted large scale and commercial deployment are still far away. The increase in ORE installed capacity will only be possible if a dramatic reduction of the LCOE of these renewable sources is achieved. In an analysis in 2014 led by the Vanguard Initiative ADMA Pilot [11], market experts, wind farm developers and technology OEM companies suggested that a competitive LCOE should be around 130-150 €/MWh for wave and tidal generation by 2020. The SI Ocean report 'Wave and Tidal Energy Market Deployment Strategy for Europe' indicates the expected cost reduction through the cumulative deployed capacity (Figure 5). This shows the necessity of demonstration projects to drive down the cost, in the coming years.

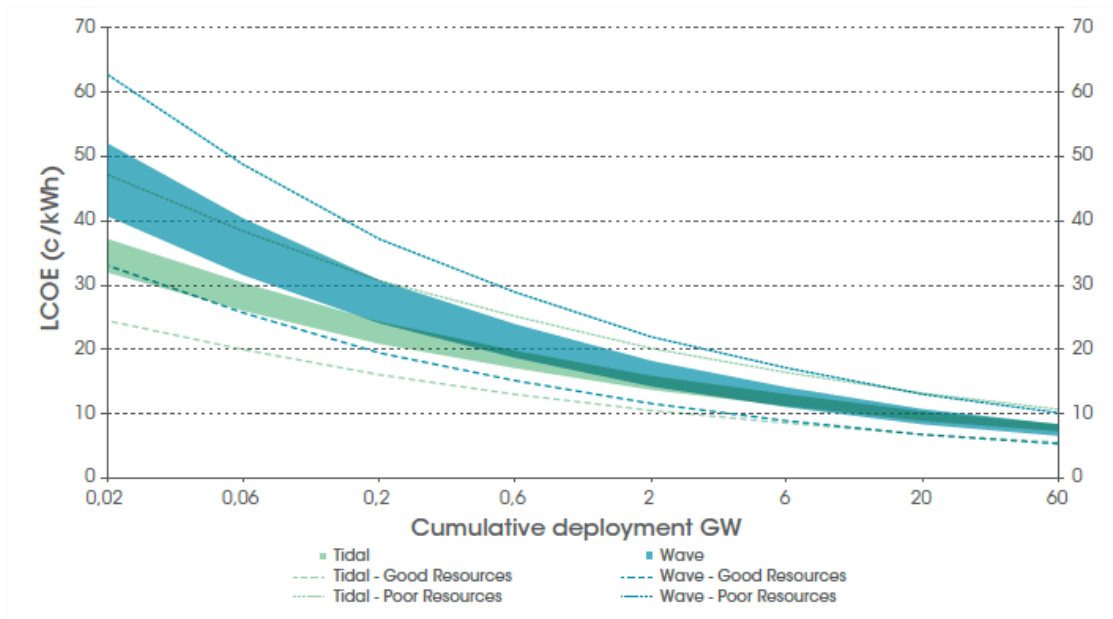


Figure 5 – Expected Wave & Tidal LCOE evolution as of cumulative deployment [10]

4.2 Market Offshore Wind energy

4.2.1 Market status and prospects

As the Global Offshore Wind 2016 and Beyond report from the GWEC states [12], offshore wind is a more developed market that has shown steady annual growth in the past year, building up to a global installed cumulative capacity of 14.4 GW in 2016 (Figure 6). A total of 2.2 GW offshore wind was installed in 2016. Although numbers were down 31% from the 2015 record, the future looks promising as the industry continues maturing, investor confidence grows, and the new generation of machines are expected to increase in capacity and to become more cost-efficient.

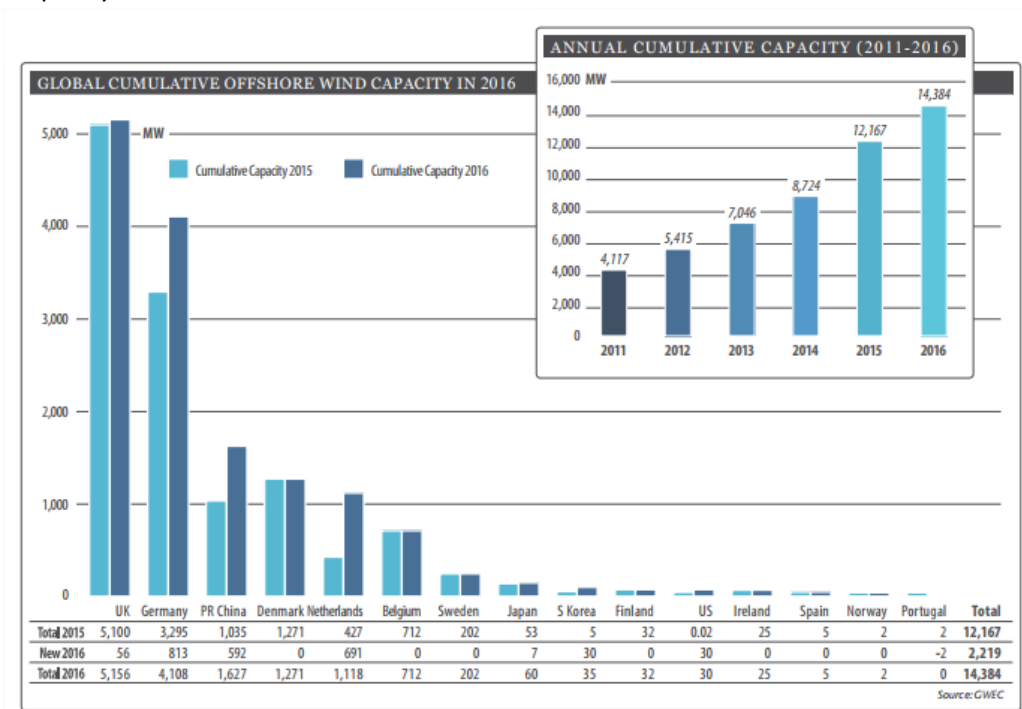


Figure 6 – Global Cumulative Offshore Wind Capacity in 2016 [12]

Over 85% of global offshore wind power is located in Europe, where the North Sea basin countries currently dominate the market. The UK is the world’s largest market and accounts for just under 36% of installed capacity, followed by Germany with 29%. Denmark now accounts for 9%, the Netherlands for 8% and Belgium for 5% of the world’s offshore wind market [12].

The quality of the wind resource and the shallow depths of the North Sea basin countries will keep their focus on offshore wind development in Europe in the next five years. In fact, the high number of projects that started construction confirms a noticeable activity in the next years, with an annual average of 3.4 GW added in 2017 and 2018 [13] (Figure 7).

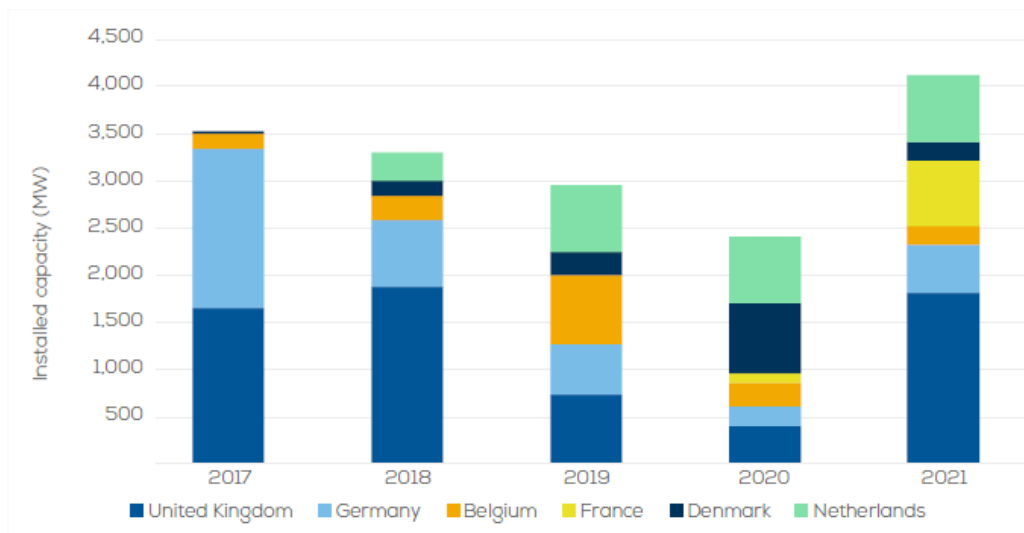


Figure 7 – European offshore wind project pipeline five-year outlook [13]

There will be significant capacity addition in all North Sea basin countries (UK, Germany, Belgium, France, Denmark and the Netherlands). By 2020, the European cumulative offshore wind capacity will be about 25 GW [13].

The short-term growth of the offshore wind market will be led by fixed-bottom structures that need lower levels of investment. However, given that there are limited locations with shallow waters suitable for fixed-bottom foundations and that there is extensive wind resource in deep waters, floating wind is potentially a highly scalable future energy source in a number of markets.

There is significant potential and interest in floating structures in Japan, the United States, and a number of European countries including the UK, Norway, France, Portugal and Spain. This is shown in Table 3 from the Carbon Trust report [14].

Country/Region	Share of offshore wind resource in deep water locations (>60m depth)	Potential capacity	floating wind
Europe	80%	4,000 GW	
USA	60%	2,450 GW	
Japan	80%	500 GW	

Table 3 – Offshore wind resource and potential floating wind capacity in Europe, USA, and Japan [14]

4.2.2 LCOE status and prospects

There has been a significant LCOE reduction for offshore wind, with the reduction expected to continue in the coming years. Figure 7 shows the current and projected LCOE range trajectory from 2015 to 2030 included in Wind Europe’s 2017 offshore wind resource assessment. The LCOE values of 2018 fall in the range of €100-€140/MWh. Wind farms to be commissioned after 2020 have prices ranging 65-95€/MWh [15]. This is below the competitive value of €100/MWh as indicated by the previously mentioned Vanguard Initiative ADMA Pilot report [9]. For example, in early 2017 the UK government awarded a contract to Dong Energy at a price of 65€/MWh for its 1.4 GW Hornsea II Project off England’s north-east coast, which will become the world’s largest offshore wind farm [16]. In addition, Vattenfall won a bid mid-2017 for two wind farms (Vesterhav Nord and Vesterhav Syd) with a combined capacity of 350MW just off the west coast of Jutland (Denmark) with a LCOE of €61/MWh [17]. These low LCOE values can be realized due to the advantageous locations. The sites have a good resource, are close to shore - removing the need for an offshore substation thus saving money in the transmission system, are close to potential construction ports and operation and maintenance ports and are suitable for monopole foundations.

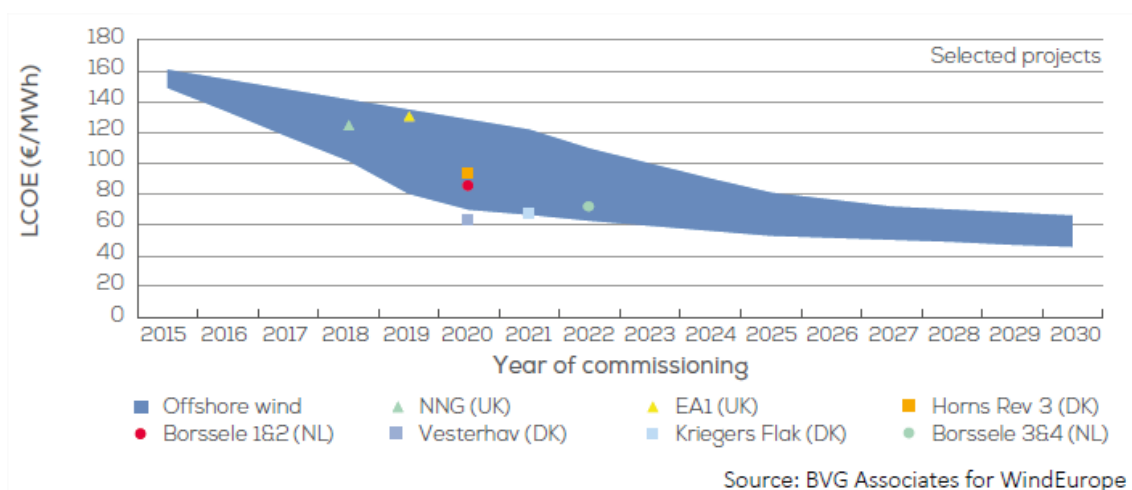


Figure 8 – Offshore wind LCOE range and trajectory from 2015 to 2030, including estimated LCOE [15]

4.3 Capacity targets of North Sea basin countries

The renewable energy targets of the North Sea basin countries are briefly described in Table 4, with a specific focus on the wave, tidal and offshore wind activities where applicable.

Country	Targets
Belgium	The country’s binding target for 2030 is 13% of renewable energy generation. The offshore wind energy concessions in the Belgian North Sea will have the biggest impact on renewables, leading up to a total of 2.2 GW of offshore wind power installed by 2020 [18]. Offshore wind already constitutes a mature market in Belgium with a large offshore development. Belgian wind projects in the North Sea may not require any state subsidy in the near future [19]. Regarding wave and tidal energy deployment, the focus is on R&D and demonstration projects, such as FlanSea and Laminaria devices, rather than deploying commercial ocean energy systems due to the mild sea climate [18].
Denmark	Denmark is known as the wind energy pioneer, with a clear target of 50% of electricity generation to be met by wind energy before 2020 [20]. A stable tender framework offers selected bidders 15 years of stable cash flows. The 2012 Energy Agreement set out Denmark’s significant offshore wind expansion in the form of tenders, in which the lowest bidder wins and cover the first 50,000 full-load hours [21]. The National strategy on wave energy of 2012 resulted in both the ‘Danish Partnership for Wave Energy’, to encourage innovation and collaboration, and the Roadmaps for Wave Energy Development in 2015.

	In addition, Denmark has a test centre, DanWEC. This centre includes the grid connected test site of Nissum Bredning and the Hanstholm site [18].
Germany	The total of offshore wind energy capacity has reached 5.3 GW in 2017 [22]. The offshore wind power industry is moving away from subsidy-based deployment through the implementation of auctions. Tidal and wave energy is covered under the EEG (Renewable Energy Sources Act) with fixed feed-in tariffs of €12.4 cents/kWh for projects below 500 kW [4]. In addition, tidal and wave R&D, such as the TidalPower project, is funded under the energy research programme of the Federal Ministry for Economic Affairs and Energy [4].
Netherlands	The European and national renewable energy targets have resulted in new legislation coming into force that should ensure 4.45 GW of offshore wind capacity by 2023 [23]. The Ministry of Economic Affairs and the Ministry of Infrastructure have acknowledged the energy and export potential of marine renewables (wave and tidal). This resulted in industry, governmental and research organizations to join forces in a trade association called the EWA (Dutch Energy from Water Association) [18]. There are no capacity targets set specifically for tidal or wave energy.
Norway	The Norwegian 2020 renewable energy target is 67.5% of gross final energy consumption generated from renewable sources [24]. This relatively high share of renewables is possible due to the large hydropower resource. Norway recognizes the large offshore wind energy resources. There is a specific interest in floating structures due to the potential of deployment at larger water depths [25]. There are no specific policies applied for wave and tidal energy, it is included in the general renewable energy policies and programmes.
Sweden	Sweden plans to have 100% clean energy generation (including nuclear energy) by 2040 [26]. In 2017, an installed capacity of about 200 MW of offshore wind was grid-connected [27]. Regarding tidal and wave energy, Swedish technology is at the forefront of innovation with at least seven relevant developers (Ocean Harvesting, Waves4Power, Minesto, Corpower, Wavetube, Seabased and Gaiatellus).
UK	The UK targets to source 15% of all energy and 10% of transport fuels from renewables by 2020. Currently, the UK has the largest amount of installed offshore wind capacity in Europe. In 2017, the total installed offshore wind capacity in waters off the UK reached 7.5 GW [28]. R&D on marine energy is supported by the UK governments (and the EU), for example through Wave Energy Scotland [29] and Marine Energy Wales [30].

Table 4 – Renewable energy capacity targets of North Sea basin countries, including wave, tidal and offshore wind energy activities.

4.4 ORE Market Challenges

OREs have various market challenges that will need to be tackled to reach their market potential. This requires the involvement of companies directly involved in the sector, such as the technology developers, but also companies with products and services that could be adapted to help solve some of these challenges. The diversification of the oil and gas, and maritime sectors into offshore renewable energies would provide a lot of prior experience and knowledge transfer of ACS.

A study by the UK Energy Research Centre (UKERC) identified the main high-level challenges for wave and tidal energy deployment as follows [31]:

- **Affordability:** refers to achieving a lifetime cost that is competitive with other energy sources.
- **Reliability:** refers to the operational health of the device over its lifetime.
- **Survivability:** refers to the ability of a device to survive extreme events. Components are critical to this challenge, either in resisting such events or in mitigating the impacts of failures.
- **Installability:** relates to the ability to install the energy converter. Vessels, crew and equipment increase the deployed costs of components.
- **Predictability:** is the ability to understand the interaction between the environment and the devices. Components can help capture information to help predict future events.
- **Operability:** is the ability to control, operate and maintain devices.

- **Manufacturability:** refers to the development of structure that can easily be manufactured.

A study by one of the NeSSIE partners added the following aspects to the above mentioned challenges:

- **Environmental Impact:** refers to the effect that the deployment of the structures has on the environment.
- **Health and Safety:** refers to the safety of device operators and the general public alike.

As part of the European Technology and Innovation Platform for Ocean Energy (ETIP Ocean), a prioritisation was made of challenges for ocean energy to move to commercialisation are identified [32]. A prioritisation was made of these challenges to indicate the challenges with highest importance to be addressed by the sector, divided in the categories technology, financial, and environmental and socio-economics.

4.4.1 The combination of technical and non-technical challenges

In the ‘Study on Lessons for Ocean Energy Development’ by the European Union [33], it is pointed out that the encountered difficulty in the development of the ORE market, specifically wave and tidal energy, is based on several challenges technical and non-technical challenges (see the previously mentioned challenges).

Specifically the combination of these challenges complicate the path towards commercialisation, as the challenges are interlinked. Several factors, from technical performance to funding availability, influence the successful implementation.

5 Finance mechanisms

The maturity of the technology varies for each type of offshore renewable energy and therefore also their funding challenges and financial barriers. There is a wide range of existing public and private funding mechanisms, which should be specific for each alternative technology.

This chapter will discuss the current and expected status of investment in ORE. This is followed by an indication of potential early stage project funding as well as medium and long-term funding possibilities, followed by the ORE funding challenges.

5.1 Early stage demonstration project funding

The maturity of a technology is a key factor concerning the offer of available financing mechanisms. Funding is particularly challenging for technologies transitioning from R&D towards the prototype and demonstration stages, as there often is a long timeframe to deployment and intensive CAPEX investment required. The probability of failure along the innovation chain in combination with the cost of investment is a key risk for developing technologies. The probability of a technology failing to reach the market decreases along the innovation chain while technology investment reaches a peak between late stage R&D and early stage deployment.

In the case of marine energy, currently there is a focus on deployment of demonstration projects. In most cases, the marine energy technology developers do not have the scale of capital needed to finance those projects, which make alternative sources of finance crucial.

The risk attached to projects involving emerging technologies limits the number of potential investors, where mainly risk-tolerant investors are interested, as there is uncertainty about the development and the success that the technology will have in the future. There are a range of possible stakeholders that fit into this profile and are able to fund technology development along the innovation chain, including various finance focussed organisations (private equity, venture capital etc.), governmental support and corporations active in renewable energy technologies (technology developers and users). Figure 9 shows the most common investor profiles for each renewable technology in 2016. As can be seen, the majority of investments in marine energy was in the form of R&D support from governments. This is an indicator of the early stage of this sector and the difficulties with ensuring financial backing. Other sources that are or will become of relevance to finance demonstration projects for MRE could be those indicated in the figure, namely, public markets, venture capital or private capital and companies investing in R&D. Since the wind sector is a much more mature sector, including a higher level of investor confidence, the majority of the project financing comes from asset finance (Figure 9).

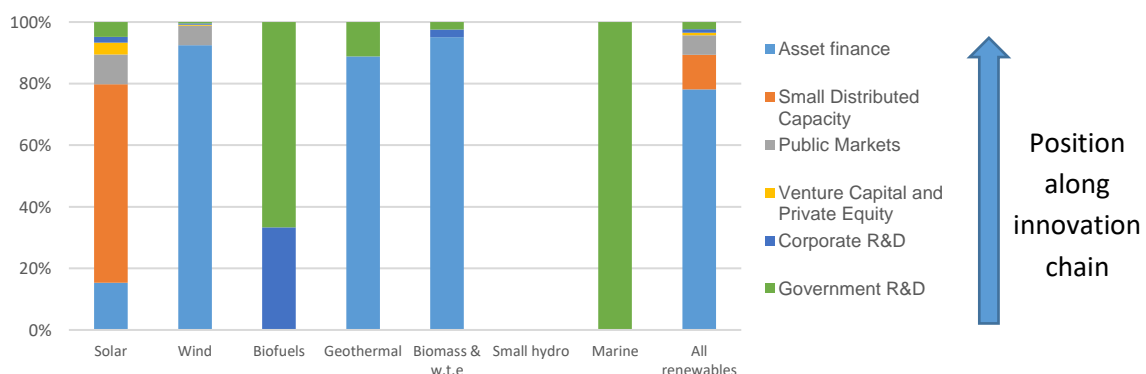


Figure 9 – Average investment distribution breakdown for each renewable technology in 2016 [34]

Attention should be paid to the early stages of technology development, from R&D towards demonstration of full-scale devices, since it is the phase in the project lifecycle when proposals are most likely to be cancelled.

To understand the origin and characteristics of the different investment sources in marine technologies, public and private early stage funding methods for ORE will be analysed separately in the following sections.

5.1.1 Public early stage demonstration project funding

As previously mentioned, public funding is the most important source of investment for wave and tidal technologies. Public policy support instruments for ocean energy technologies include both push and pull mechanisms such as:

- **Public research grants – push:** the main financial source for emerging technologies in the path towards becoming commercially competitive, in the form of government support programmes.
- **Risk insurance funds - pull:** the insurance industry is offering innovative products for the renewable energy sector with the aim of reducing the volatility associated with these technologies. The available products are mainly directed to cover the financial impact of the intermittency of renewable sources caused by the variability of resources.
- **Feed-in-tariffs (FIT) - pull:** a policy mechanism designed to accelerate investment in renewable energy technologies by means of offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology.
- **Feed-in-premiums (FIP) - pull:** under this policy scheme, electricity from renewable energy sources is sold on the spot market for electricity and the producers receive an additional amount on top of the market price.
- **Tradable certificates - pull:** these certificates are a market-based subsidy; they are a financial asset issued to certified green electricity producers to ensure a certain amount of electricity come from renewable sources.
- **Tendering - pull:** auctions and tendering schemes for RES are competitive mechanisms to financially support RES projects. In auctions, the cost of electricity production is the only criterion to be evaluated, while tenders may include additional criteria.
- **Soft loans - pull:** a loan with a below-market rate of interest, in some cases with long repayment periods. The providers are usually governments.

Depending on the support scheme applied to a project, the implied risks to the investors are different. In general, the sector is demanding new financing instruments focused on flexibility, in order to reduce the short-term risk inherent to the early stage of the ORE market.

5.1.2 Private early stage demonstration project funding

As previously stated, high CAPEX, low revenue projections and high investment risk due to uncertainties make it challenging to find private investors willing to support wave and tidal energy demonstrators. Moreover, a lack of operational experience drives up insurance premiums limits the coverage available and makes it difficult for potential backers to assess technology risk.

Figure 10 shows the relationship between investor types classified by risk appetites and the technology readiness in wave and tidal energy, as investigated by ORE Catapult [35]. Usually neither commercial banks nor state-backed banks or utilities are interested in the high-risk demonstration projects with low financial

returns. According to ORE Catapult, any stakeholder seeking to finance a MRE demonstration project should either ask for public support or engage a venture capital or an OEM, since those investor profiles are willing to accept a high risk and often have a profound knowledge of devices [35].

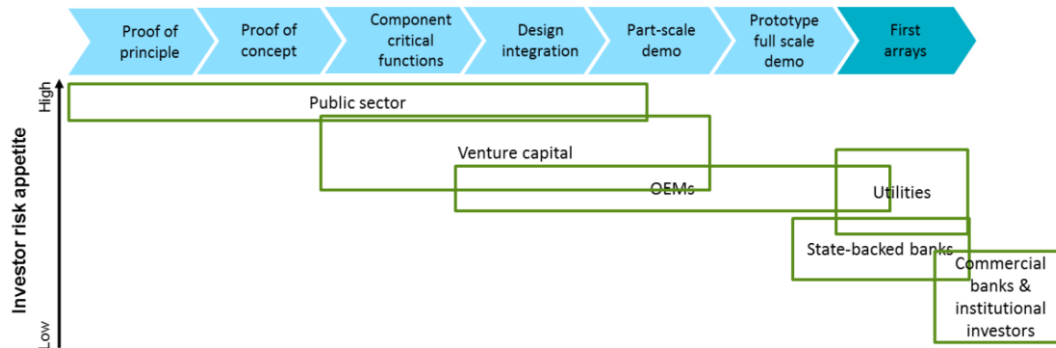


Figure 10 – Investor type by risk appetite and technology readiness of wave and tidal energy [35]

- **Venture Capital (VC):** private equity investors that act in small or early-stage projects/technologies/firms that are deemed to have a high growth potential. At present, they are unlikely to be the initial investors in ORE projects due to the lack of confidence in the ORE market associated with the profitability delay of the investment. There is a need for other financial backers, with a preference for the public sector.
- **Utilities:** end-users of marine energy converters, who could potentially take an investor role when risks are mitigated.
- **OEMs and supply chain:** companies involved in the marine energy supply chain have a good understanding of the technological risks. Due to their direct involvement in the development of the projects, they encounter high losses if a project is unsuccessful.
- **State-backed banks:** banks that are able to fund projects with higher risks compared to commercial banks due to the support they receive from governments. A well-known example is the Green Investment Bank (GIB).
- **Institutional investors:** investors likely to be involved when projects start to become bankable, therefore at a point the risks have been significantly reduced, such as pension funds.
- **Commercial banks:** investors with a very low risk profile and therefore unlikely to participate in early stage funding.

5.2 Finance over medium to long term

Medium to long-term financing means investment requirements for the commercial project lifetime, namely up to 15 to 25 years. Where offshore wind energy deployment is at the stage of requiring medium to long-term financing, wave and tidal energy is focused on acquiring early stage financing. Therefore, the financing options discussed below are based on offshore wind examples.

Investors will often be a combination of the previously mentioned public and private early stage investors; however, the reduction in investment risk increases the number of interested parties at this stage of financing. Figure 11 provides an overview of the investment sources in wind energy up to 2013, showing the great variety of entities/investors participating in offshore wind energy.

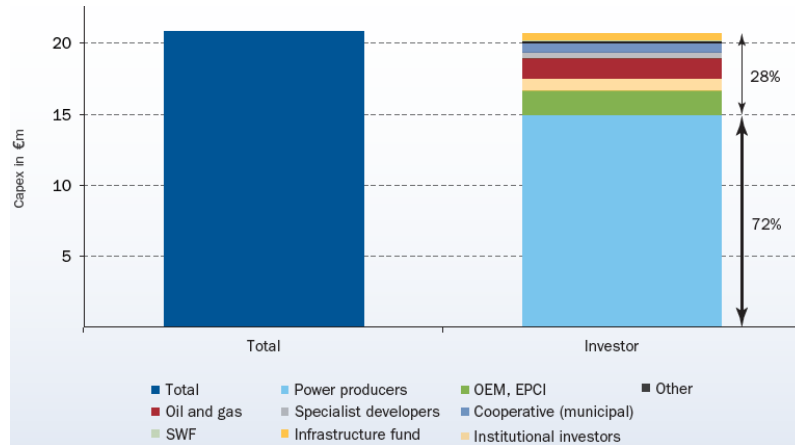


Figure 11 – Cumulative wind energy investment in Europe up to 2013 [36]

The ‘Finance and Investment trends’ report by WindEurope provides a list of major equity investors in offshore wind energy in 2016 [37], summarised in Figure 12. Power producers provided almost 70% of the equity investment in offshore wind energy.

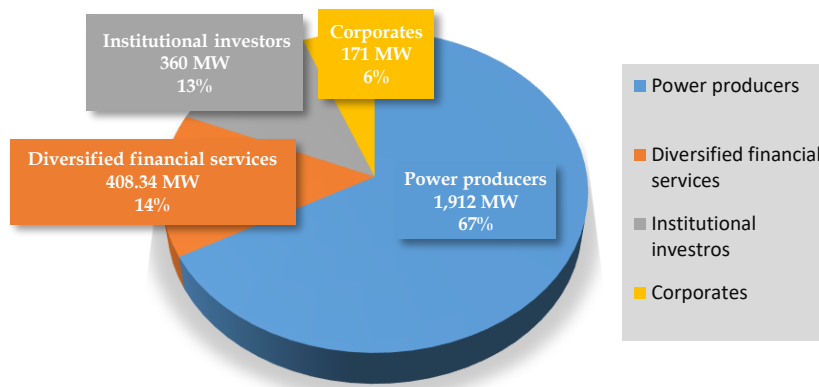


Figure 12 – Major equity investors in offshore wind in 2016 [37]

The same report reveals relevant finance structures applied in offshore wind in 2016 [37]:

- **Bond financing:** capital is raised for the project by selling project bonds or green bonds. This is a fixed-income security for the investor. The increase in the number of offshore wind project bond transactions in recent years demonstrates the progress achieved in understanding the sector’s risks.
- **Initial Public Offerings (IPOs):** shares are sold on the capital market, making the project or company a public entity. In 2016, Europe reached the highest level of issuance in the last seven years, raising a total of €5.2bn IPOs.
- **Equity financing:** raising capital through selling stock, giving the investors ownership in return in the form of stocks. This is one of the most critical phases in the collection of funds for a project, most of the transactions were carried out in the pre-construction phase.
- **Power Purchase Agreements (PPAs):** a contract between two parties where one party sells both electricity and renewable energy certificates (RECs) to another party. PPAs are widely used in Europe, facilitating investments for utility scale projects.

Depending on commercial, financial and tax reasons, a range of funding structures can be applied to make

the projects more attractive to potential investors. The table below shows an overview of these structures based on an analysis carried out by WindEurope [36]. Given the current large offshore wind projects, multi-source financing solutions will play a more important role, with the additional benefit of partners sharing their knowledge within the project.


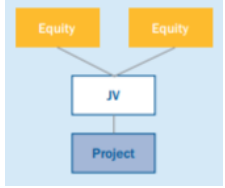
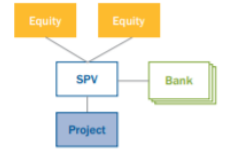
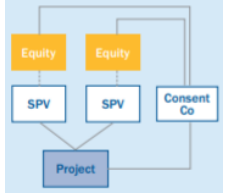
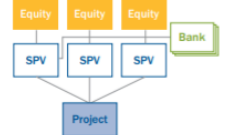
Name	Structure	Characteristics
<p>Sponsor equity</p>		<ul style="list-style-type: none"> • One entity has full ownership of the project. • Benefits: <ul style="list-style-type: none"> ○ Simplicity; ○ Full control of the project. • This model becomes less sustainable with the increasing capacity of the projects.
<p>Incorporated joint venture (JV) or Special Purpose Vehicle (SPV)</p>		<ul style="list-style-type: none"> • The ownership of the project is divided between multiple partners, together forming a joint venture or special purpose vehicle. • There are two ways of considering the incorporated joint venture: (1) held on the balance sheet as an investment or, (2) consolidated as a subsidiary of the shareholder's group. • In case of tax losses, there cannot be a transfer to the shareholder's group (significant in early years).
<p>SPV with debt finance</p>		<ul style="list-style-type: none"> • A funding structure with a loan, therefore relying on the future cash flows generated, with the project's assets, rights, and interests held as secondary security or collateral. • Lenders may also have limited recourse to the assets of the sponsor. • Benefits: <ul style="list-style-type: none"> ○ Clarity on income flows; ○ Ability to obtain solid security structure; ○ Clarity on ownership of asset and obligations; ○ Clarity of contractual structure and counterparty.
<p>Unincorporated Joint Venture</p>		<ul style="list-style-type: none"> • This structure allows the project to be considered as an investment by the sponsor. • Each investor can consolidate all the profits and losses of the SPV into one group account.
<p>Unincorporated Joint Venture with debt</p>		<ul style="list-style-type: none"> • Same basis as the traditional unincorporated joint venture apply. • The debt is mostly used to allocate different risks or to apportion PPA liability or responsibilities.

Table 5 – Offshore wind funding structures based on WindEurope report [36]

5.3 Finance Wave and Tidal energy

5.3.1 Finance status and prospects

Wave and tidal energy are Capital Expenditure (CAPEX) intensive as the cost of the device; infrastructure and installation represent a very high share of the kilowatt-hour (kWh) cost, estimated at 60–80% of the final cost of energy. In order to ensure the development of wave and tidal technologies, it is necessary to focus the funding to the progress of those technologies along the innovation chain and therefore enable cost reductions. This means that developers need access to high levels of funding upfront, before any revenue is generated, whether this be debt, grant or equity-based.

In the current context, demonstration of wave and tidal power technologies is critical, since successful results increase investor confidence. It should be stated that the landscape of these investments changed drastically after the economic crisis of 2008, when finance became more difficult to secure, particularly for high risk ventures such as wave and tidal energy [35]. Nonetheless, the global wave and tidal energy market is poised to grow at a CAGR of around 7.7% over the next decade to reach up to \$1.8bn by 2025 [38].

5.3.2 Public early stage funding

At European level, the European Commission (EC) provides early stage financial support aimed at bringing innovative ideas from the laboratory to the market with Horizon 2020 (H2020). Being the largest EU Research and Innovation programme, it has €80bn available to allocate over 7 years (2014-2020). Examples of funded wave and tidal projects facilitated by the European Commission can be found in Table 6 (wave energy) and Table 7 (tidal energy) [6].

Horizon 2020 funds directed to wave energy specific R&D accounted for a total of €30.1M, of which the majority was addressed to the development and optimisation of wave energy PTOs.

Project acronym	Project title	Technology Developer	Focus
CEFOW	Clean Energy From Ocean Waves	Wello Oy	Reducing LCOE, optimise O&M and achieve high operational hours.
OPERA	Open Sea Operating Experience to Reduce Energy Cost	OceanTEC	Gathering data from ocean deployment, developing and testing a new biradial turbine, and assessing dynamic mooring configurations. Reducing LCOE by 50%.
Waveboost	Advance Braking Module with Cyclic Energy Recovery System (CERS) for enhanced reliability and performance of WECs	CorPower	Improving the PTO for the next generation of the CorPower device to reduce the LCOE by 30%
WETFEET	Wave Energy Transition to Future by Evolution of Engineering and Technology	OWC (general); Symphony	Numerical modelling and tank testing to achieve breakthroughs for innovative PTO's

Table 6 – H2020 projects funded to support wave energy innovation actions [6]

Since 2014, the Horizon 2020 framework programme has funded 10 tidal energy projects for a total of about 30M€, five of which were directed to Research and Innovation Actions (RIA) to improve existing technologies and the others to Innovation Actions (Table 7). Many of these projects share a common goal of reducing the cost of existing technologies and incorporating the results of the ongoing R&D activities in their future devices.

Project acronym	Project title	Technology Developer	Focus
FloTEC	Floating Tidal Energy Commercialisation project	ScotRenewables	Reduction of lifetime cost of 20% through expansion of rotor diameter, and improved access for maintenance
InToTidal	Demonstration of Integrated Solution for Offshore Tocado Tidal powerplants	Tocado International	Demonstration of deployment solutions for tidal turbines
PowerKite	Power Take-Off System for a Subsea Tidal Kite	Minesto	Optimisation of power electronics components, reduction of environmental concerns through enhanced monitoring
TAOIDE	Technology Advancement of Ocean energy devices through Innovative Development of Electrical systems to increase performance and reliability	Ocean Renewable Power Company	Development of wet-gap generators, lifetime cost reduction, achieve availability of 96%
TIPA	Tidal Turbine Power Take-Off Accelerator	Nova Innovation	PTO optimisation and cost reduction of 20% of lifetime costs

Table 7 – H2020 projects funded to support tidal energy innovation actions [6]

At a regional level, in 2016 ocean energy was identified as one of the key areas for collaboration within the framework of the Smart Specialisation Platform on Energy (S3PEnergy) initiative, launched by the European Commission. The S3PEnergy initiative is designed to harmonise the regional effort to address identified opportunities and market developments in a coherent manner. Further collaboration at regional level was facilitated by the Ocean-ERA project, which coordinates activities between European Countries and regions to support Research Development and Innovation activities for the development of ocean energy technology [6].

In addition to H2020, Table 8 profiles some of the prevalent and highly regarded funding mechanisms in Europe gathered from the National Renewable Energy Action Plan for the United Kingdom [39]. The list is not exhaustive, but it highlights the key funding and financial support for tidal and wave energy development. Some of these programmes have finalised and details of others are subject to change.

Programme	Technology, stage & form of support	Description
OCEANERA-NET	Ocean energy	OCEANERA-NET is a Network of 15 national and regional funders and managers of research and innovation programmes, from 8 European countries.
	Funding coordination network	The objective of OCEANERA-NET is to coordinate funding programmes between European countries and regions to support research and innovation in the ocean energy sector.
European Structural and Investment Fund (ESIF)	Sustainable economic development	The European Union's investment fund to support sustainable economic development and job creation. Its budget is €454 billion for 2014-20, and it is administered on a decentralized basis by the EU countries.
	Grants	Through the European Regional Development Fund (ERDF), €13m of ESIF funds were awarded in 2015 to Swedish company, Minesto, for the first phase of its 10 MW Deep Green tidal power project in Holyhead Deep, off the coast of Anglesey, Wales. There is €100 m available in Wales for marine renewable energy from this fund. The Sabella D10 project in the Pas du Fromveur, in France, also received support from the ERDF.

Funding Ocean Renewable Energy through Strategic European Action initiative (FORESEA)	Ocean energy to TRL 5+	In July 2016, is €11 m, funded by the European Regional Development Fund. The programme will offer a series of “funding and business development support packages” to fund ocean energy technology testing and demonstration of TRL 5+ technologies in ocean energy test facilities at EMEC (Scotland), SmartBay (Ireland), SEM-REV (France), or the Tidal Testing Centre (Netherlands).
	Funding to access test centres	
Fast Track to Innovation pilot fund (FTI)	Innovation TRL 6-9	The European Union’s FTI is administered by Horizon 2020. The FTI is designed to provide funding to consortia of 3-5 organizations that are predominantly private, for-profit businesses, to support an innovation at approximately TRL 6, up to TRL 9, so to be ready for market launch. Projects must be close to market - within 36 months of market launch - and have strong business cases. FTI funds up to 70% and between €1-3m. FTI funding for two full-scale tidal energy testing and demonstration tidal energy projects at EMEC was announced in June 2016: Tocardo’s InToTidal project, and Magallenes’ Ocean 2G project.
	Grants	
New Entrants Reserve (NER 300)	Renewable energy	The NER300 is a public-private investment fund developed by the EC and managed by the European Investment Bank. It leverages private investment and co-investment of other EU countries’ governments. It is a demonstration programme supporting carbon capture and storage and renewable energy technologies to “boost deployment of innovative, low-carbon technologies. The EU funds the NER 300 with proceeds from the sale of 300 million carbon emission allowances. The funds were distributed to projects through two calls for proposals.
	Public-private investment fund	

Table 8 – Examples of European Funding mechanisms for wave and tidal energy [39]

5.3.3 Private early stage funding

Utilities have invested in both wave and tidal technology developers and the initial stage of array projects in the past. However, the lack of profitability of these projects to date has changed the attitude of utilities to an observer mode. This change means additional funding difficulties for the ORE market evolution, since a number of public innovation support programmes were based on continued utilities involvement [35]. Once again, the key to investments is increasing the investor’s confidence in the performance of converters.

Another option for wave and tidal energy funding at the current stage are state-backed banks. An example of this type of funding is InnovFin [40], a financing support initiative from the European Investment Bank Group. In most cases, public funding is only provided when private investors cover a certain percentage of the project cost.

5.3.4 Medium to long term funding

As wave and tidal technology is in early stages of development, this type of investment is not in place. The wave and tidal energy sector is expected to tap into similar investment streams as offshore wind energy in the future as it reaches a similar stage of technology maturity.

5.4 Finance Offshore Wind energy

5.4.1 Status and prospects

Expenditures on new wind energy capacity carried out in Europe between 2010 and 2016 are shown in the Figure 13, including investment projections in the near future according to WindEurope [41].

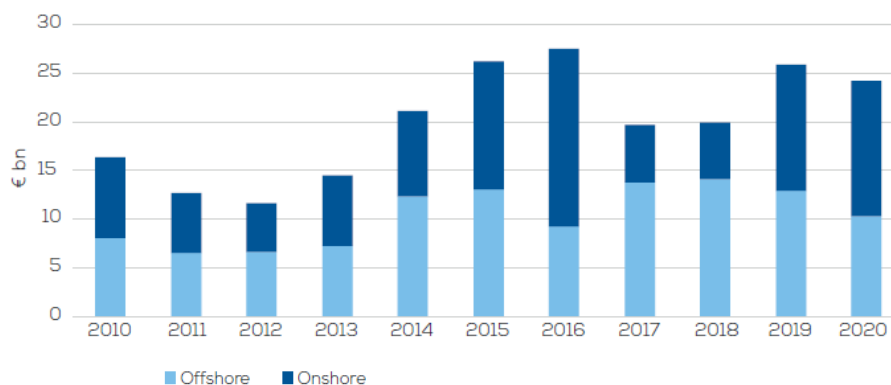


Figure 13 – Investment outlook in new assets for the period 2010-2020 under WindEurope’s Central Scenario (in €bn) [41]

5.4.2 Public early stage funding

The previously presented Horizon 2020 programme currently allocates more than €140M to 60 projects as early-stage public assistance to wind energy in general, of which 40% is allocated to offshore wind technology development [42]. Considering these offshore projects, a focus is found on reducing LCOE by investigating innovative turbines, materials and components as well as logistics, assembly and testing, both for fixed and floating wind technologies. In most cases, H2020 covers 70% to 100% of the total project costs, the remaining part has to come from private funding.

Regarding countries involved, Spain has the strongest presence, participating in more than 40% of H2020 projects. The UK ranks second with a participation percentage of 32%. Germany, the Netherlands and Denmark participate in many collaborations, resulting in 22%, 20% and 18% of the funded projects, respectively. Table 9 provides a non-exhaustive list of examples of the offshore wind energy projects that have been funded through the H2020 programme.

Project acronym	Consortium	Description
DEMOGRAVI3	EDPR, EDP CNET, TYPSA, ASM Energia, ACCIONA, HRL-UPM, WAVEC, Fraunhofer IWES, Global Maritime and GDG	Focused on designing, building, assembling, transporting, installing and demonstrating an innovative full-scale gravity-based foundation, equipped with a 2 MW offshore wind turbine, in a consented and grid connected demonstration site. [43]
Elican	ESTEYCO, ADWEN, ALE, DEWI, GAMESA and PLOCAN	Designing, building, certifying and demonstration in operative environment a cost-effective substructure for offshore wind energy that can work in deep waters, a self-installing pre-cast concrete tower and foundation. Designing, building, certifying and demonstration a self-installing pre-cast concrete tower and foundation [44].
LIFES50Plus	SINTEF Ocean, Danmarks Teknise Universitet, ORE Catapult, Politecnico di Milano, Tecnalía, IREC, University of Stuttgart, Iberdrola, DR. TECH. OLAV OLSEN, RAMBOLL, DNV GL and Ideol	Proving cost effective technology for floating substructures for 10MW wind turbines at water depths greater than 50 m [45].
TELWIND	ESTEYCO, ALE Heavylift, MECAL, IHCantabria, CEDEX, Cobra, DSI and TUM	Testing of a spar floating substructure with self-installing tower for wind turbines over 10 MW, with the aim of reducing the construction and installation costs [46].

FLOWSPA	OCEAN FLOW ENERGY LTD	Demonstration of the feasibility of an innovative floating offshore wind foundation structure “Starfloat” that combines “spar” technology with “semi-submersible” technology to provide a compact and cost effective low motion platform for supporting large capacity wind turbines at deep-water offshore wind farm sites [47].
Demowind (and DemoWIND2)	DECC, IWT, DEA/ENS, MinEZ/MinEA, Enova, RCN, CDTI, MINECO and MoST Taiwan	DemoWind 2 proposes to bring together a number of national and transnational organisations with an interest in accelerating cost reduction in offshore wind. It follows on from the first DemoWind initiative launched in 2014 [48].

Table 9 – Examples of H2020 funded wind energy projects [42]

5.4.3 Private early stage funding

In the case of funding fixed offshore wind energy projects, the main funding comes from the developers’ own capital. In 2016, the top five wind farm owners, namely DONG Energy, Vatenfall, E.ON, Innogy and Stadtwerke München, represented 45.1% of all installed capacity in Europe [13].

Floating wind is in a similar situation as wave and tidal energy, however, where private funding is a critical requirement for obtaining public funds for a projects. Generally, this is done by acquiring a part of the capital of the technology developer, with an attitude of passive surveillance. Examples are Aker Solutions and Nautilus Floating Solutions. The former, a Norwegian oil & gas specialist, transfers their offshore oil & gas engineering knowledge into the floating offshore wind market through a stake in the Principles Power floating wind energy technology [49]. The latter, Nautilus, is an industrial and technological consortium formed by ASTILLEROS DE MURUETA, TAMOIN, VELATIA and VICINAY MARINE INNOVACIÓN, four leading companies of advanced technology [50].

5.4.4 Medium to long term financing

Wind energy is at a stage where the major project finance banks are now experienced in lending to offshore wind projects, having the expertise to understand the risks. In fact, with growing numbers of new lenders considering investing in offshore wind, there is positive sentiment in the market and good appetite for well-structured projects. This is reflected in a growing competition among lenders, a reduction in the pricing and improvements in the investment terms being offered [37].

To date offshore wind projects have been developed by utilities and partnerships of utilities. Nonetheless, other alternative formulas can also be applied, such as “non-utility” projects undertaken by IPPs (Independent Power Producers), and in fact, they are increasingly used. This alternative form is carried out with the help from banks through non-recourse debt financing from banks. With this type of loan, the financier only has the right to the collateral, such as property, and no further compensation [37].

Emerging new business and ownership models have unlocked the potential for long-term sources of finance. The financial sector has become keen to invest in Europe’s wind energy projects. This has led to a significant amount of affordable debt, in particular in the form of non-recourse financing. Moreover, as risk perceptions change and power producers become more comfortable with multi-contract structures, the offshore wind sector is witnessing a growing demand for off-balance sheet financing of the CAPEX. This is a form of financing in which large capital expenditures are kept of a company's balance sheet through various classification methods. In 2016, 33% of the new capacity in offshore wind was financed with this method, the previous year even being 44% [37]. Increased market competition across the value chain and changing financial structures were the main factors driving this trend.

5.5 Financing ORE in North Sea basin countries

For the offshore renewable energy sector to successfully achieve growth at a global level, it is vital that the right conditions for investment are established. Funding and financial supports offered to ORE in the NSB countries are shown in Table 10 from the 2016 Joint Research Centre (JRC) Ocean energy Status Report [6], categorised as push and pull mechanisms. Pull mechanisms or market-based incentives create a demand or price for renewable electricity and are meant to encourage large-scale deployments. Push mechanisms are designed to facilitate the development of technology to ensure cost reductions and performance improvements. Some of these support mechanisms have run their course and details of others are subject to change.

Country	Push and pull mechanisms		Open sea testing centre
	Type	Description	
Belgium	Pull	Renewable energy certificates, a market to support renewable energy production with Tradable Green Certificates (TGC) [51].	1 operational 1 planned
	Push	Offshore wind farms connected to the BOG (Belgian Offshore Grid) are eligible for a financial support for the financing of the submarine cables if they are situated at a distance of more than 9 km from the BOG [52].	
Denmark	Pull	Maximum tariff of 8 c€/kWh (sum of market price and bonus) for ocean energy.	2 operational
	Push	National energy development programmes such as EUPD, Energinet and the Danish Strategic Research Council are able to fund the development of wave energy. Energinet funded €2.4 million for minor renewable energy technologies (e.g. wave) by ForskVE. In the 2015 round, the programme for development and demonstration projects will provide about €13.4 million of funds.	
France	Pull	Feed-in Tariff for renewable energy, where wave and tidal fall under hydro power energy.	4 operational
	Push	Two marine energy have been projects awarded funding through ADEME, the French Environment and Energy Management Agency: Normandy Hydro and Nepthyd. The National Research Agency (ANR) supported different ORE R&D projects through tenders [4].	
Germany	Pull	Offshore wind energy competes in market-based auction scheme. Fixed Feed-in Tariffs for wave and tidal energy depending on plant capacity [4].	-
	Push	Research programme for "Next generation maritime technologies" (Ministry of Economics and Technology), which was valid for the period 2011-2015 and covers shipbuilding, navigation and maritime technologies. And an energy research programme from the Federal Ministry for Economic Affairs and Energy expected to continue in 2018 following the initial version in 2014 [4].	
Netherlands	Pull	Tenders as part of the SDE+ scheme [53], no specific market incentives for wave and tidal energy.	3 operational
	Push	The generic DEI (Demonstration of Energy innovations) subsidy scheme supports projects with a focus on export of Dutch technology. The grants are between 125k€ and 4m€ per project. Two marine projects have been granted in the DEI subsidy scheme; BlueTec and Tocado-Huisman [54]. Different R&D projects have been supported in National funding programmes, such as the Archimedes Wave Swing (for wave (swell) energy) and Tocado Tidal turbines, as well as R&D Institutions like Marin and TNO.	
Norway	Pull	The Norwegian-Swedish Electricity Certificate Market: Norway and Sweden have been in a joint green certificate market, since 2011. Since 2012, one certificate per MWh has been given to all new renewable energy generation for 15 years, independent of technology. From year 2022, Norway will no longer participate in the scheme, while Sweden will increase its target build-out under the scheme with 18 TWh by 2030.	1 operational

	Push	<p>Innovation Norway runs a programme supporting prototypes within the category of “environmentally friendly technology”. Ocean energy is included in this definition. Projects are supported with up to 45% of eligible costs [4]. Langlee Wave Power [55] and Inwind have received funding through this programme [56].</p> <p>The Norwegian Energy Agency, Enova, offers capital grants for full scale demonstration projects of ocean renewable production (up to 50% of eligible costs)</p> <p>The Research Council of Norway runs an energy research programme called ENERGIX, for R&D within all renewable energy technologies [4].</p>	
Sweden	Pull	The Norwegian-Swedish Electricity Certificate Market, this is for renewable energy in general.	3 operational
	Push	The Swedish Energy Agency run an ocean energy R&D programme, 2015-2019 [4]. Within this programme, 16 projects were approved for funding. Minesto’s technology was one of the projects that received funding [57].	
UK	Pull	<p>Renewable Obligation Certificate (ROCs) Scheme. Tidal energy is eligible for 2 ROCS/MWh (5 ROCS/MWh in Scotland), as well as wave energy (3 ROCS/MWh in Scotland). The ROC scheme was replaced by a Contract for Difference (CfD) scheme in 2017.</p> <p>CfDs offer long-term price stabilisation and are awarded via competitive auctions. CfD allocations are made in competition with other “less established technologies” including offshore wind. Strike prices of £310/MWh for wave and £300/MWh for tidal stream projects due to deploy in 2021/22 were debated, however were not established as bids for wave and tidal stream.</p>	5 operational
	Push	<p>Marine Energy Array Demonstrator (MEAD), £20 m 2012. MEAD aimed at supporting two pre-commercial projects to demonstrate the operation of wave and/or tidal devices in array formation for an extended period of time (approx. 5 MW capacity). The devices had to be demonstrated at full-scale in real sea conditions. MEAD grants were offered to two projects: MeyGen in Scotland and SeaGeneration Ltd. in Anglesey, Wales.</p> <p>Marine Renewables Deployment Fund (MRDF), for marine device array deployment</p> <p>Marine Renewables Commercialisation Fund (MRCF), with the goal of helping commercialise the marine energy industry in Scotland. £18 m for capital support and £5 m for enabling technologies</p> <p>Saltire Prize, Scotland, £10m innovation prize for first device delivering >100 GWh for two years</p> <p>The Renewable Energy Investment Fund (REIF) from the Scottish Government, designed to help ocean energy projects take the leap towards commercialisation, has so far invested over £40 million in a range of innovative wave and tidal schemes. The fund provides loans, guarantees and equity investments on commercial terms. It was a three-year fund, to be distributed by March 2015, and electricity to be generated before 2017, to help meet Scotland’s 2020 renewable energy goals.</p> <p>Wave and Tidal Energy Research and Development Scheme (WATERS) run by Scottish Enterprise in collaboration with Highlands and Islands Enterprise and the Scottish Government to support wave and tidal energy developers in research and development (£12m fund). Three funding rounds have been successfully completed.</p> <p>The Energies Technology Institute (ETI) is a public-private partnership between energy and engineering companies and the government. ETI makes commercial investments in low-carbon technologies and enabling infrastructure.</p> <p>The Marine Farm Accelerator, led by UK Offshore Renewable Energy Catapult and the Carbon Trust, is designed to develop the technologies needed to reduce the cost and risk of early arrays, in particular, electrical systems, yield optimization, installation methods, insurance, O&M, site characterization, electrical architecture, subsea electrical connection systems, uncertainty in yield in resource modelling, and tidal foundations.</p> <p>The UK Green Investment Bank (GIB) has made offshore wind a priority area.</p> <p>Wave Energy Scotland (WES) – fully funded by the Scottish Government supports wave energy technology development until the technical and commercial risks are low enough for private investment to re-enter the sector. WES committed almost £30m in funding since 2014 [29].</p> <p>Marine Renewable Energy Strategic Framework which is carrying out largescale investigations in to the Welsh marine energy resource and the infrastructure requirements of ocean energy developments.</p> <p>The Research Councils UK Energy Programme provides funding for a wide range of technology areas, including marine, covering research and training. It brings together investments from across the UK research councils.</p>	

Table 10 – Push and Pull support mechanism within the North Sea basin countries [6]

At a European level, North Sea basin countries have a great variety of financial support mechanisms. Some support mechanisms have been implemented for several years, whereas others have lacked persistence in implementation. The effectiveness of these mechanisms provides a good learning opportunity for future applications. The perceived challenges with funding ORE projects are therefore discussed below.

5.6 ORE Funding Challenges

As mentioned throughout this chapter, the access to financial resources for the development of projects is a key challenge for emerging technologies such as wave and tidal. The lack of previous experience means uncertainties and therefore risks, which complicate the attraction of promoters and funders.

5.6.1 Public funding coordination

Despite the EU's and Member States' funding efforts, some studies state that the current coordination of the public financing landscape is insufficient, specifically in the following areas [35]:

- Grant funding which is available from a variety of governments and government agencies has been principally focused on overcoming specific obstacles, which has driven **R&D in a stop-start manner**.
- The vision on **the future of public endorsement is unclear**; this maintains the uncertainty in the private sector and hampers the attraction of matching private funds. With most countries implementing technology-neutral auctions, the opportunities for wave and tidal projects are minimal.
- Due to the **sporadic nature of public funding**, the necessary technology development to achieve commercial stage has not occurred.

Hence, there is a great need for coordination of public funding at a global, European and country level, primarily to reinforce private sector confidence in the market.

5.6.2 Funding coverage for trajectory to commercialisation

The current available support mechanisms do not fully cover the market development trajectory of technologies, as shown in Figure 14. A critical stage in this transition is the pre-commercial stage, often referred to as the valley of death.

In order to reduce this pre-commercial gap, the European Union has launched a new funding call directed at the development of wave energy within the framework of the H2020 programme. The call, the European Pre-Commercial Procurement Programme for Wave Energy Research & Development, challenges the design, development and validation of cost-effective wave energy converters that can survive in the harsh and unpredictable ocean environment through demand-driven Pre-Commercial Procurement. The challenge is open to proposals seeking to steer wave energy research and development in an effective way at a European level, establishing convergence of wave energy technologies and to bring these technologies to the market [58].

Specific concerns about funding mechanisms and the post-2020 plans for technology-neutral auctions undermine confidence in the long-term market for wave and tidal. Since investors and the supply chain require clear visibility of a long-term market, such policy uncertainties have the potential to threaten interest in these technologies in the present.

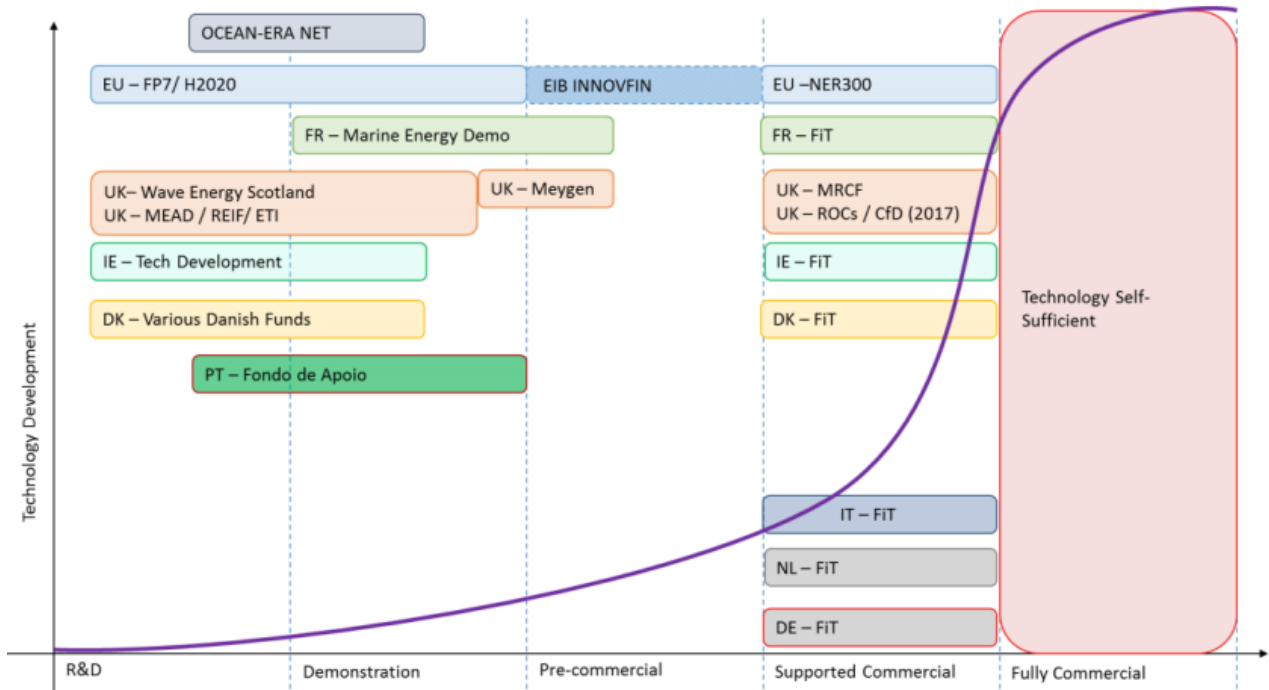


Figure 14 – Summary of market push and pull mechanisms for ocean energy in the EU based on Carbon Trust deployment scenarios [6]

5.6.3 Communication

To attract funding, developers of the energy technologies need to be clear in their communication to investors. The JRC report on the status of ocean energy states that ‘a clear picture to investors on the development level and performance expectations’ has been found difficult [35]. A clear and transparent overview of the path forward for the developing technologies is needed to provide a better understanding of the technologies and reducing the risks to the potential investors.

6 Infrastructure

Infrastructure requirements for project NeSSIE can be classified into hard and soft infrastructure. Hard infrastructure refers to the tangible facilities such as ports, vessels, transport, power, manufacturing facilities, etc. required to facilitate the integration of established ACS value chains with offshore renewables. Soft infrastructure encompasses the health and safety regulations and legislation, personnel training, design/manufacturing standards and offshore environmental impact assessments required before being able to transfer knowledge relating to ACS technologies between industries.

There are infrastructural aspects that cover both categories, as they encompass a combination of features, namely the various North Sea basin region testing facilities, research and development (R&D) and regulatory verification service value chains.

The required infrastructure for wave, tidal and offshore wind energy is rather similar, therefore there is not a distinction made in this chapter between the different resources.

6.1 *Hard infrastructure*

Marine Spatial Plans (MSPs) are made to indicate the use of the ocean by multiple stakeholders, including industry, government, conservation, recreation and energy. Therefore, these plans provide a good insight for decisions regarding allocation of resource areas in a sustainable manner. The countries that have developed MSPs are discussed in more detail in section 6.3.1.

Guidance on optimal demonstration project hard (and soft) infrastructure locations can also be found from regional initiatives documentation. In Scotland, this has been produced to help guide renewables developers and licensing authorities targeting the long term contribution of low carbon energy generation technologies to Scotland's defined targets. Marine Scotland's 'Pilot Pentland Firth and Orkney Waters Marine Spatial Plan' regional location guidance (RLG) document [59] is a prime example. This document aims to balance the needs of growing renewable developments with existing users whilst minimising environmental disturbances and makes up the suite of Marine Spatial Plans (MSP) for the Pentland Firth and Orkney Waters (PFOW) area. Spatial information utilises Geographical Information Systems (GIS) as a data foundation to explore interactions and overlaps between potential offshore developments (via resource assessments/Crown leasing designations) and existing users and environments. This method allows for a concise analysis of the existing hard infrastructure in place. The PFOW MSP also considers natural habitats, species and landscape situations. These topics will be discussed further in section 7. Offshore resource assessments are split into offshore wind, wave and tidal in the PFOW area, as shown in Figure 15. One great example in the PFOW area is the world leading European Marine Energy (EMEC) wave and tidal test centre [60], with EMEC test site locations shown in Figure 16. This is a good example of the RLG document providing hard infrastructure guidance. There is a wide range of existing PFOW marine users, and so the relevant hard infrastructure data sources include the following (similar to the information in MSPs):

- Aviation (for personnel and equipment transfer transport);
- Bathymetry/Seabed maps (wind device thresholds, seabed sediment types, marine habitats);
- Commercial fishing (port facilities, processing factories and marine specialised personnel);
- Grid infrastructure provision (subsea power cables, sub stations, power stations);
- Oil and Gas infrastructure (pipelines, fields, associated shipping traffic, processing plants);
- Local Development Plans (renewable energy offshore and onshore support);
- Ports, Piers and Harbours (locations, size and economic investment);

- Shipping (densities by vessel type, shipping lanes);
- Supply Chains (preferred offshore ports in PFOW area-Lyness, Wick, Scrabster and Kirkwall);

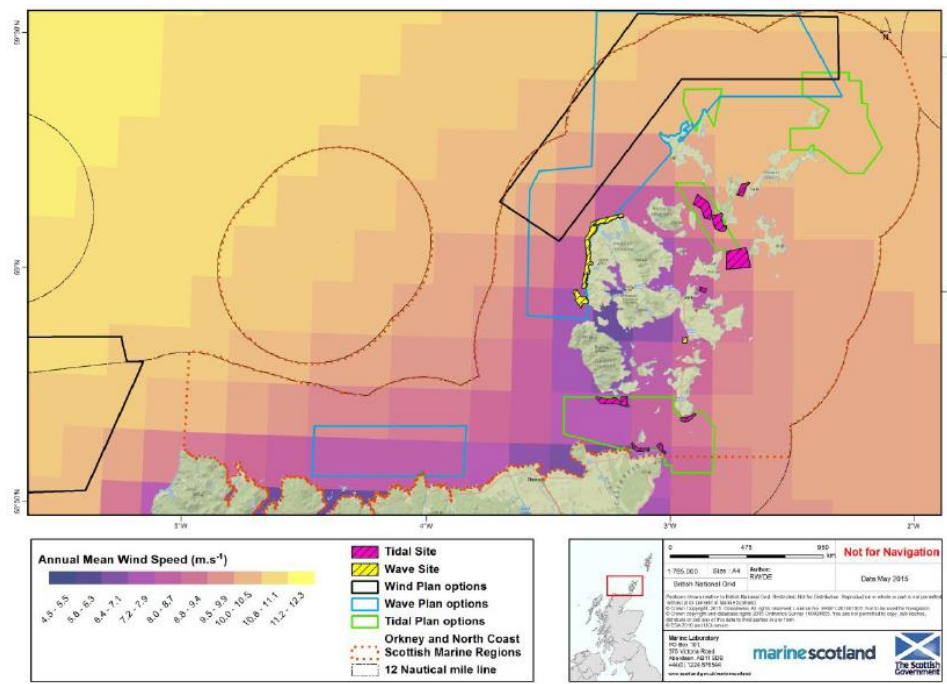


Figure 15 – Mean annual wind speed (m/s) across PFOW area [59]

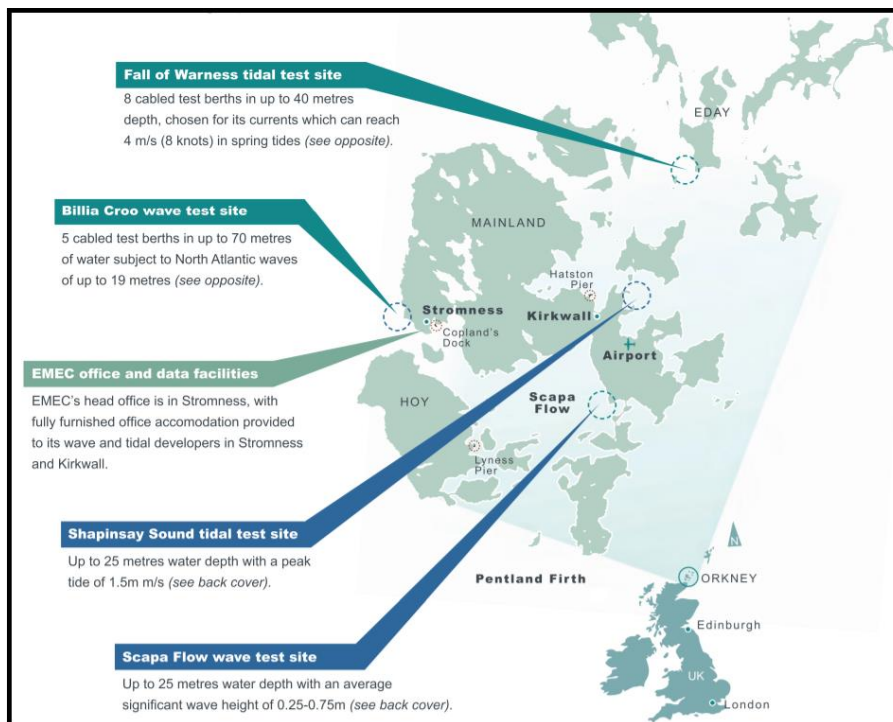


Figure 16 – EMEC test centre location and facilities [60]

Further regional guidance on important infrastructure locations relevant to ORE demonstration projects can be found in National Renewable Infrastructure Plans (N-RIPs). Scotland’s regional development organisations, Highland and Islands Enterprise and Scottish Enterprise [61] have published these phased plans to develop regional growth within regional clusters through strong supply chain development aligned towards the growing offshore renewables sector. Stage one and two N-RIP identified regional supply chain infrastructure support to the offshore wind sector (Figure 17) by regional cluster. Each cluster assessed the Port site characteristics, access, potential future renewables roles, required infrastructure development and timing. The report focused on supply chains for offshore wind, and it was recognised that as tidal and wave evolve into commercialization, specific infrastructure amendments will need to be undertaken.

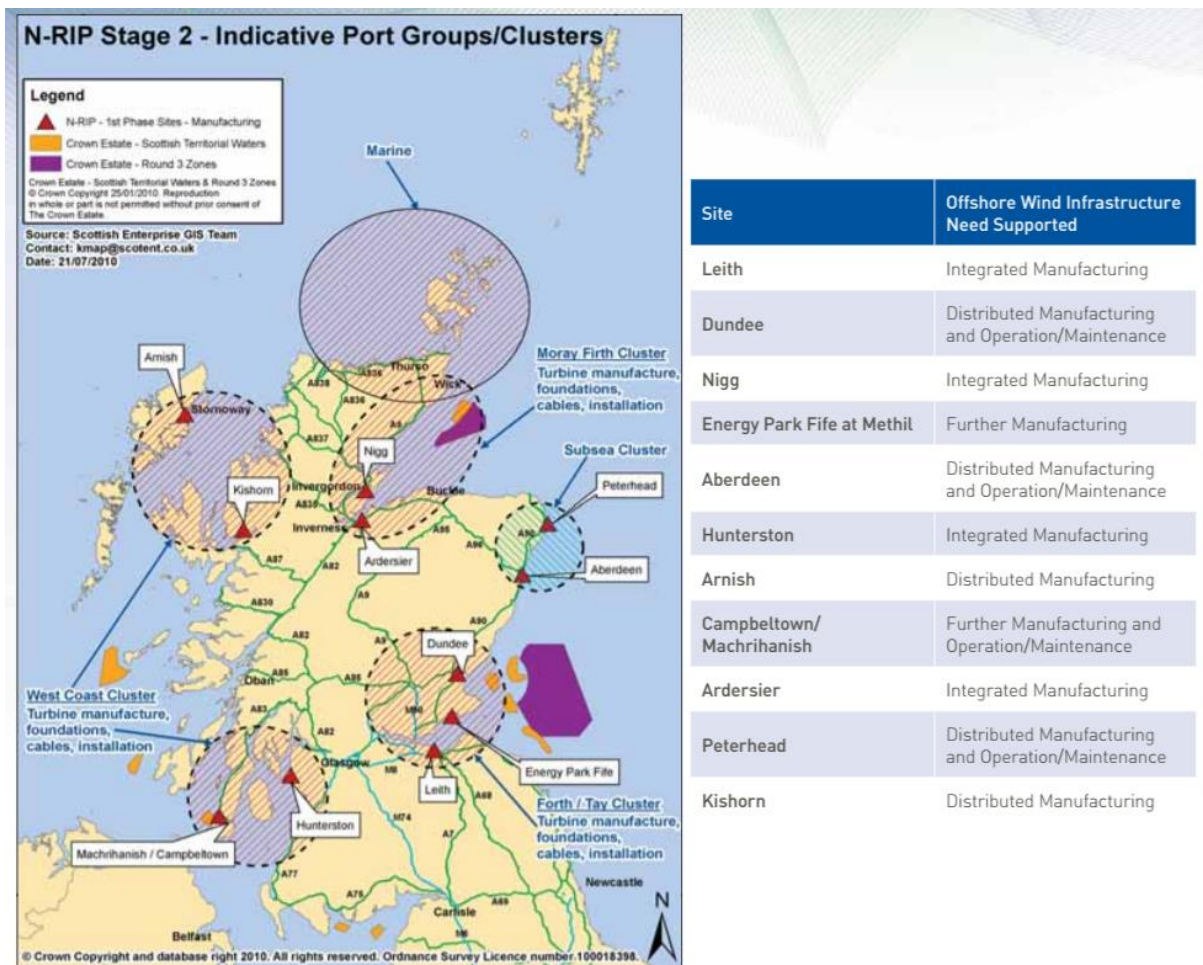


Figure 17 – Scotland’s regional supply chain support to the offshore wind industry [61]

Considering the identification of renewable energy project locations, the Dutch National Water Plan [62] and Dutch offshore wind energy white paper [63] investigate the optimum spatial position for offshore wind farms necessary to achieve EU renewable energy targets. Other Dutch marine space users include oil and gas sites, shipping, mineral extraction, fishing, grid infrastructure and natural ecosystems. With the designation of the most cost-effective wind energy areas minimising spatial conflicts between the sea-space users, efficient use of space and the perceptual impact (meaning to keep a clear view of the horizon) are taken into account [63].

The suggested locations for phase expanding wind farm developments are pictured in Figure 18. Phase 2

wind energy development areas identified include Borssele, IJmuiden Ver, Coast of Holland and North of Wadden Islands. Site data, including soil characteristics, wind and water conditions and obstructions, is gathered at these identified wind farm zones and provided by the Netherlands Enterprise Agency [64].

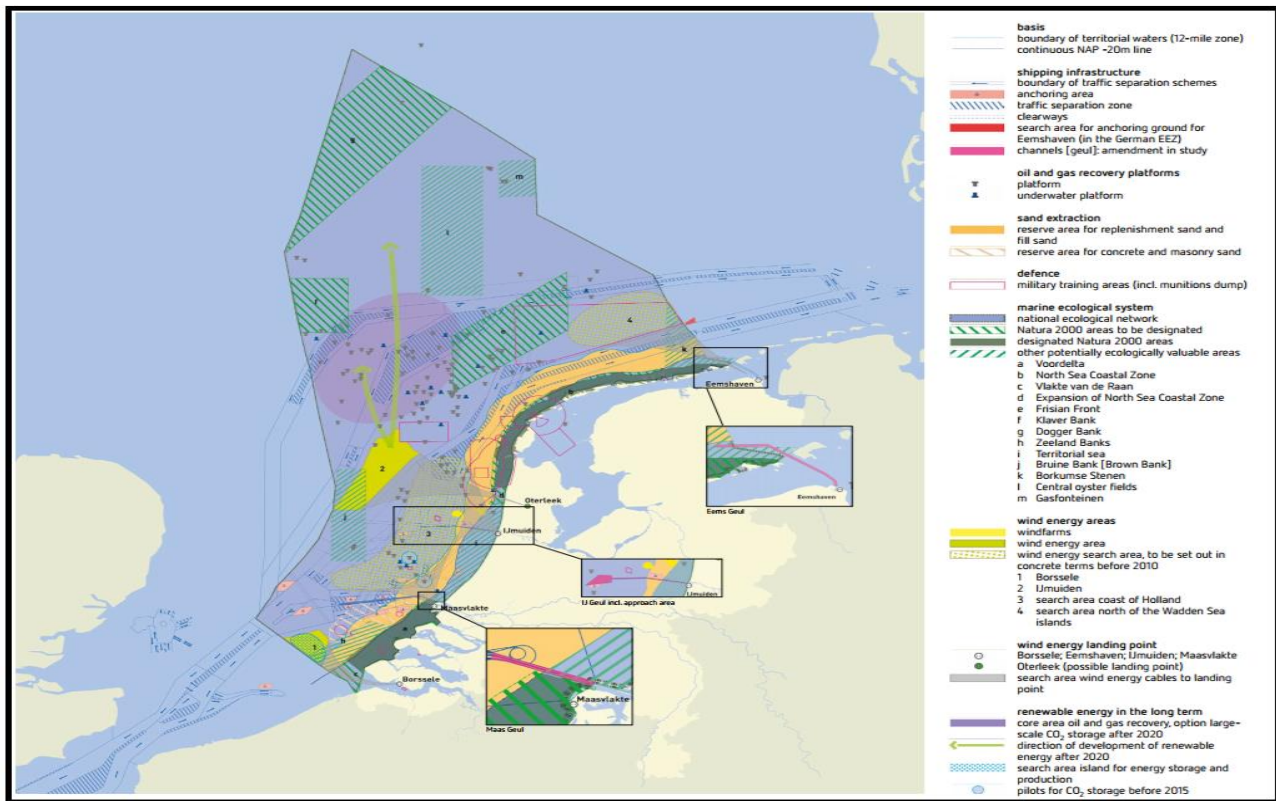


Figure 18 – Dutch National Water Plan 2009-2015 showing wind farm and onshore port locations [63]

Similar approaches to those of the Scottish and Dutch MSPs can be used to identify hard infrastructure hotspots for wave, tidal and wind energy deployment and supply chain across the North Sea basin and the NeSSIE consortium countries.

6.2 Soft Infrastructure

In addition to the required hard infrastructure, soft infrastructure in the form of health and safety regulations, financing, legislation, personnel training, design/manufacturing standards and offshore environmental impact assessments are necessary for the roll-out of ACSs for offshore renewables.

Of these soft infrastructure aspects, financial possibilities and capabilities have been discussed in section 5. Regulations, legislation, environmental impact and standards will be discussed in section 7.

For the development of ORE projects, there is a need for trained personnel to carry out the work; as such, the sector creates job opportunities. Existing knowledge, for example on the topic of corrosion, would be beneficial in the training process. Therefore, diversification of other sectors is encouraged.

The potential market in marine renewables provides the possibility of growth for the established offshore sectors through diversification to this emerging sector. Simultaneously, the application of existing expertise supports the potential of the renewables market.

Scottish Enterprise encourages diversification by providing guidance, aiming to couple the existing offshore sector to the emerging renewable energy developers with the guide to Oil and Gas diversification

opportunities [65]. Another example of encouraging diversification is the cross-sector Matchmaker, a combined effort of Wave Energy Scotland and the National Subsea Research Initiative [66].

6.3 Infrastructure in the North Sea basin countries

6.3.1 Marine Spatial Plans

The NSB countries are at different stages of MSP development under the EU's Maritime Spatial Planning Directive (2014/89/EU). The European MSP Platform contains the collection of developed MSPs [67]. The MSPs of the North Sea basin countries can be found in Table 11.

Country	MSP title	Department	Year	Source
Belgium	MSP for the Belgian Part of the North Sea	Marine Environment Division of the Directorate General of Environment of the Federal Public Service Health, Food Chain Safety and Environment	2014	[68]
Germany	Spatial Plan for the German EEZ in the North Sea	German Federal Maritime and Hydrographic Agency	2009	[69]
Netherlands	National Water Plan (including Policy document on the North Sea 2016-2021)	Dutch Ministry of Infrastructure and the Environment	2015	[62] [70]
Norway	Integrated Management of the Marine Environment of the North Sea and Skagerrak (Management Plan)	Norwegian Ministry of the Environment	2013	[71]
UK (England)	East Inshore and East Offshore Marine Plans	Department for Environment, Food and Rural Affairs (Marine Management Organisation)	2014	[72]
UK (Scotland)	Scotland's National Marine Plan	The Scottish Government (Marine Scotland)	2013	[73]

Table 11 – Marine Spatial Plans (MSPs) of North Sea basin countries

Currently, Denmark does not have an official MSP, though there is information on different sectors available such as fisheries, offshore wind and shipping. The Danish Maritime Authority is developing a comprehensive plan that considers the different sector interests, to be completed in 2021 [74]. England has divided the development of its MSPs into 12 areas, with all areas planned to have a MSP by 2021 [75].

The currently ongoing EU-funded project NorthSEE (North Sea Perspective on Shipping, Energy and Environmental Aspects in Maritime Spatial Planning) coordinates knowledge transfer between the development of MSPs of the different countries in the North Sea basin in order to achieve coherence and to create sustainable development [76].

According to UNESCO [77], EU countries' phased MSP developments are at various maturity stages as of June 2017. This is shown in Table 12.

STATUS OF MSP BY PHASE OF PLANNING IN COUNTRIES WITH MSP INITIATIVES		Pre Planning	Plan Analysis	Plan Develop	Plan Complet	Plan Approv	Plan Implem	Plan Revision
EUROPE								
Belgium		★	★	★	★	★	★	★
Bulgaria		★	★					
Croatia		★						
	•Zadar County	★	★	★	★	★	★	
Cyprus		★						
	•Limassol District	★	★	★	★	★		
Denmark		★						
Estonia		★						
Finland		★	★					
France		★						
Germany	Exclusive Economic Zone (Baltic Sea)	★	★	★	★	★	★	
	Exclusive Economic Zone (North Sea)	★	★	★	★	★	★	
	<i>(TS covered by 3 Länder plans)</i>							
	•Mecklenburg-Vorpommern Länder	★	★	★	★	★	★	★
	•Schleswig-Holstein Länder	★	★	★	★	★	★	
	•Niedersachsen Länder	★	★	★	★	★	★	
Greece		★						
Iceland	Exclusive Economic Zone	★	★					
Ireland	Exclusive Economic Zone	★	★					
Italy		★						
Latvia	Exclusive Economic Zone	★	★	★	★			
Lithuania	Exclusive Economic Zone	★	★	★				
Malta		★						
Netherlands		★	★	★	★	★	★	★
Norway	<i>(TS & EEZ covered by 3 regional plans)</i>							
	•Barents Sea and Lofeton Islands	★	★	★	★	★	★	★
	•Norwegian Sea	★	★	★	★	★	★	
	•North Sea	★	★	★	★	★	★	
Poland		★	★					
Portugal		★	★					
Romania		★	★					
Russia			★					
Slovenia		★						
Spain		★						
Sweden		★	★					
United Kingdom	•England	★	★					
	<i>(TS & EEZ will be covered by 11 regional plans)</i>							
	•East Inshore & Offshore	★	★	★	★	★		
	•South Inshore & Offshore	★	★	★	★			
	•Northeast Inshore & Offshore	★						
	•Northwest Inshore & Offshore	★						
	•Southwest Inshore & Offshore	★						
	•Southeast Inshore							
	•Isle of Man (TS only)	★	★					
	•Northern Ireland	★	★					
	•Scotland	★						
	<i>(TS will be covered by 11 regional plans)</i>							
	•Argyll	★						
	•Clyde	★	★	★	★			
	•Forth & Tay	★						
	•Moray Firth	★						
	•North Coast	★						
	•North East	★						
	•Outer Hebrides	★						
	•Orkney Islands (pilot)	☆	☆	☆	☆			
	•Shetland Isles	★	★	★	★			
	•Solway	★						
	•West Highlands	★						
	•Wales	★						

Table 12 – Status of Marine Spatial Planning across the EU [58]

6.3.1 ORE deployment 'Hotspots'

Examples of onshore hard infrastructure hotspots in the North Sea basin supporting manufacturing and O&M operations to develop wave, tidal and wind energy supply chains based on the MSPs, RLGs and N-RIPS can be found in Table 13.

Table 13 also indicates the locations of open sea test centres or sites. These test centres are specifically developed hotspots for innovative renewable energy investigation. For NeSSIE, the North Sea basin testing centre locations, with their hard infrastructure in place, will heavily influence demonstration project and supply chain locations.

Country	Location	Type of Site	Services/facilities
Belgium	Oostend	Port/Test centre	Includes, e.g., Maritime Research Centre, installation and O&M [78]
Denmark	Hanstholm and Nissum Bredning	Test centre	Danish Wave Energy Centre, wave test sites [79]
Netherlands	Eemshaven	Port	Includes construction of offshore wind park [80]
	Afsluitdijk and Marsdiep	Test centre	DMEC, Tidal test sites of Dutch Marine Energy Centre (as a participant in FORESEA and MaRINET2, DMEC has access to a wider range of onshore test facilities across the Netherlands [81])
France	Dunkerque	Port	Distribution port [82]
Germany	Wilhelmshaven	Port	Includes, e.g., construction, repair and maintenance of wind farms [83]
	Emden	Port	Large component and reaction and supply port, with offshore research [84]
	Bremerhaven	Port	Includes Offshore Terminal Bremerhaven handles, pre-assembles and stores offshore wind turbines [85]
UK (England)	Great Yarmouth	Port	Includes, e.g., Energy Skills Centre and plans for extending O&M facilities [86]
	Blyth	Port/Test Centre	Includes operation and maintenance base of Offshore Demonstrator Wind Farm project [87]. National Renewable Energy Centre (NAREC), wind turbine test site [88]
	Hull	Port	With centre for renewable energy 'Green Port Hull', which includes manufacturing, assembly and servicing facilities and training facilities [89]
	Cornwall	Test centre	WaveHub, wave energy test site [90]
	Falmouth	Test centre	FaB Test, nursery wave device test site [91]
UK (Scotland)	Leith	Port	Includes, e.g., ship inspection, repairs and steel fabricators (part of Scottish Energy Ports) [92]
	Dundee	Port	Includes, e.g., heavy lift facilities, support and decommissioning part of Scottish Energy Ports) [92]
	Nigg Energy Park	Port	Includes a dry dock with associated facilities (part of Scottish Energy Ports) [92]
	Energy Park Fife	Port	Engineering and fabrication facilities for park occupiers (part of Scottish Energy Ports) [92]
	Aberdeen	Port/ Test centre	Includes a wide range of facilities from dry docks to decommissioning (part of Scottish Energy Ports) [92]. European Offshore Wind Deployment Centre (EOWDC), Offshore wind deployment centre under construction [93]
	Cromarty Firth/ Invergordon	Port	Includes, e.g., fabrication, maintenance and decommissioning (part of Scottish Energy Ports) [92]

	Peterhead	Port	Specialism in decommissioning (part of Scottish Energy Ports) [92]
	Montrose	Port	Includes, e.g, specialism in decommissioning, subsea and mooring (part of Scottish Energy Ports) [92]
	Lyness	Port	Includes base for service and deployment of wave devices at Billia Croo (part of Scottish Energy Ports) [92]
	Hatston Pier & Kirkwall	Port	Includes deep water facilities (part of Scottish Energy Ports) [92]
	Rosyth and Babcock Rosyth	Port	Include, e.g, fabrication, dry docks and subsea vessel base (part of Scottish Energy Ports) [92]
	Wick Harbour	Port/Harbour	Includes the O&M base for the Beatrice offshore wind farm (part of Scottish Energy Ports) [92]
	Orkney	Test centre	European Marine Energy Centre (EMEC), wave and tidal energy test sites [94]

Table 13 – Examples of infrastructure hotspots for ORE demonstration projects in the North Sea basin

The European funded Ports Energy and Carbon Savings (PECS) project within the framework of the Interreg 2 Seas funding programme of the European Regional Development Fund (ERDF) focusses on “carbon reductions through introduction of low carbon technologies” [95]. As this project supports ports in developing low carbon technologies, including energy topics, this is of interest to NeSSIE.

6.4 ORE Infrastructure challenges

The challenges encountered by the deployment of ORE regarding infrastructure can be divided into three categories: the conflict of marine space use, the lack of skills and experience to perform the required work and the limitations of the grid capacity.

6.4.1 Conflicts of use

Marine energy parks coexist with other uses of the sea (fishing, transport, tourism, etc.). MSPs can reduce this challenge involving an approach to planning and managing sea uses and users to support sustainable development of marine areas. The rationale for MSP is to provide a stable and transparent planning system for maritime activities and users within agreed environmental limits to ensure marine ecosystems and their biodiversity remain healthy, working across multiple sectors.

6.4.2 Lack of skilled workers

Installation, operation and maintenance of marine energy parks require skilled workers with experience working at sea. The 2015 ‘Sector insights: skills and performance challenges in the energy sector’ report by the UK Commission for Employment and Skills indicates a scarcity of trained employees in the energy sector in general [96]. A ‘flow of skills’ between different energy subsectors is recommended. Specific training programmes are also mentioned as needed to mitigate this risk.

6.4.3 Grid capacity

The grid capacity at the ‘hotspot’ locations should be sufficient to incorporate the electricity produced by the offshore renewable energy sources. This refers to both the physical existence and the ability to deal with the variability of ORE of the electricity grid.

7 Regulatory structure/instruments

This chapter discusses consenting and licensing including environmental assessments for marine renewables to provide an overview for the demonstration projects and potential support with their deployment.

7.1 Regulatory aspects

7.1.1 Laws and Regulations

Within the European Union and the Member States, there are different legal instruments, with different levels of enforcement power for the implementation of the demonstration projects in the North Sea basin. At the top of the legislative structure there are the treaties, which are international agreements between two (or more) partners. Treaties can be referred to as conventions, which are the events where treaties between multiple countries are established. Legal instruments are implemented to put the laws into effect, of which regulations and directives are examples. Regulations, both on an EU and national level, are binding legislative enforcements. Whereas directives indicate a goal of the European Union, providing a legal framework for Member States to set up their own legislation and regulations to reach this goal. Implementing, supplementing and amending these legislative instruments is performed through legal acts. Table 14 presents a list of examples of these conventions, directives, regulations and acts that are to be considered with the development of ORE projects.

Regulatory Organisation	Main Sectors	Main requirements
United Nations	Maritime	THE UNITED NATIONS LAW OF THE SEA CONVENTION 1982 (LOSC)
OSPAR (North Atlantic Law)	Maritime	The Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (1992). (North Atlantic maritime areas pollution protection)
Bonn Agreement	O&G	The Bonn Agreement for Co-operation in Dealing with Pollution of the North Sea by Oil and Other Harmful Substances 1983 (North Sea and EU pollution from OIL protection)
Bern Convention	Environment	The Convention on the Conservation of European Wildlife and Natural Habitats
Bonn Convention	Environment	The Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
Valletta Convention	Environment	European Convention on the Protection of the Archaeological Heritage, 2000
IMO (International Maritime Org)	Maritime	International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78/97 International Convention for the Safety of Life at Sea (SOLAS), 1974 Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (LC), 1972 (and the 1996 London Protocol) International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC), 1990 International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), 2001
European Union	All	Marine Strategy Framework Directive 2008/56/EC The Birds Directive 2009/147/EC The Habitats Directive 92/43/EEC Natura 2000 Renewable Energy Directive (2009/28/EC) EIA Directive (85/337/EEC) 1985 / Directive 2009/31/EC

Table 14 – Examples of International Conventions, Agreements and Directives applicable to Marine Renewable Energy project development (adjustment of NeSSIE D2.2 report)

Within the EU, the Marine Strategy Framework Directive has applied for the coastal and marine area since 2008. This Directive is focussed at protecting marine biodiversity, aiming for a Good Environmental Status (GES) by 2020 (Figure 19) [97]. As mentioned, each Member State is responsible for the implementation of the Directive in their marine waters, yet their legislation and regulations for the coastal areas are different.



Figure 19 – Cyclical process of the Marine Directive [97]

7.1.2 Consenting and Licensing

For projects to be deployed in the open sea, licenses need to be acquired. The consenting process can be seen as a hurdle within the project development. In the 2016 report ‘Consenting Processes for Ocean Energy’ [98], one of the main barriers cited in the consenting process is the lack of clarity. With offshore renewable energy technologies such as wave and tidal energy which are in the early stages of development, little information is known on the impact of such technologies on the marine environment. As such, consenting often does not have a dedicated process, resulting in a lack of guidance and multiple authorities responsible for different approvals. This report mentions that Nova Scotia and the UK provide the best practice for a streamlined consenting process.

In Scotland, a ‘one-stop-shop’ has been set up by Marine Scotland, namely the Marine Scotland-Licensing Operations Team (MS-LOT). A ‘one-stop-shop’ refers to a place that is the sole contact point for all necessary licences, in this case for renewable energy projects, therefore simplifying the consenting process. Renewable energy projects are subject to the Marine Scotland Act 2010 [99]. This Act provides a framework for the marine environment, including aspects such as marine planning, protection and licensing. Examples of ORE related actions that require licensing are dredging, depositing objects on the seabed and decommissioning [100].

France and the Netherlands have made arrangements to streamline for the deployment consenting process for offshore wind energy. The French government has made advances towards a ‘one-stop-shop’ consenting approach, with the enactment of the ‘Litigation regime concerning offshore energy production and transportation facilities from renewables’ Decree no. 2016-9. This provides a simplification and consolidation of the offshore wind legal framework [101]. The Dutch government introduced a streamlined wind energy deployment process with the implementation of the Wind Energy at Sea Law (‘Wet windenergie op zee’). This Law is set up to support the deployment of offshore wind energy by designating different lots specifically for wind energy for which tenders are held, as mentioned in Sections 5 and 6 on finance and infrastructure.

The Risk based Consenting for Offshore Renewables (RiCORE) project, a Horizon 2020 research and innovation programme funded project, was set up to establish a ‘risk-based approach to consenting’ [102]. It aims to improve the consenting processes, specifically regarding the environmental aspects, by ensuring a cost efficient and transparent application method, improving knowledge sharing and reducing the barriers

to ORE project deployment. As this is of importance to the development of ORE projects, this is of importance to NeSSIE.

7.1.3 *Environmental Impact Assessments*

The EU has several directives to protect nature and biodiversity under its Biodiversity Strategy, with the Birds Directive 2009/147/EEC (formerly 79/409/EEC) and the Habitat Directive 92/43/EEC at its base and the establishment of a network of Special Protection Areas (SPAs). These SPAs are included in the Natura 2000 ecological network [103].

A Strategic Environmental Assessment (SEA) is the process of appraisal through which environmental protection and sustainable development is considered, and factored into national and local decisions regarding Government (and other) plans and programmes. In the EU, a SEA is required by the EU SEA Directive 2001/42/EC [104].

In the UK, the EU SEA Directive is implemented with the Environmental Assessment of Plans and Programmes Regulations of 2004 [105]. The Department of Business, Energy and Industrial Strategy (BEIS) employed SEAs to balance and guide economic development and environmental considerations of offshore activities [106]. Although these SEAs focus mainly on offshore oil and gas, and offshore wind prior to 2009 (Figure 20), the 26th Offshore SEA included offshore wind, and the 27th and 28th rounds included wave and tidal developments.

As previously mentioned in Section 6.1, the current hard infrastructure is indicated in the MSPs. The pilot Pentland Firth and Orkney Waters (PFOW) MSP seeks to guide marine users in making decisions that have an impact in these waters and coastal areas. In addition, this plan provides a guide for government agencies regarding marine licensing and consenting. In parallel to the PFOW MSP, a Strategic Environmental Assessment (SEA) was performed, being legally obligatory in combination with the development of spatial plans under the Environmental Assessment (Scotland) Act [107].

The SEA assesses the potential impact on the biological environment, such as marine birds and mammals, and the human environment, such as fisheries, recreation and shipping. The SEA process also includes the determination of mitigation measures to reduce the impact of the marine energy device(s). The SEA is part of the Sustainability Appraisal, encompassing the SEA, a Socio-Economic Assessment and works conforming the Habitats Regulations Appraisal (HRA) process if the European Committee. Considering project development, a separate Environmental Impact Assessment (EIA) should be performed to cover the project effects at specific locations.

Under the aforementioned Wind Energy at Sea Law ('Wet windenergie op zee') the Dutch government has integrated ecological aspects in the area designation process. Within this process, the Framework Ecology and Accumulation investigates the cumulative effects of offshore wind farms according to the nature protection Law of 1998 ('Natuurbeschermingswet') and the Flora- and fauna Law [108].

This Framework was commissioned by the Rijkswaterstaat Waterdienst, a Dutch Governmental body, in response to the uncertainty in the significance of a project's impact after the performance of an EIA.

France has also set up a guide for the environmental assessment: Guide d'évaluation des impacts sur l'environnement des parcs éoliens en mer, 2017 [109]. Germany [110] and Belgium [111] have also performed SEAs for their North Sea territories.

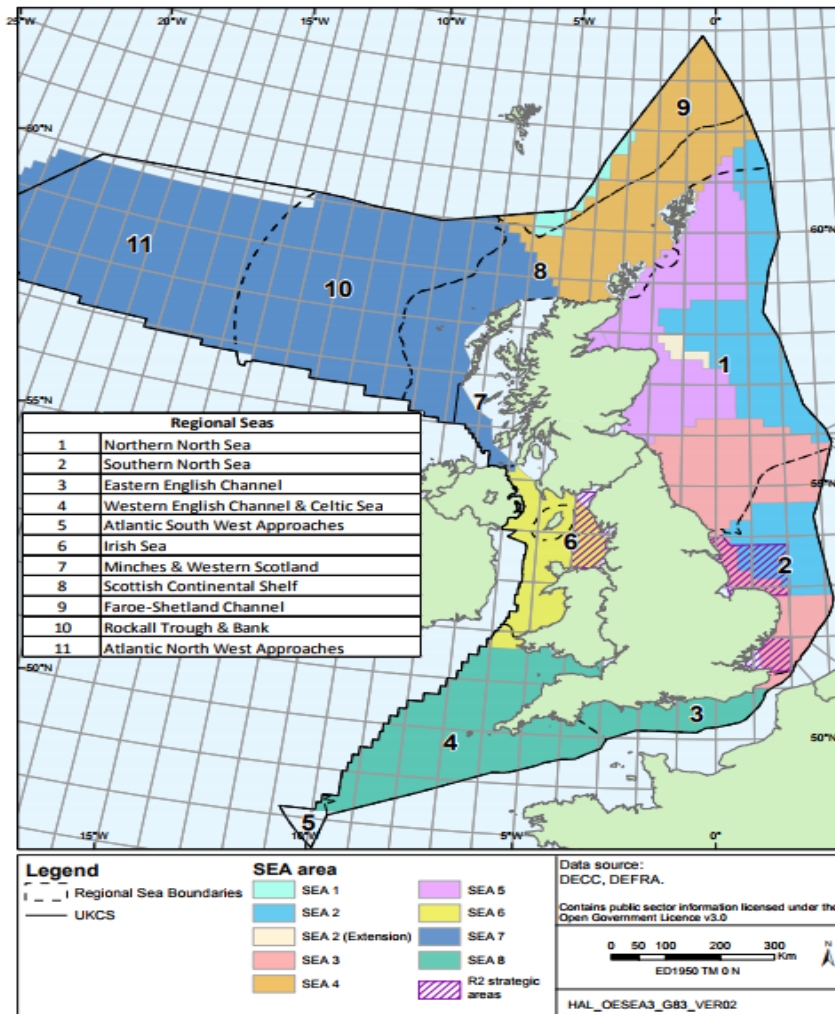


Figure 20 – Existing UK SEA programmes conducted prior to 2008 [106]

A new EU-funded project ‘Strategic Environmental Assessment North Sea Energy as an aid for Maritime Spatial Planning’ (SEANSE) is set up ‘to develop a coherent (logical and well-organised) approach to SEAs, with a focus on renewable energy projects’ [112]. This project is a collaboration between the Dutch Ministry of Infrastructure and Environment, the Danish Maritime Authority, the German Ministry for Shipping and Hydrographics, the Scottish Government and the French Conference of Peripheral Maritime Regions of Europe.

7.1.4 Standards and Certification

Certification according to standards is a method of validating the quality of products and services, based on the knowledge and consensus of technical experts. It should be noted that certification according to standards is not obligatory. In some cases however, laws and regulations refer to standards, making their compliance assessments mandatory. This reason, as well as the realisation of the benefits in showing competence and competitiveness with the standard conformity have led to compliance with standards becoming a well recognised and important step [113].

There is a wide range of established standards used in the offshore oil and gas and maritime sectors. The standards developed for offshore wind have taken advantage of the existing knowledge of onshore wind energy standards and the existing oil and gas standards; a good example of cross-sector knowledge exchange.

The fixed offshore wind energy sector has adopted among others, standards on steel manufacture, coatings and composite manufacture.

A similar approach is currently being implemented for the development of wave and tidal energy standards. The Technical Committee 114 'Marine Energy' within the International Electrical Commission (IEC) is developing standards focussing on resources assessment, device performance and electrical power delivery quality.

The early development stages, the gap between the application of the established standards and the need for performance confidence of ORE have evoked the development of stage-gate metrics [6]; where technologies are assessed, monitored and compared with the successes of developing technology towards commercialization. The development of stage-gate (or phase-gate) metrics has been made an action point within the roadmap of the Ocean Energy Forum [3]. Wave Energy Scotland has developed stage-gate metrics based on the challenge areas, such as reliability, survivability and performance [114]. An example of a target outcome, metric and success threshold is shown in Figure 21. Implementing this assessment scheme for technologies reduces the risks with deployment with the aim of increasing investor confidence.



Figure 21 – Stage-gate metrics to be developed around the challenges of ocean energy [115]

The existing standards applicable to ORE and corrosion have also been listed and discussed in NeSSIE reports within the state of the art study and the economic opportunity of anti-corrosion solutions for ORE, with some additions shown in Appendix I. In addition to the benefits of standards, there should be an awareness of their shortcomings, as discussed below.

7.2 Regulations in North Sea basin countries

Some Member States treat marine renewable energy development under their renewable energy legislation, i.e. Denmark and Germany. Whereas in France, Ireland, Portugal, Spain, Sweden and the Netherlands marine renewables deployment falls under both the energy legislation and marine environment legislation or equivalents.

Examples of the acts and regulations that enforce the legislation in the North Sea basin countries that conform to the Marine Strategy Framework Directive can be found in Table 15.

Country	Act
Belgium	Act for the protection of marine environment and for the organisation of maritime spatial planning in the marine regions under the Belgian jurisdiction (previously Marine Environment Act) 1999 [68]
	Marine Spatial Plan 2014 [68]
Denmark	Act on Maritime Spatial Planning 2014 [74, 116]
	The Danish Act on Maritime Spatial Planning 2015 [74, 116]
	The Act on Environmental Targets 2015 [74, 116]
	The Act on a Marine Strategy 2015 [74, 116]
Germany	Maritime Spatial Plan in the German EEZ of the North sea (AWZ Nordsee-ROV) [117, 69, 110]
	Energy Act 2011 [117, 69, 110]
	Renewable Energy Act 2014, amendment 2017 [117, 69, 110]
	Offshore Wind Act 2017 [117, 69, 110]
Netherlands	Environmental Impact Assessment Act [70, 64, 63]
	Environmental Management Act 1979 [70, 64, 63]
	Water Act 2009 [70, 64, 63]
	Spatial Planning Act 2006 [70, 64, 63, 62]
UK (Scotland)	Offshore Wind Energy Act 2015 [61, 73]
	Marine Scotland Act 2010 [61, 73]
	Marine and Coastal Access Act 2009 [61, 73]

Table 15 – Examples of Acts and Regulations in North Sea basin countries that implement the Marine Strategy Framework Directive

7.3 ORE Regulation challenges

Regulatory challenges have a commonality of uncertainty, namely in terms of the environment, consenting, and the certification process.

7.3.1 Uncertainties environmental impact

In general terms, ORE have a positive environmental impact as sources of clean energy. However, potential impact in the environment should be analysed for each specific project such as: collision risk for animals, risk to marine animals from underwater sound, effects of electromagnetic fields on marine animals, changes in physical systems (energy removal and changes in flow) or changes to habitats (benthic habitats and reefing patterns). The projects of wave and tidal energy that have been deployed to date have been in the water for relatively short periods of time. Therefore, the long-term impact of these marine energy sources needs to be monitored and investigated.

7.3.2 Consenting and Licensing uncertainties

The previously mentioned report on the consenting processes, by Ocean Energy Systems (OES) and the International Energy Agency (IEA), indicate that developers have encountered constantly changing consenting systems within the same jurisdiction [98]. Changes in the system go hand in hand with a lack of knowledge within the consenting authorities, leading to uncertainties and a decrease in efficiency in consenting and deployment. In addition, the uncertainties cause difficulties in the planning process.

7.3.3 Standards/certification process

Standards ensure reliability on the functioning of a product or service, providing confidence and reducing risk. There is often a gap between the application of standards and the ‘real world’ application. At the early stage of ORE technologies, stage-gate metrics can aid in overcoming this gap. It is important that the

standards and stage-gate metrics that are being developed contain realistic demands and consider 'real world' situations. The standards for early stage technologies should not exclude or hold back innovation. On the other hand, the use of unnecessarily complex language and unclear definitions within standards can result in too rigorous criteria to ensure compliance and therefore leading to unrealistic demands. Extensive knowledge and experience in the sector is needed with the certification process. The previously mentioned report by the UK Commission of Employment and Skills also indicated the need for higher-level standards, where these are lacking, and the need for close collaboration between academia and industry to accomplish this [96].

8 Conclusion

This report has discussed the status and challenges of the market, finance mechanisms, infrastructure and regulatory aspects of the ORE sector. This has led to the key conclusions set out in the sections below.

8.1.1 *Market structure*

There are several barriers for ORE to move towards commercialisation, examples include performance and survivability aspects. These challenges are often interlinked; the difficult route towards commercialisation is therefore a result of a combination of these challenges.

Through focussing on solutions for corrosion issues, NeSSIE aims to reduce the cost of operation and maintenance, and improve performance. Therefore reducing the overall cost of energy.

8.1.2 *Financial mechanisms*

The uncertainties due to the early development stage of ORE come with high risks, which lowers the interest of investors. Public financial mechanisms in the form of technology push and market pull are required to move the sector towards commercialisation. Studies have identified that the intermittent nature of public funding and the uncertainty in future public investment are perceived as barriers to the sector deployment. In addition, continued funding throughout the complete path towards commercialisation is lacking, especially in the pre-commercial stage. For technology developers to attract investment throughout the path towards commercialisation, a transparent overview of the technology development is required.

8.1.3 *Infrastructure*

Evidently, the location of ORE deployment is of great importance in terms of the resource but also for the coexistence with other sea uses. Marine Spatial Plans provide a design of sea territories considering all the different marine activities and environmental considerations. In addition, the need for a supply chain and trained personnel are of importance in determining an optimal deployment site for ORE.

8.1.4 *Regulatory aspects*

Within the Member States of the EU there are elaborate consenting and licensing processes encompassing all the procedures around ORE deployment. To improve the effectiveness and efficiency of these processes, a streamlined process is recommended.

The environmental impact of deployment plays a significant role. The lack of knowledge and of data gathered and published is seen as key barriers to deployment. It is of great importance to keep investigating this to gather a comprehensive understanding of the impact of ORE.

Standards and certification are meant to ensure reliability of the developed technologies and processes, however here the lack in clarity can be encountered as a barrier to in development. Therefore, a close collaboration between industry and academia is encouraged to ensure comprehensive and realistic demands.

The findings of this report will feed in to the Roadmap for NeSSIE to identify and support the development of demonstration projects of ACSs.

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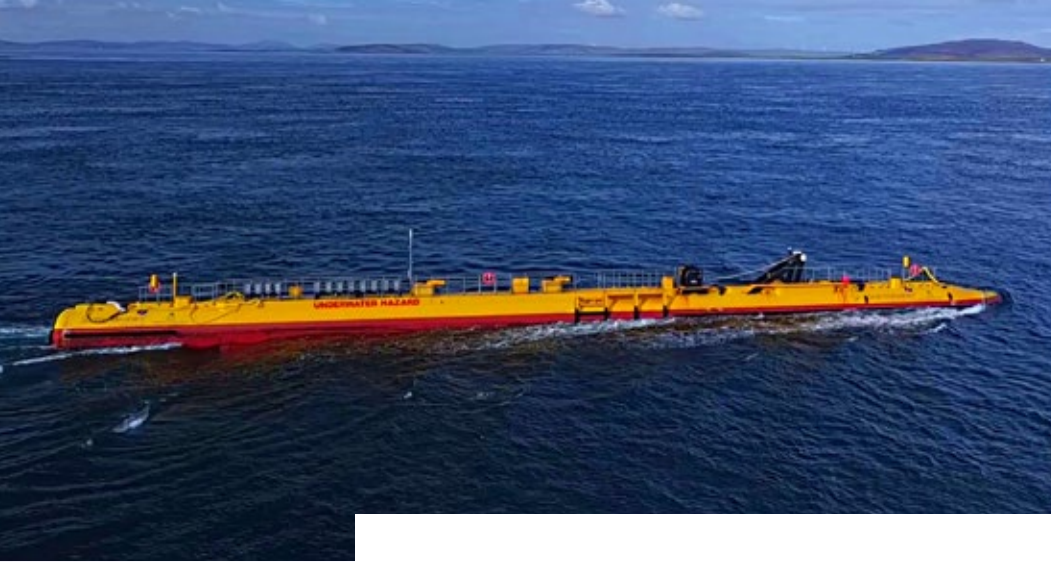
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10 Appendix I

Standards Organisation	Main Sectors	Country HQ	Applicable ACS and MRE certifications/standards/guidelines
Standards Norway (NORSOK)	O&G/Shipping	Norway	Norsok -M501 Surface prep/coatings Norsok -M001 Materials Selection Norsok -M101 Steel fabrication Norsok -M102 Aluminium fabrication Norsok -M503 Cathodic Protection Norsok -M506 CO2 Corrosion rate model Norsok -M601 Pipe weld inspection Norsok -M622 GRP pipe fabrication Norsok -M650 Special materials manufacturers Norsok -M710 Non metallic materials manufacturers
ISO	All sectors	Switzerland	ISO/TC 156 Corrosion of metals and alloys ISO/TC 79 Light metals and their alloys ISO/TC 26 Copper and copper alloys ISO/TC 67 Materials, equipment and Offshore Structures for Petroleum and Natrual Gas Industries /WG 7 Corrosion-resistant materials ISO21457 O&G materials/corrosion controls ISO 13628 O&G subsea systems design ISO/TC 156/EN 12473 General principles of CP in seawater EN 12475 CP for fixed steel offshore structures ISO 20340 Offshore protective paints
DNV-GL	All sectors	Norway	DNVGL-RP-0416 Corrosion rotection for Wind Turbines DNVGL-RP-F106 Factory applied external pipeline coatings for corrosion control DNVGL-RP-C302 Risk based corrosion management DNVGL-RP-B101 Corrosion protection of floating production and storage units DNVGL-OS-B101 Metallic Materials DNVGL-OS-D101 Marine and machinery systems and equipment DNVGL-OS-C101 Design of offshore steel structures, general- LFRD method DNV-OS-312 Certification of tidal turbines and arrays DNV-OS-C401 Fabrication and Testing of offshore structures DNV-OS-J101 Design of FIXED Offshore Wind Turbine Structures DNV-OS-J103 Design of Floating Offshore Wind Turbine Structures DNV-OS-C105 Structural design of tension leg platforms (LFRD Method) DNV-OS-E301 Positioning Mooring (for mooring line positioning) DNV-OS-J201 Offshore Substations for Wind Farms DNV-OS-C502 Offshore concrete structures
EMEC	Marine Renewables	UK	Assessment of Performance of Wave Energy Conversion Systems Assessment of Performance of Tidal Energy Conversion Systems Assessment of Wave Energy Resource Assessment of Tidal Energy Resource Guidelines for Health & Safety in the Marine Energy Industry Guidelines for Marine Energy Certification Schemes Guidelines for Design Basis of Marine Energy Conversion Systems Guidelines for Reliability, Maintainability and Survivability of Marine Energy Conversion Systems Guidelines for Grid Connection of Marine Energy Conversion Systems Tank Testing of Wave Energy Conversion Systems Guidelines for Project Development in the Marine Energy Industry Guidelines for Manufacturing, Assembly and Testing of Marine Energy Conversion Systems
Bureau Veritas	All sectors	France	Asset Integrity management Project development assistance Equipment and Certification Safety and Environmental management
ASTM	All sectors	USA	ASTM A690/A690M-13a - standard specs for metal alloys in marine environment
NACE	Oil & Gas	USA	SP0492-2006 Metallurgical and Inspection Requirements for Offshore Pipeline Bracelet Anodes SP0607-2007/ISO 15589-2 Cathodic Pipeline Protection SP0169-2013 Control of External Corrosion on Underground or Submerged Metallic Piping Systems SP0572-2007 Design, Installation, Operation, and Maintenance of Impressed Current Deep Groundbeds SP0185-2007 Extruded Polyolefin Resin Coating Systems with Soft Adhesives for Underground or Submerged Pipe SP0187-2008 Design Considerations for Corrosion Control of Reinforcing Steel in Concrete SP0387-2006 Metallurgical and Inspection Requirements for Cast Galvanic Anodes for Offshore Applications SP0290-2007 Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures SP0690-2009 Standard Format for Collection and Compilation of Data for Computerized Material Corrosion Resistance Database Input RP0104-2004 The Use of Coupons for Cathodic Protection Monitoring Applications SP0106-2006 Control of Internal Corrosion in Steel Pipelines and Piping Systems SP0108-2008 Corrosion Control of Offshore Structures by Protective Coatings SP0308-2008 Inspection Methods for Corrosion Evaluation of Conventionally Reinforced Concrete Structures SP0408-2008 Cathodic Protection of Reinforcing Steel in Buried or Submerged Concrete Structures TM0169/G31-12a-2012 Laboratory Immersion Corrosion Testing of Metals TM0174-2002 Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials on Metallic Substrates in Immersion Service TM0499-2009 Immersion Corrosion Testing of Ceramic Materials TM0204-2004 Exterior Protective Coatings for Seawater Immersion Service TM0304-2004 Offshore Platform Atmospheric and Splash Zone Maintenance Coating System Evaluation TM0404-2004 Offshore Platform Atmospheric and Splash Zone New Construction Coating System Evaluation TM0106-2006 Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion (MIC) on External Surfaces of Buried Pipelines
IEC (International Electrical Commission)	All sectors Marine Renewables	Switzerland	IEC / TC 88 Wind energy generation systems IEC / TC 114 Marine energy - Wave, tidal and other water current converters



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