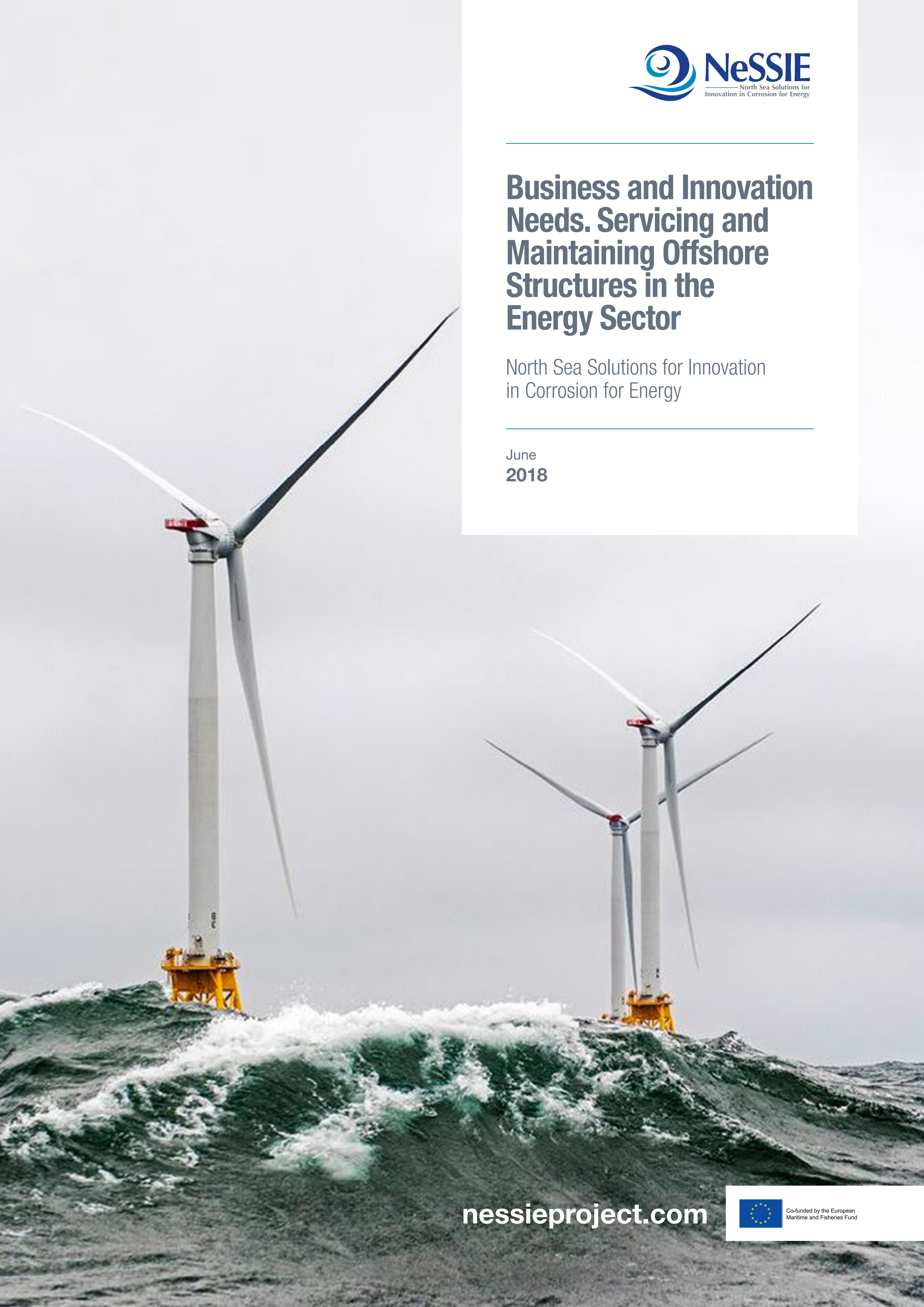


NeSSIE
North Sea Solutions for Innovation in Corrosion for Energy

Business and Innovation Needs. Servicing and Maintaining Offshore Structures in the Energy Sector

North Sea Solutions for Innovation in Corrosion for Energy

June
2018

nessieproject.com

Co-funded by the European Maritime and Fisheries Fund

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).

The NeSSIE project is cofunded by the European Maritime and Fisheries Fund (EMFF).

PUBLICATION
This report has been produced by the NeSSIE Project Consortium (Deliverable 2.3).

AUTHOR
Francesco Matteucci (ASTER)

ACKNOWLEDGEMENTS
We would particularly like to thank for their input:
Jeroen Tacq (Sirris)
Joseph Huffmeier (RISE)
Charles Abbott (Scottish Enterprise)
Mark Georgeson (Scottish Enterprise)
All the companies surveyed

Table of Contents

List of Figures

1. Abbreviations and Acronyms

ADMA:	Advanced Manufacturing for Energy Related Applications in Harsh Environments
CAPEX	Capital expenditure
CCP	Cathodic Coating Protection
FLOW	Far and Large offshore wind
LCoE	Levelised Cost of Energy
O&G	Oil and Gas
O&M	Operations and Maintenance
OE	Ocean Energies (wave and tidal energy)
OEM	Original equipment manufacturers
OPEX	Operational expenditure
ORE	Offshore Renewable Energies
OWE	Offshore Wind Energy
OWF	Offshore wind farm
OWT	Offshore Wind Turbine
R&D	Research and Development
SME	Small to Medium Enterprise
TE	Tidal energy
TRL	Technology readiness levels
VC	Value Chains
WE	Wave energy
WP	Work Package

2. Executive Summary

Offshore Renewable Energies (ORE) represents the largest known untapped resource that can contribute to an EU sustainable energy supply and to the achievement of greenhouse gas reductions. One of the key factors in designing reliable offshore structures is controlling corrosion. This report aims at identifying a set of business and innovation needs within the corrosion topic through surveying the companies working within ORE sector. Such companies' needs can serve as a guideline for further development of Anti Corrosion Solutions (ACSs) and can be a tool to make strategic plans for the future decrease of the Levelised Cost of Energy (LCoE) of the emerging ORE sector. This report starts with an overview of the current status and challenges of the ORE sector taken from the literature. This is followed by the description of how the companies to be surveyed were selected and by how the questionnaire for the survey was designed and prepared. This document will then describe how the survey data were collected and discuss the main business and innovation needs collected.

3. Introduction

The NeSSIE project is aimed at promoting and supporting the development of collaborative demonstration projects, through the establishment of strategic cross-sectoral public-private partnerships in the North Sea basin. Such partnerships will be aimed at:

1. increasing the know-how of designing reliable offshore structures, in the offshore energy sector, and
2. delivering new business and investment opportunities in the offshore energy sector.

One of the key factors in designing reliable offshore structures is controlling corrosion. Developing a map of the current anti-corrosion solutions (ACSs) and their application in existing offshore structures is a key part of assessing how to improve the medium to long term viability of installations in the emerging ORE sector. An attempt at such mapping has been documented in report 2.1 of the NeSSIE project. To complement this work, it is important to connect end-users with solution providers. Potential solutions are often developed without really understanding the needs of the end-user and, vice versa, end-users are not always aware of newly developed solutions. This situation slows down technological progress of ACSs for the offshore sector.

To support the development of the innovation process within the offshore renewable energy sector, this report identifies a set of technological challenges in corrosion and materials that will significantly impact cost reduction. Such a set of challenges can serve as a guideline for further development of ACSs for the offshore energy industry. An overview of the current status of the sector will support this assessment.

This report (deliverable 2.3) fits into the overall NeSSIE WP2/WP3 scheme as illustrated in Figure 1. Information provided by surveyed companies is used to identify innovation barriers, relating to the adoption of corrosion solutions and materials. In a later stage of the project, this information will support the definition of critical success factors for the development of NeSSIE demonstration projects. These success factors will be made available to value chain companies and research organisations active in the ORE value chain and help them to develop effective, market-ready solutions. The information from this report will also help the NeSSIE project team to connect ORE developers with the offshore value chain, allowing them to set-up projects targeted at specific industry needs.

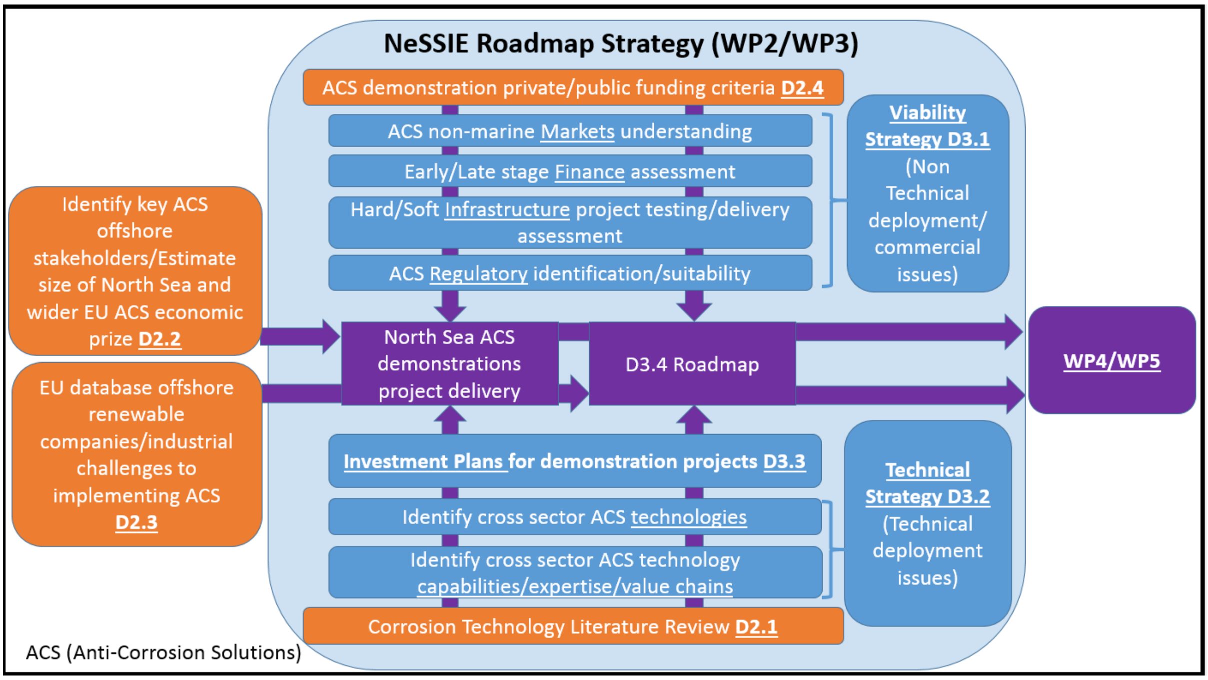


Figure 1 – D2.3 position in the wider WP2/WP3 NeSSIE project (UEDIN, Laurie 2017)

Some companies were contacted through email to fill in the survey. In other cases one-on-one meetings were organised. A technical workshop was also organised with companies operating in the offshore energy sector. The key output was to collect quality data from companies and each partner had the flexibility within their region to use the approach that best suited their company base. To increase the industry engagement and get out of the box their ACSs needs, in fact, not always the "easy" approach of an email is sufficient, but a more time-consuming approach is strongly recommended. Such a method is time-consuming, but in this case the results were very positive and many inputs, not only on corrosion, but also on other offshore energy issues, were discussed with the stakeholders. Besides, such a method allowed to strengthen the network of the stakeholders on offshore energy, because it allowed the partners to introduce the Nessie project and its partnership.

The subtasks of this deliverable were:

- A study of the literature concerning the main challenges to decrease Offshore wind farms (OWFs) and Ocean Energies (OE) Levelised Cost of Energy (LCoE).
- Identifying pivotal companies and value-chain companies in the ORE field to survey.
- Drawing up of the questionnaire for the survey (e.g. industrial challenges on corrosion, technological needs, research needs, etc.);
- Collection and analysis of the data and drawing up the final report.

This report will result in:

i) A better understanding of the critical factors to decrease LCoE costs in ORE.
ii) Planning of appropriate innovation strategies to connect the value chain with developers and end users.
iii) Development of the investable demonstration projects.

In conclusion, NeSSIE partners set up and implemented a survey amongst the companies of the ORE value chain focused at showing their business and innovation needs in the service life of offshore structures. This report starting from a literature study of the ORE challenges to decrease their LCoE will show and discuss the main business and innovation needs of the ORE value chain companies.

3.1. Definitions

In this paragraph all the technical concepts discussed in this report are defined as follows:
Vanguard Initiative: A coalition of regions that places the EU Smart Specialisation (S3) agenda at its core and whose main implementation processes are clustering and open innovation. Its partners seek to 'lead by example' and to drive and support new efforts to generate the scale and capacity for the EU to compete on an international level in several key domains These are Bio-Economy, Efficient and Sustainable Manufacturing, Production through 3D-Printing, Offshore energy applications and New nano-enabled products. The Vanguard Initiative has been in operation since 2014 and is an active European network seeking to 'test' and implement the Commission's economic policy of smart specialisation. NeSSIE is a result of cooperation initially engendered through the VI ADMA Energy Pilot.

ADMA Energy Pilot: The Vanguard pilot for "Advanced Manufacturing for Energy Related Applications in Harsh Environments" (Offshore energy applications). Its main goal is to create new business opportunities and increased growth for the sector. The ADMA Energy pilot is focused around 4 sectors:
i) Offshore Oil and Gas – especially deep-water fields.
ii) Unconventional Oil and Gas – such as shale gas and coal-bed methane.
iii) Offshore wind.
iv) Ocean energy – especially wave and tidal.
ADMA aims at helping larger companies strengthen their supply chains by working with innovative SMEs all over Europe, and provide SMEs with new, high-demand customers to grow their businesses.

Pivotal companies: Companies (mainly large) that have known capabilities and ambitions to significantly influence the direction of the sector and the future development of a new value chain.

Value chain companies: A value chain is a set of activities that an organization carries out to create value for its customers [1]. Therefore, value chain companies (mainly SMEs) are the ones that perform support activities (manufacturing of subcomponents, assembly, operations, etc..) transforming inputs from Pivotal companies or other customers in outputs for the whole sector.

3.2. Offshore renewable energy status

The global energy consumption is growing, and is expected to increase 36% by 2035 [2]. As well known, the use of fossil fuels as energy source has several disadvantages: they are non-renewable at human time-scale, they increase the green-house effect through the release of CO_2 and they are not evenly spread throughout the world. Hence, countries with either small or no fossil resources should minimize their dependency. The solution is to either decrease the energy consumption or use sustainable, clean and renewable sources of energy. Development of the latter solution, as well as addressing climate change, requires a globally coordinated, long-term response across all economic sectors.

Global investments in renewable energy sources (RES) have shown a steady growth for more than a decade. The EU-wide share of renewable energy in final EU energy use increased from 15 % in 2013 to 16 % in 2014. As shown by the European Environment Agency (EEA) in November 2016, this figure continued to grow in 2015 and hopefully will further increase in the next years (see Figure 2).

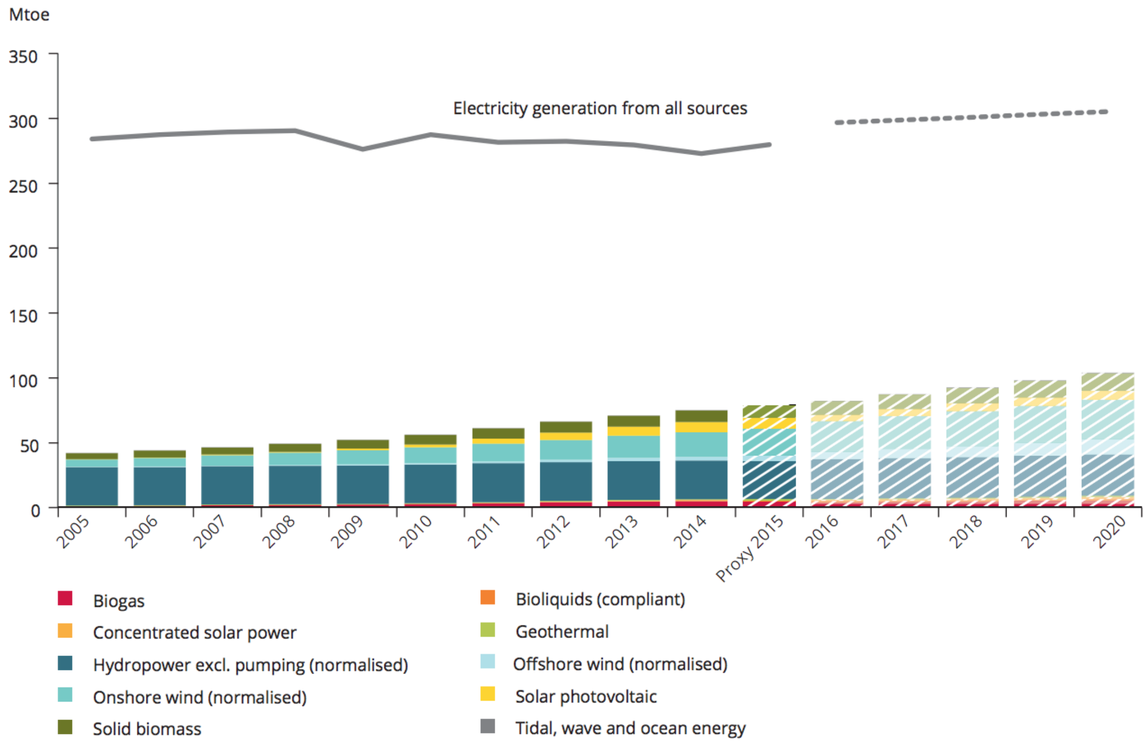


Figure 2 – Renewable Energy Source – Electricity generation in the EU-28 [3]

Information from Eurostat, updated in March 2017, illustrates that the official EU-wide RES share reached 16.7 % in 2015. The EU's binding renewable energy target is to reach a share of at least 27 % of renewable energy in its gross final energy consumption by 2030. EU Policy has very successfully taken the first generation of renewable energy technologies, such as solar and onshore wind, to commercially competitive levels. EU will, however, need other technologies to further diversify its low-carbon generation capacity, if it is to meet its objective of reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050.

ORE represents the largest known untapped resource that can contribute to an EU sustainable energy supply. ORE could be an EU industrial success story providing a significant contribution to the EU energy system in the midterm (5-10 years) supporting the achievement of greenhouse gas reductions. Analysts state that within the next 20-30 years the power generated by the ORE sector could strongly increase mainly from the UK, French and Dutch markets [4]. ORE can be divided in the following main categories: Wave / Tidal (OE), OW and others (ocean thermal energy conversion (OTEC) and salinity gradient energy). This report will focus on OE and Offshore Wind (OW) energy, given OTEC and salinity gradient technology are still at early stage of deployment.

3.2.1 Ocean Energy status

Most of companies developing OE devices and of OE projects under development is located throughout EU (see Figure 3). With continuing support over the coming decade, the EU could maintain its leadership in the OE global market which is worth a potential €653bn between 2010 and 2050 with an annual market of up to €53bn. This sector could provide significant benefits in the EU economy, provide export opportunities in growing global market [5] and lead to job creation and growth across the EU.

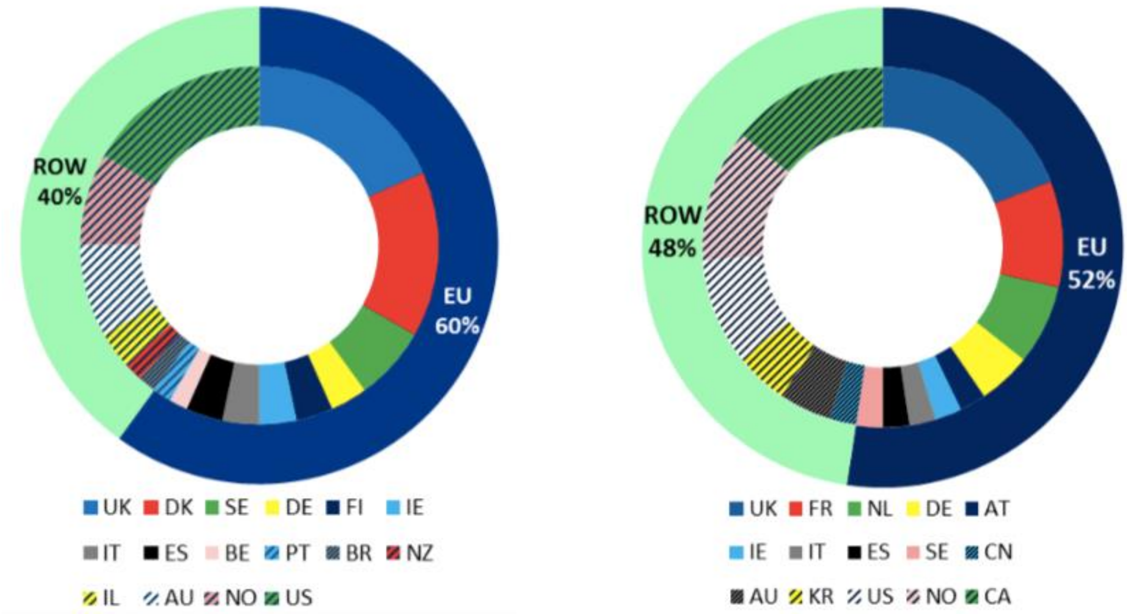


Figure 3 - Distribution of Tidal Energy developers (a) and Wave Energy developers (b) in the world
Source: JRC Ocean Energy Database, authors' analysis

To support the growth and development of the OE sector with a view to maintaining global leadership, the EU has created a positive policy framework and provided significant public financial support to R&D sector activities as outlined in Figure 4 below.

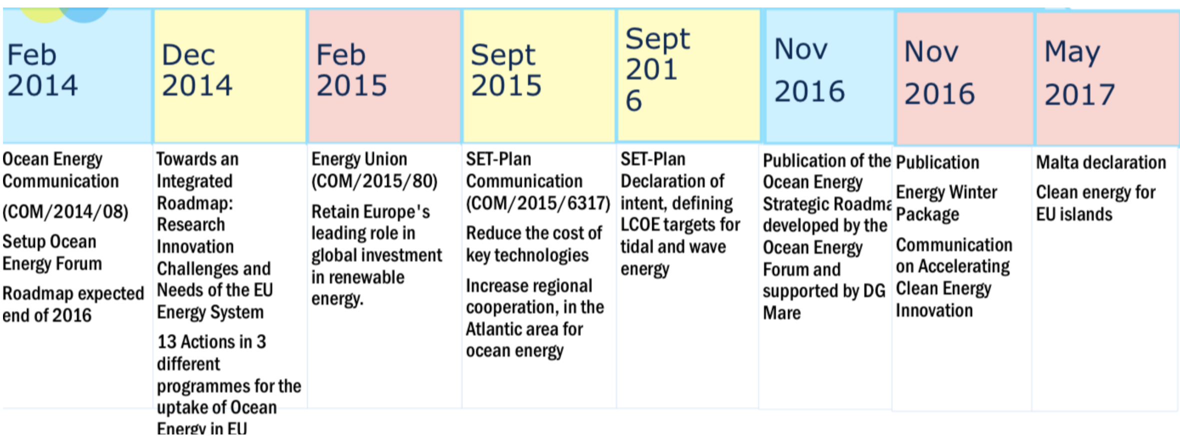


Figure 4 – OE policies at EU Level

In January 2014, the EU launched the Ocean Energy Communication [5] which highlighted the expected contribution of OE in the EU. The communication also set the framework for the development and uptake of the OE technologies by 2020 and beyond. The communication laid out

i) the setup of the Ocean Energy Forum, a platform to bring together the different actors and stakeholders that in 2016 produced the Strategic OE Roadmap for the industrial development of the sector and its implementation [6],

ii) the prioritization of the TE and WE key actions which were aimed at filling the residual gap between research or prototype demonstration projects and their commercial deployment within the 2016 EU SET Plan (Strategic Energy Technology Plan) [7], and

iii) the EU Technology and Innovation Platform (TP-Ocean) for OE that in 2016 produced the Strategic Research Agenda for OE [8].

Despite this support, the installation of OE devices and market uptake in the EU is progressing at a slower pace than expected. By 2020 the pipeline of EU announced projects could be over 500 MW for TE, of which at least 20% could be operational and over 50 MW for WE, of which at least 20% could be operational [6]. This requires that the main technological challenges for cost-reduction are tackled through demonstration of the technologies' reliability and survivability in aggressive sea conditions, and that existing financial barriers can be overcome. However, in reality, most TE and WE technologies are still in the pre-commercial stage.

Today, many projects are in the R&D stage and have not yet entered the operational stage. There are several full-scale devices deployed in real sea environments. A few arrays of multiple devices have even been installed, however also these projects are still pre-commercial. [9-11]. Currently, the LCoE of these technologies is higher than 150 €/MWh. In many cases the immediate priorities of OEM's (Original Equipment Manufacturer) and developers' active in OE are to secure financing for the pilot array demonstration projects and to increase the technology reliability, rather than reduce the LCoE [11]. The 2016 EU SET-Plan targets TE LCoE to at least 100 €/MWh in 2030 and Wave energy LCoE to at least 100 €/MWh in 2035.

Although WE and TE are not yet "industrialized" and their market is still small, they already have a large value chain involving many companies, are getting increasing funds for their development and iii) will be able to support renewable energies balancing and grid integration in the future. There is a number of reasons for this. They can be installed at a wide range of (remote) locations throughout the EU, have minimal visual impact and can provide a balanced energy system with other renewable technologies, and transport and storage solutions.

3.2.2 Offshore wind status

The OW industry grew on average 36.1% yearly since 2001 and is becoming a mainstream supplier of low-carbon electricity. As shown in Figure 5, 2015 was a very good year both for onshore and OWFs installations. In 2015, OW new capacity additions totalled nearly 3.4 GW across five markets globally bringing the total OW installations to more than 10 GW (see Figure 6 and 7).

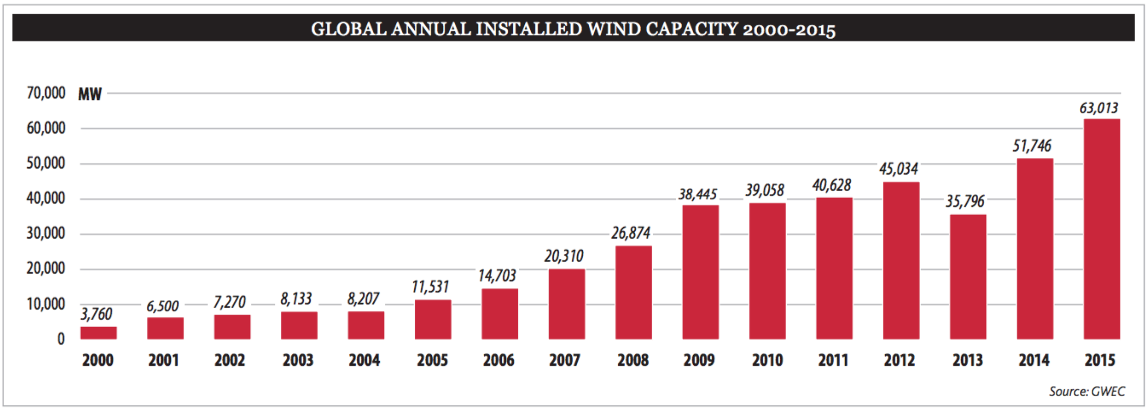
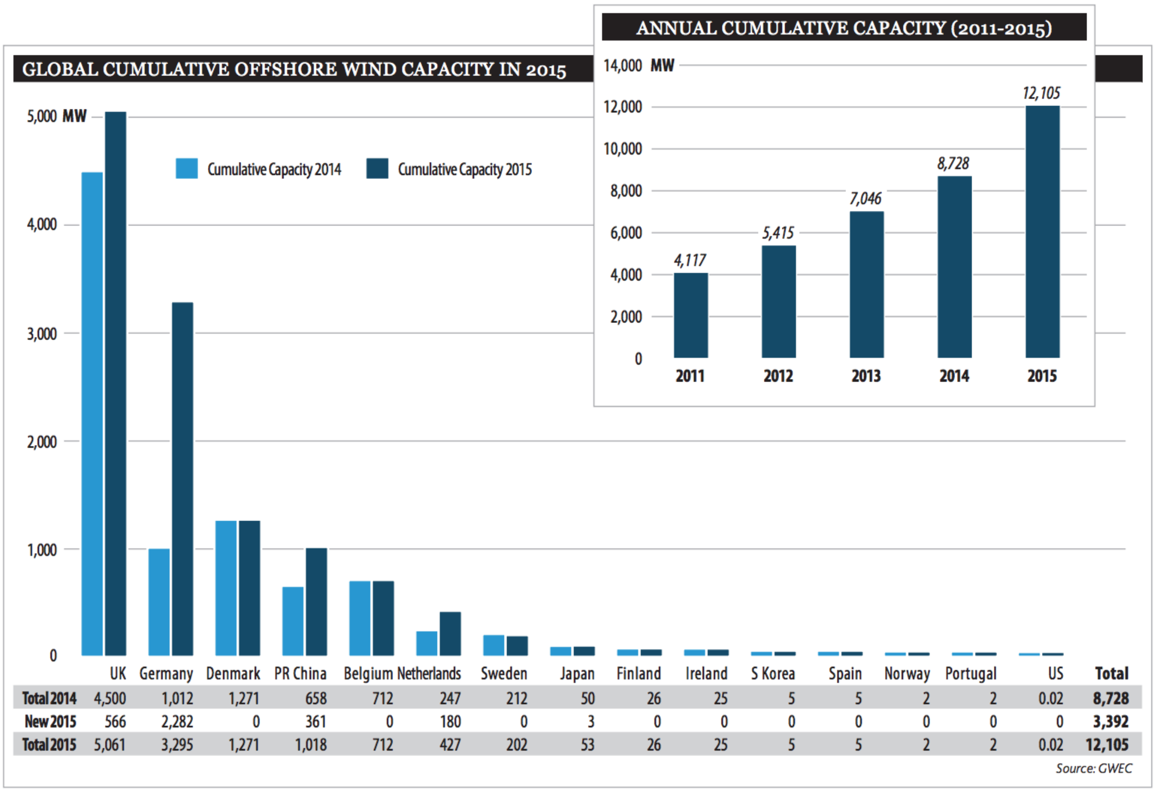


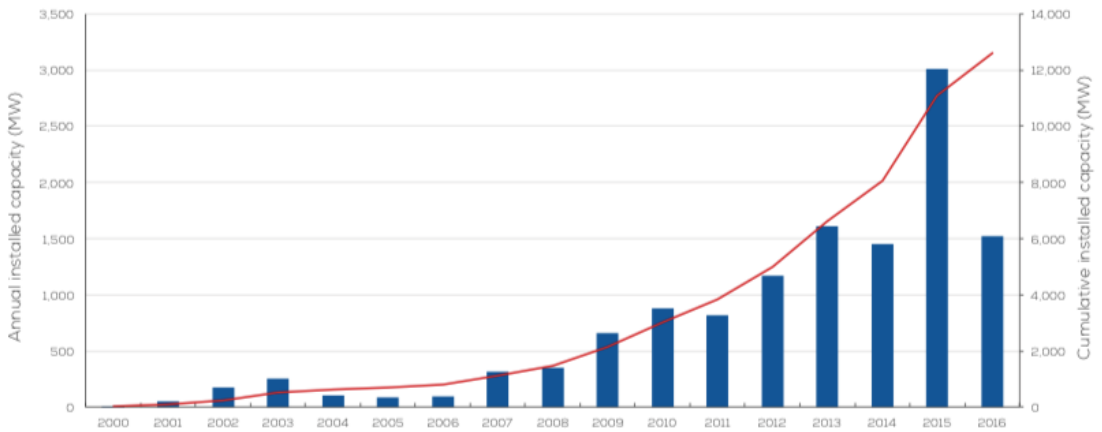
Figure 5 - Global Annual Installed Wind Capacity 2000-2015



	UK	Germany	Denmark	PR China	Belgium	Netherlands	Sweden	Japan	Finland	Ireland	S Korea	Spain	Norway	Portugal	US	Total
Total 2014	4,500	1,012	1,271	658	712	247	212	50	26	25	5	5	2	2	0.02	8,728
New 2015	566	2,282	0	361	0	180	0	3	0	0	0	0	0	0	0	3,392
Total 2015	5,061	3,295	1,271	1,018	712	427	202	53	26	25	5	5	2	2	0.02	12,105

Figure 6 - EU and Global OW cumulative capacity in 2014-2015 and in 2011-2015

In 2015, 91% of the OWE produced all over the world was in EU. The remaining 9% of the installed capacity is largely located in China, Japan and South Korea. In the EU, the UK is the largest offshore wind market having approximately 46% of EU OW market. In the same year, EU OWE rose to approximately 5% of the total electricity produced from renewable energy sources [13]. As of January 2017, there were 3.589 OWT installed and grid-connected in EU waters, making a cumulative total of more than 12 GW of generating capacity.



Source: WindEurope

Figure 7 – Cumulative and annual offshore wind installations 2000-2016 [14]

The average distance to shore and the water depth in which offshore wind turbines are installed is increasing. Although this means the average investment cost per project is rising, the multi-GW plans of the northern EU and Asian countries indicate that the industry will continue to grow. The necessity to increase the share of the OWE in the energy-mix is a priority in the EU. The EU is targeting 40 GW of OW capacity deployed by 2020, which would represent 10% of the total electricity produced from renewable energy sources. The target is 150 GW by 2030 which would meet 10% of the EU's power demand by 2030 [15,16, 17]. Nowadays, based on the number of OWFs under construction, it is estimated that the total EU OW capacity will be 24.6 GW by 2020 [17].

Over the medium term, the North Sea is likely to stay the main region for OWFs deployment (accounting for 78% of the European total, followed by the Baltic Sea (accounting for 14.1%) [16] (see Figure 8).

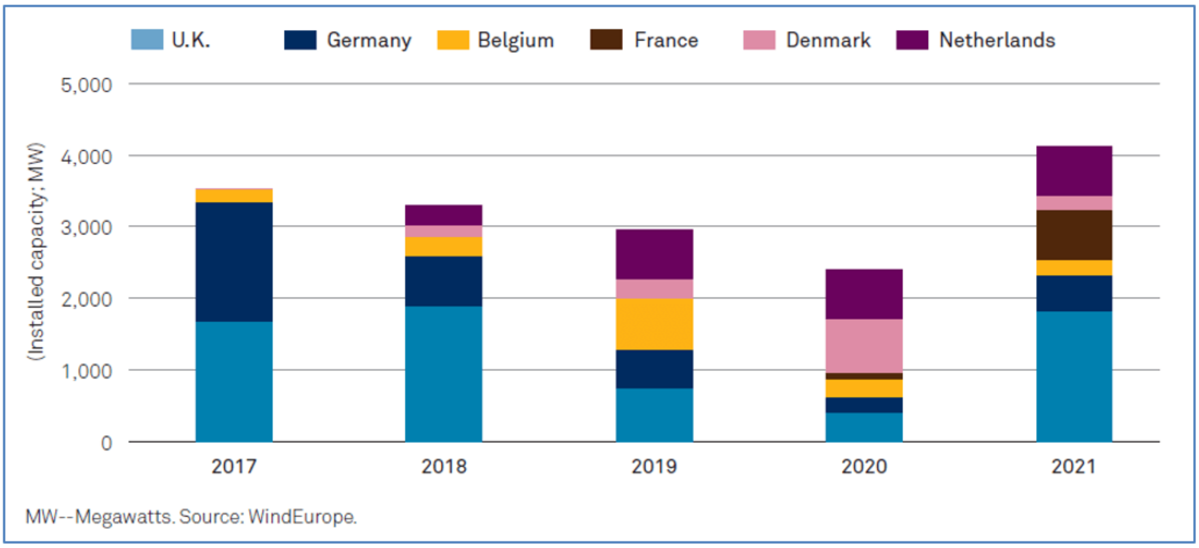


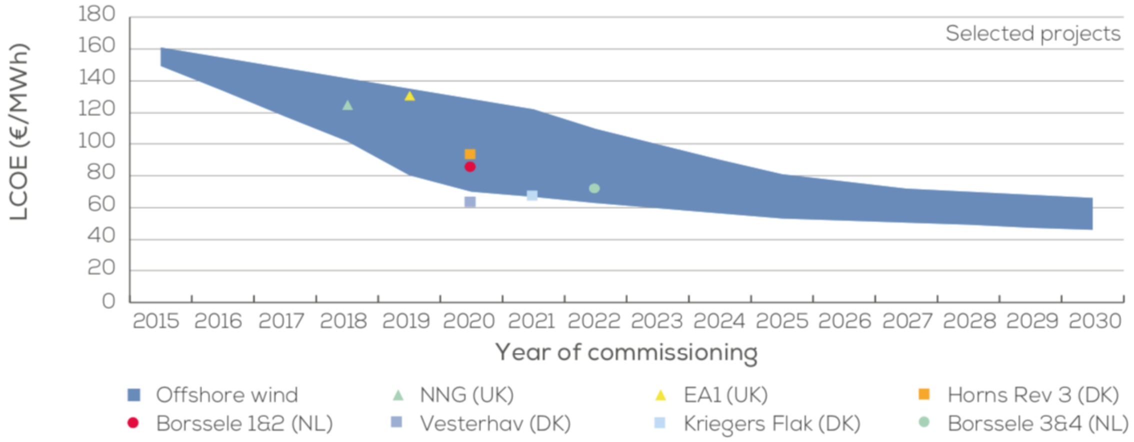
Figure 8 – EU's Project Pipeline: Five-Year Outlook [16]

While the LCoE for offshore wind is decreasing, as shown in Figure 9, further reduction will be required if the EU wants to meet its renewable energy targets. This will only be possible if favourable regulatory, economic and technological conditions are created and maintained.

In recent years, the OW industry showed that it can deliver new projects quickly, at much reduced cost, and OWFs are considered commercially safe to attract significant finance at low cost. Although OWE has an average production cost of 110-130 €/MWh, there already are windfarms that will be commissioned after 2020 with prices in the 50-95 €/MWh range [19], as is evidenced by the unprecedented pricing breakthrough during the 2016-2017 period:

i) In July 2016 DONG Energy surprised the industry with its record-low bid of €72.7/MWh in the Dutch tender for the Borssele I and II wind farms.
ii) In November 2016 Vattenfall amazed the market with a winning bid of €49.9/MWh for the Danish Kriegers Flak project.
iii) In December 2016, a Shell-led consortium proved that the previous bids were no exceptions as it won the Borssele III and IV tender in the Netherlands with a €54.5/MWh strike price.
iv) In April 2017, the results of the German offshore tender shocked the energy business as EnBW and DONG Energy announced the world's first subsidy-free offshore wind farms (to be developed by 2025) [18].
v) Denmark's Dong Energy and Spain's EDP won the rights to build offshore wind farms in the last UK CFD round in September 2017 for £57.50/MWh. This figure is 50% below the guaranteed development price for offshore wind set two years prior to the auction.

The reduction of OW LCoE has been steep and non-linear, due to rapid evolutions in project finance costs, turbine technologies and supply chain capability, alongside the effect of competitive auctions and greater volumes.



Source: BVG Associates for WindEurope

Figure 9 – OW LCoE range and trajectory from 2015 to 2030

As demonstrated in onshore wind, to further decrease offshore wind LCoE, many technical and economic improvements still need to be made. OWFs in low water depths already developed and introduced many innovative technologies into the market that allowed to reach LCoE of approximately around 100 €/MWh and will soon go below such figures. However, OWFs in high water depths are still in the development/commercialisation stage of floating substructures and other technology improvements or innovations and therefore their LCoE is much higher than 100 €/MWh and is expected to strongly decrease after 2020 [20]. Nevertheless, the first “industrial” installations are getting better results than expected [21]. If we consider that a technology commercial maturity is a combination of Technology Readiness Level (TRL) and Commercial Readiness Index [22], floating wind is between CRI2 and CRI3 (see Figure 10) and time will be required to bring it to CRI6 as required by OW in deep water.

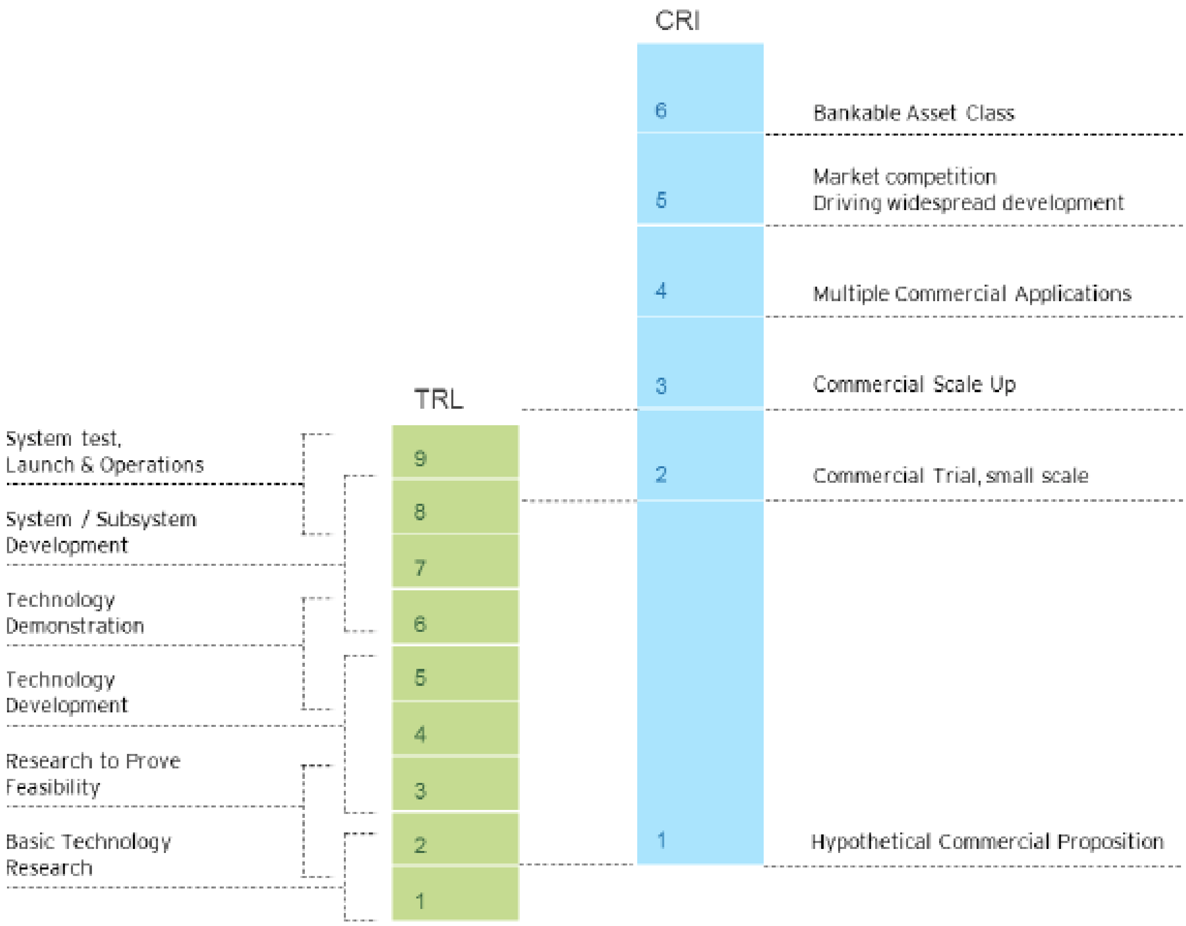


Figure 10 – TRL and CRI mapped on the Technology Development Chain [22]

3.3. Offshore renewable energy challenges to reduce LCoE

4.3.1 Ocean Energies challenges

The EU has identified OE resources in the range of 1000-1500 TWh of WE and around 150 TWh of TE annually. Tapping into this resource to deliver competitive energy has proved to be a challenge. Despite substantial dedicated EU development efforts over the last three decades (amounting to about €200M euros as estimated by Fraunhofer IWES based on information from the EU commission through Cordis) technological and non-technological progress in the OE sector has been slower than initially expected a decade ago. There are many interrelated reasons for this, including R&D framework conditions, the speed of technological innovation, critical mass in terms of deployment, financial and regulatory issues, market conditions and grid availability [23]. Taken together the progression of the sector and its ability to attract investment and to engage with the supply chain to unlock cost-reduction mechanisms has been slower than anticipated.

For technologies that are not market ready, such as OE, the consolidation of the supply chain, and its capability to decrease costs thanks to economy of scale, is dependent on the reliability of the technology and its progress to higher TRL levels. A number of elements can help to overcome the barriers faced by OE:

1) An integrated approach involving all the stakeholders leading to more shared risk.
2) A shared knowledge of best practices and the development of shared standards.

3) Lessons learned from early project implementation.
4) Learning and adopting technology solutions from other sectors.

The goals for the sector are clear, but the following "high-level" or strategic challenges must be overcome:

1) Address technology fragmentation to increase supply chain appetite for investment.
2) Address lack of cooperation and collaboration by identification of collaboration opportunities.
3) Identify the best strategies that will allow safe and efficient deployment of arrays.

By working together, the industry can overcome these challenges and demonstrate that the sector is capable of large-scale technology production, addressing the three-fold challenge of energy security, CO_2 emission reduction, and inward investment within the EU. It is by facing these challenges that the sector can gain traction and accelerate towards 2030 and 2050 OE deployment targets forecasted at a global capacity of 337 GW in the IEA Vision Document [23].

Governments at an EU, Member State and Regional Level, could consider some additional activity to support the sector:

1) Coordinate technology development: Discuss and write strategic documents involving all the major stakeholders (academics, RTOs, test centres, industrial actors, power plants developers/EPC/owners, etc.) to set the technological and non-technological framework. This could avoid raising unreachable expectations and use an evidence-based approach based on metrics currently applied to due diligence and evaluation of technologies.

2) Promote certification, performance guarantees, standardisation and accreditation: Using pilot project data and working with organisations such as the International Energy Agency, common standards will help to build confidence to investors, enable the bankability of projects and move the sector towards commercialisation.

3) Align framework conditions and support activities: Alignment of public funding activities between the EU, Member State, regional and national funding schemes to ensure suitable mechanisms are in place at the right time to support technology development.

4) Support technology development: It is essential to prioritise the use of limited funds. This means defining the conditions for continued funding, and at what point it is better to stop. This will require the use of a logical approach combined with the more "risky" technology-agnostic approach (not only picking winners).

5) Build and use a monitoring framework applying performance criteria: Progress needs to be monitored both on the technological side (reliability, installability, manufacturability, etc..) and the non-technological side (supply chain involvement, knowledge sharing, investor confidence, etc..). This could be done by involving a high-level expert Group in the monitoring, coming from the different stakeholders and trying to set up a covenant between industry and public sector [24].

In November, the Strategic Research Agenda for Ocean Energy was published by the European Technology and Innovation Platform for Ocean Energy (TPOcean) [8]. The research agenda covers all the OE technologies. Setting it up involved more than 200 expert and professionals from 150 organisations across the EU. Figure 11 shows the fourteen priority challenges that were identified and classified in three main categories. The anti-corrosion solutions, tackled by Nessie, is included in the "Increasing device reliability and survivability" challenge within the Technology category. The report focused on the following four research themes across all the OE technologies:

1) Demonstration, Testing and Modelling.
2) Materials, Components and Systems,
3) Installation, Logistics and Infrastructure.
4) Non-technological issues.

Category	Challenge
Technology	Developing novel concepts for improved power take-offs (PTOs)
	Increasing device reliability and survivability
	Investigating alternative materials and manufacturing processes for device structures
	Investigating novel devices before moving towards convergence of design
	Defining and enforcing standards for stage progression through scale testing
	Developing and implementing optimisation tools
Financial	Providing warranties and performance guarantees
	Linking stage-gate development processes to funding decisions
	Maintaining grant funding for early TRL technologies
	Establishing long term revenue support
Environmental and socio-economics	Enhancing social impact and acceptance
	Minimising negative environmental impacts
	Facilitating knowledge transfer and collaboration
	Implementing adaptive management systems

Figure 11 – Main priority challenges for Ocean Energy Development [8]

Summarised below are the challenges within the Strategic Energy Technology (SET) plan considered most relevant for the NeSSIE project. Each category (technology, financial, administrative and environmental) is addressed in turn.

TECHNOLOGICAL CHALLENGES

Some of the most important issues that the ocean energy sector needs to address in the short to medium term are of a technological nature. One of the key issues is the reliability and the performances of OE devices and the critical components/subcomponents. These include power take off, power electronics, gearboxes and mooring systems. Another aspect that needs to be considered relates to the survivability of the devices, especially during storms or extreme conditions. The lack of design convergence amongst OE devices, and their components, constitutes a further technological hurdle that the sector should overcome. Finding solutions to the technological challenges is fundamental to overcoming other barriers slowing the sector's development, and especially the issue of attracting finance to the sector [25].

In the TE sector the attention is now shifting from the development of prototypes to the development of an industrial supply/value chain. In the last three years TE has made significant progress toward commercialisation. At the end of 2016 fourteen TE projects based on different technologies (see Figure 12a) were grid-connected and operational. These included the first array installed in Shetland

and the four 1.5 MW rated turbines deployed as part of the Meygen project in the Pentland Firth [10]. To enable commercial future investments in TE it will be necessary to analyse the data from the aforementioned full-scale demonstration, and continue to improve the reliability of devices in order to build confidence with investors. In order to reach the targeted LCoE reduction of almost 75%, it will be necessary to combine R&D and industrial improvements that include:

- Access to the turbine for easier and less expensive installation and O&M procedures.
- Increased reliability and survivability of components.
- Reduction of civil and structural costs.
- Increased capacity factor (see Figure 12b).

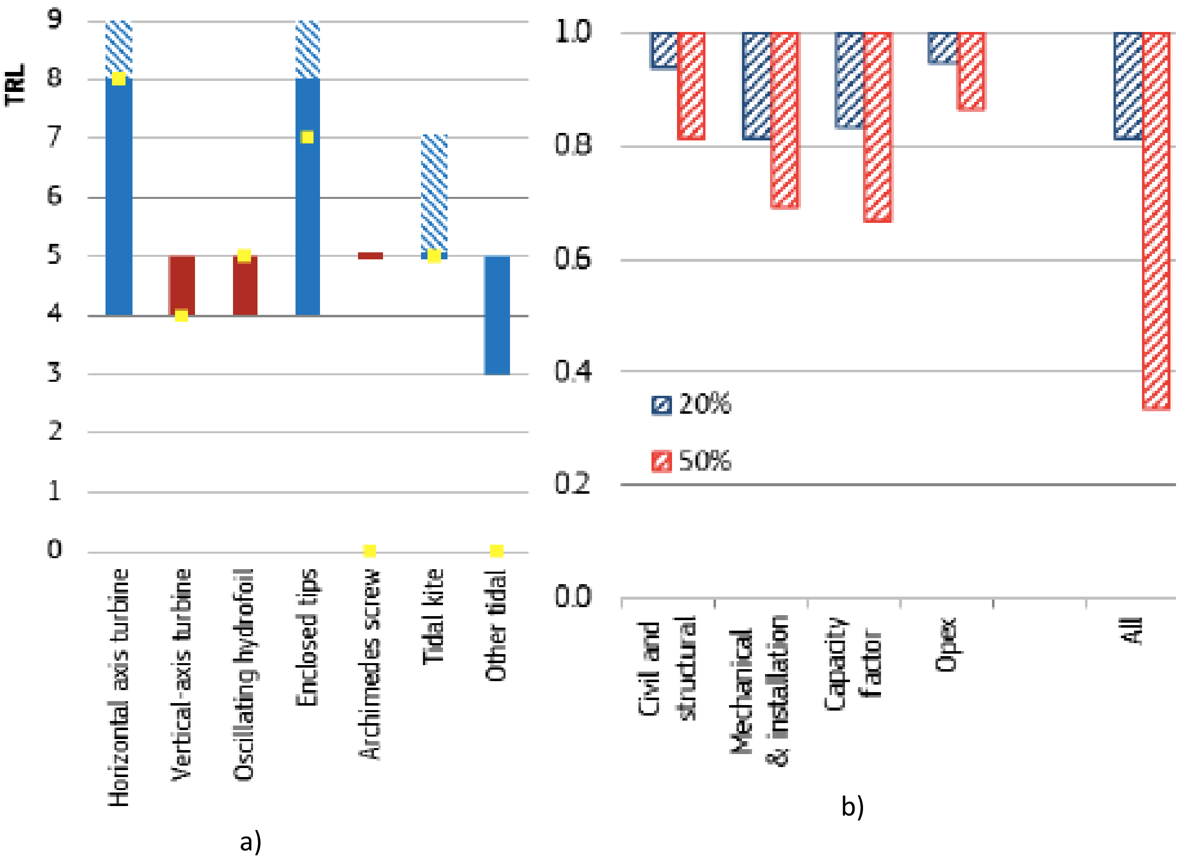


Figure 12 – a) Range of testing for TE devices and b) TE LCoE cost reduction in components

In Figure 12 (a) the blue bars refer to technology with significant progress in 2016. Red bars indicate technology with no considerable update/progress in 2016. Shaded bars indicated ongoing testing. The length of bar indicates the range of TRL attempted. The yellow dot indicates the maximum achieved TRL. In figure 12 (b) it is shown how much the LCoE (vertical axis) is influenced by a reduction of 20% (blue) and of 50% (red) for each cost components. For example, reducing the cost of mechanical equipment and installation by 50% would decrease the total LCoE by about 30% [10].

The WE sector development is at a lower TRL compared to TE. WE development slowed down over the previous years due to technological drawbacks that caused the failure/bankruptcy of companies considered at an advanced stage of development. Such failures obviously reduced the confidence of investors in WE technology. However, they also encouraged funding agencies to assess the technology status adopting stage-gate metrics that monitor and compare a technology's success, starting from technology development up to commercial viability [10]. This reduced the risks for both technology developers and funding agencies, and in the last two years WE has shown signs of recovery.

According to [5], the focus for the WE industry is to build on the demonstration of existing prototypes, and to improve the performance of key subsystems and components. This will increase the overall device reliability and survivability. Despite the relatively high TRL reached by some devices, their commercial readiness is still to be proven. Most of devices tested are still to be considered advanced prototypes, having demonstrated survivability to ocean conditions, but with limited electricity generation (see Figure 13a). Development of Power Take Off (PTO) technologies, optimisation of mooring configurations and increasing the survivability of the structures, are the key technological priorities for WE.

As for TE, also for WE LCoE can be strongly decreased by acting on civil and structural costs, mechanical equipment and installation, and OPEX. The comparison of the various cost reduction strategies shows that for WE, reduction of OPEX and reduction of mechanical equipment and installation costs are the most favourable options (see Figure 13b). A combination of all measures would lead to a LCoE reduction of almost 85 %, which is equivalent to costs of about 16 euros/MWh.

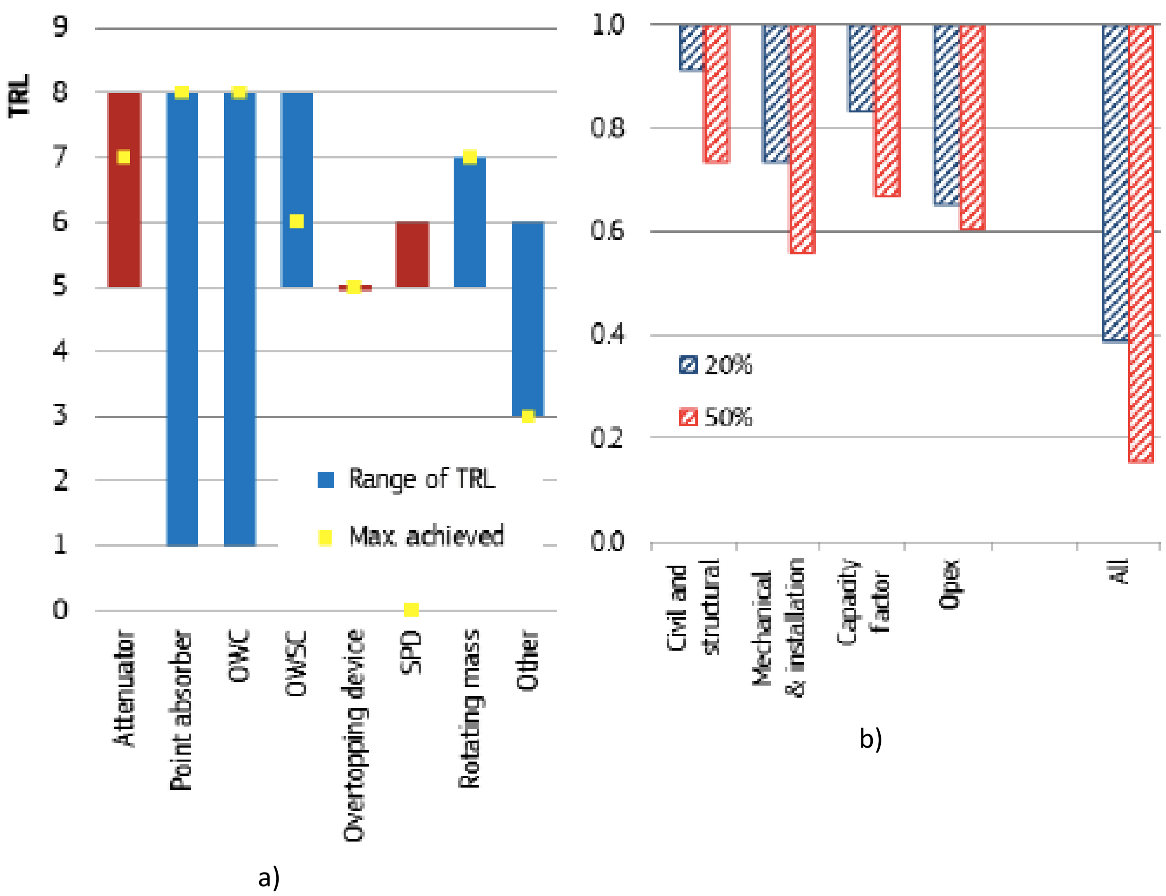


Figure 13 - a) Range of testing for WE devices; b) WE LCoE cost reduction component

a) Range of testing for WE devices. Blue bars refer to technology with significant progress in 2016. Red bars indicate technology with no considerable update/progress in 2016. Shaded bars indicated ongoing testing. The length of bar indicates the range of TRL attempted. The yellow dot indicates the maximum achieved TRL; b) it is shown how much the LCoE (vertical axis) is influenced by a reduction

of 20% (blue) and of 50% (red) for each cost components. For example, reducing the cost of mechanical equipment and installation by 50% would decrease the total LCoE by about 45% [10].
Common to TE and WE are the following technological challenges:

1) Characterisation and mapping of OE resources:
Precise estimates and description of available WE resources at high spatial and temporal resolution are needed for proper planning and the optimisation of the design of OE converters [26]. Modelling approaches for resource assessment and forecasting are already very advanced and have been performed for many regions of the world. However, a harmonisation of approaches developing a comprehensive pan-European wave and tidal power resource map is still missing.

Uncertainties concerning the available resources should also be reduced. This would allow a better determination of the value of investments and minimise risks, thereby increasing the confidence of investors. Going beyond pure resource assessment, it is necessary to consider local limitations from other activities in the marine environment. This will allow to accommodate conflicting or competing uses of the marine environment such as fishing, shipping, offshore wind, habitat protection and technical limitations (e.g. grid connection) [27].

2) Improving materials to survive the sea environment:
Materials, components and systems used in OE converters have a direct impact on system lifetime and maintenance intervals, therefore they need to be compatible with the marine environment and resist corrosion and the heavy loads they are subject to. Developing, characterising, improving and finally using the right materials is key to making OE devices survivable and reliable. Allowing them to produce energy at an acceptable cost.

Whilst many material solutions already exist that are utilised in marine applications there may be the opportunity to reduce CAPEX and OPEX using alternative materials and utilisation of new surface coatings [8]. Cost effective innovative materials for OE converters and components in seawater are needed that are:

i) Low-cost when properly applied as coating on OE devices surfaces.
ii) Resistant to biofouling, corrosion and erosion.
iii) Able to withstand the maximum loads and fatigue loading experienced during the OE converters lifecycle.
iv) Environmental friendly or greener in order to limit the overall structure impact on the marine ecosystem.

This will include the development and execution of long time or accelerated ageing tests in relevant sea environments.

3) Developing a bespoke ocean energy supply chain:
Using machines, vessels and tools that are not fully fit-for-purpose can slow the sector's progress and increase costs. The development of bespoke manufacturing procedures, vessels and installation techniques, therefore, needs to go together with the industrialisation of the ocean energy sector.

4) Grid availability:
Mainly in remote areas grid availability may be an issue. A lack of suitable grid infrastructure will

require network upgrades or the construction of new network lines, whose costs may fall on the developers. Electrical and infrastructural costs account for about 10–15% of wind and ocean energy expenditure. The identification of joint solutions for wind and ocean energy, to the availability and integration issues will provide a common avenue for the reduction of LCoE. Different EU policies are pushing for the implementation of shallow charging regimes, where developers share the cost of new grid capacity with grid operators.

Another key aspect for the OE sector is the issue of grid integration. In this context, the adoption and development of grid-codes in line with the experience of the OW and WE technologies would provide opportunities for concerted R&D efforts between the two sectors [31]. The shift towards an integrated European Energy system may provide the required support in overcoming infrastructural barriers with regards to grid availability [32].

FINANCIAL CHALLENGES

The total R&D investment in OE is about 10% of that for OW [28]. The level of public support available, through both market push and market pull mechanisms, appears to be adequate to the current state of technology development and maturity of OE technologies. However, the sector is at a critical stage. While market leaders are reaching financial close for the deployment of pre-commercial arrays, one of the main challenges is still securing investment for demonstration and pilot arrays [25]. Policy makers and developers must find and make available matching funding schemes and/or promoting the establishment of, and contribute to, a public-private partnership (PPP) through best use of existing sources of funding.

While the industry recognises the need for large utility scale deployments as an essential part of meeting the EU OE deployment targets, enhanced technology push support will help address the continued requirement for earlier stage OE R&D funding in the EU that will facilitate technologies and sub-systems that may play a future role in cost reduction and performance improvement within OE technologies. Besides, it is necessary to have a timely use of public funding with the current technological level and needs as well as developers must increase their attractiveness towards private investors because it is essential that the right support reaches the right projects at the right time [23, 29].

ADMINISTRATIVE & ENVIRONMENTAL CHALLENGES

Procedures to obtain full consent are often lengthy, delaying the project development. At EU-level, there is the need to standardize licensing procedures.

OE – as all other renewable sources of energy – can contribute to a more sustainable energy supply, but it is not environmentally friendly per se. Several funded projects have been looking at environmental uncertainties and social impacts of OE converters [30]. The main direct expected environmental impacts of TE and WE current technology include impact on the benthic community (due to alterations in flow patterns, wave structures, sediment dynamics), species-specific response to habitat change, and the entanglement of marine mammals, turtles, larger fish and seabirds. Due to the limited observations, the significance of environmental impacts of commercial deployment projects cannot fully be determined yet. Therefore, there is a significant opportunity for an 'adaptive management' approach to be utilised in the OE sector, as there is a greater value in learning the real impact of a technology through deployment, rather than speculating the possible impacts of a non-deployed technology. Adaptive management, such as 'deploy, monitor and mitigate' techniques could have binding stipulation in place that could require mitigation activity if a certain threshold is perceived to be reached, or even removal if breached. The conditions would need to be fully agreed and approved by any regulatory bodies prior to the construction and deployment of a given project, and continual monitoring would take place until sufficient evidence has been gathered to demonstrate that there is no longer a risk associated with continued device operation [23].

4.3.2. Offshore wind challenges to reduce LCoE

OW is still a developing technology whose competitiveness in comparison to traditional power generation technologies is rapidly developing. Its CAPEX has decrease significantly (see Figure 9 and Figure 14) due to technological development, in part made possible by government support schemes.

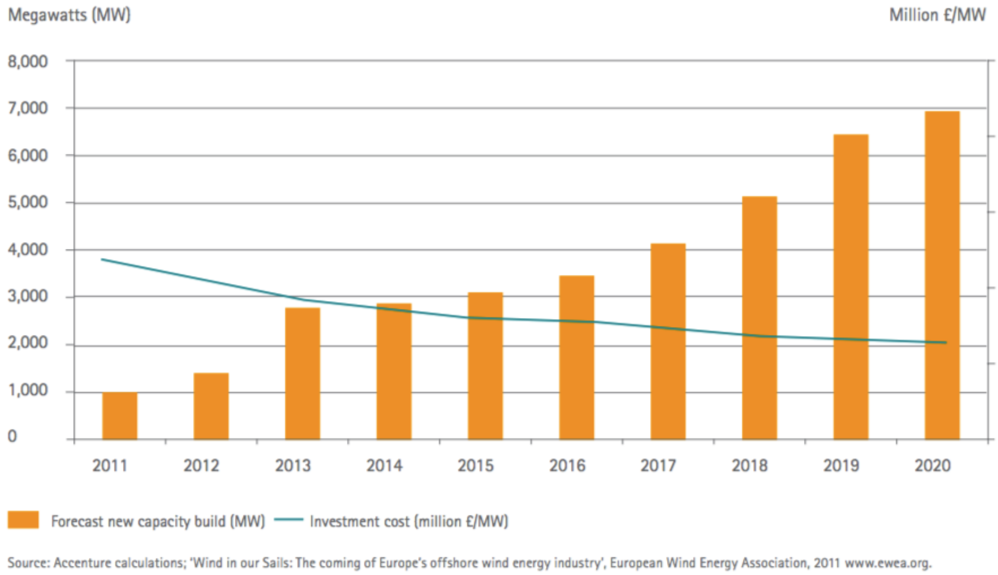


Figure 14 - Planned capacity growth of OW in EU and expected evolution of investment costs

The development of an OWF is a technically complex, lengthy, risky and capital-intensive process (see Figure 15) [33].

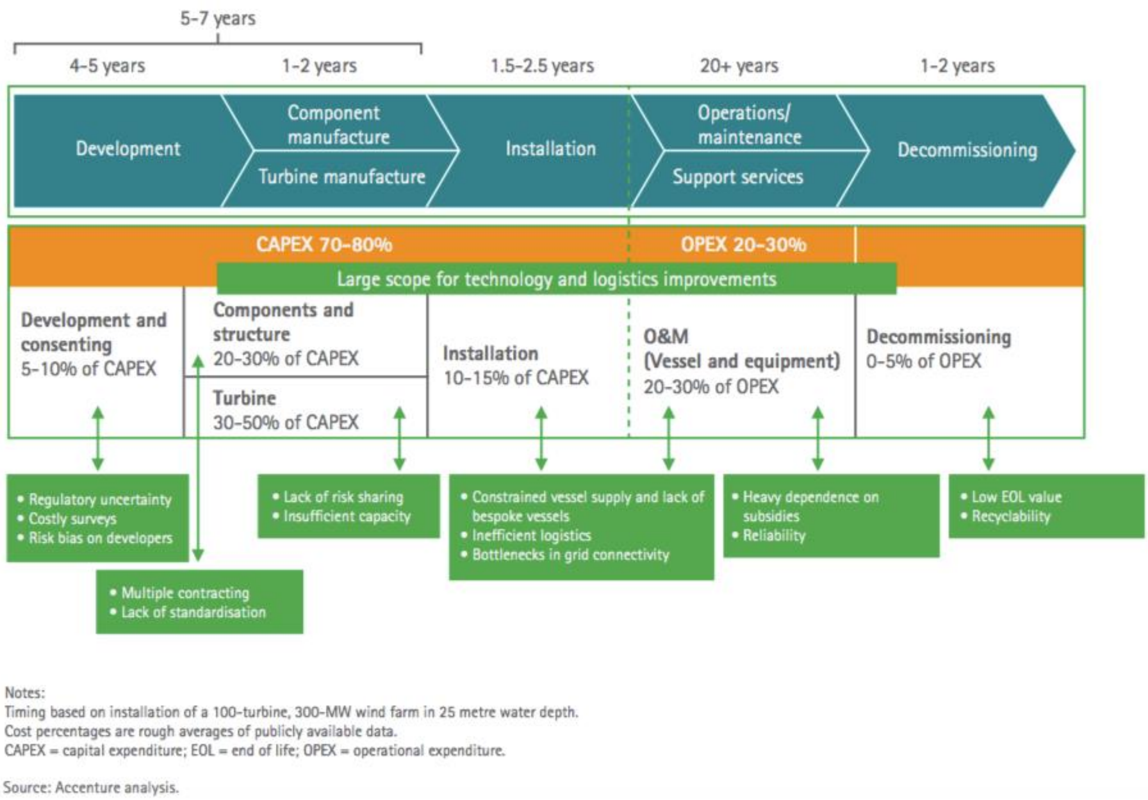


Figure 15 – Offshore wind project life cycle

Yet, while technological progress is clear, the OW industry faces significant challenges ranging from the need of trained staff to the need of a suitable electric infrastructure. In the last years, the two technologies that have resulted in most progress are larger, more effective turbines and improved foundations. However, to reach the aforementioned goals of OW LCoE there are many more challenges including:

- Reducing financing costs
- Decreasing CAPEX for Offshore Wind Turbines.
- Facilitating the development of international grid infrastructure.
- Decreasing installation, logistics and transport costs.
- Decreasing O&M costs
- Cooperation and contracting

The above list of challenges is intended as a synopsis only. In the following the individual challenges will be addressed in more detail. This is not to be considered as an in-depth study, but is aimed at providing some information to the readers and providing ideas useful for the development of the NeSSIE demo projects.

REDUCING FINANCING COSTS

Mega OWFs are capital-intensive investments and financers are typically conservative, placing a high value on measuring risk. Due to these facts, OWF project developers and operators seeking access to capital through structured finance instruments (i.e. debt pooling, investment banks, pension funds) need to consider tailoring their project to make it attractive to specific sources of financing: for example, they must decrease perceived financial risks toward OWE through installing demo cases and transparently monitoring and present their costs, thereby illustrating the business reliability (solid business case).

DECREASING CAPEX FOR OFFSHORE WIND TURBINES

As shown in Figure 12, the largest proportion of OWT CAPEX is the turbine and foundation/substructure cost (their sum accounts for almost 70% of CAPEX). There is a general consensus that significant technology development is still needed to shift project economics to attract more investors. However, the technology and R&D departments of the leading turbine manufacturers still focus predominantly on onshore technology, as onshore wind still represents the lion's share of the turbine market. In the near future, with the increase of "mega" OWFs, OWTs technology innovations will enable greater power and higher reliability without increasing the cost per MW of capacity. It is expected that offshore turbines will grow to 13-15 MW in the next decade (from 6-9 MW today) and this will have a significant effect on cost trajectories [17].

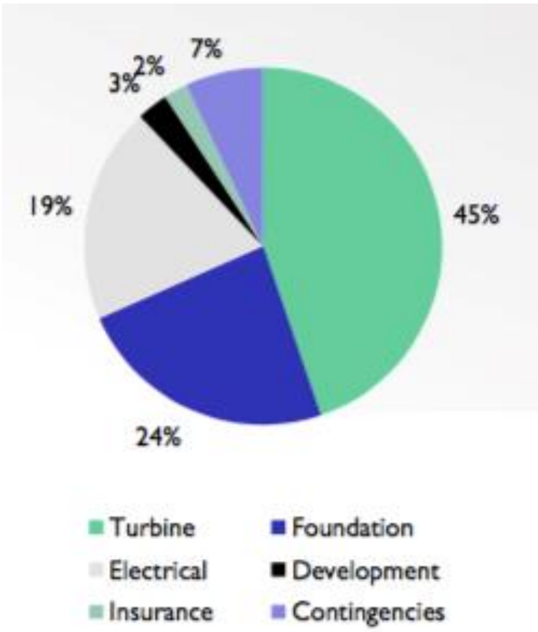


Figure 16 – Typical breakdown of OWT costs [34]

As far as the foundation is concerned, nowadays approximately 80% of the commissioned OW structures are supported on monopile structures, followed by gravity foundations (7,5%) and jacket structures (6,6%). OW substructures in low/medium water depth are increasing their reliability and many studies on gravity foundations and jacket structures are under development. Gravity foundations can be constructed entirely on land and are relatively simple to transport and install by sinking. Being made of concrete, they have the advantage of lower maintenance costs due to a lower sensitivity to fatigue failure. The challenge is to develop gravity foundations for use at greater sea depths (more than 45m) or with a hard seabed surface.

Looking to the future, more jacket structures are expected to be installed. When piled these structures require grouting in each leg. A challenge is to develop inspection and monitoring techniques that allow to assess the integrity of the grouted connection.

Due to the increasing size of OWTs, and therefore of their foundation, offshore steel manufacturers are struggling to use modern materials and fabrication techniques to produce thicker plates for monopiles or other types of substructure. In this field, the challenges are to understand the behaviour of new materials in harsh environments and the influence of new fabrication techniques (e.g. welding processes) on the crack formation and growth. Therefore, there is a need to carry out experiments on representative materials and structures in appropriate environments.

In the near future, the OW industry will be moving to more challenging sites with no visual impact (i.e. OW farms located in high water depth and in cold climates) where LCoE could be lower than 50 €/MWh due to their higher capacity factors. Therefore, other support structures such as tripod (actually 3,2%), tri-piles (actually 1,9%) and floating foundation are under development. These allow to commercially exploiting previously inaccessible regions (see Figure 17). In this field, one of the main issues is to assess the reliability of the different solutions proposed, therefore demo projects are under development or under monitoring.

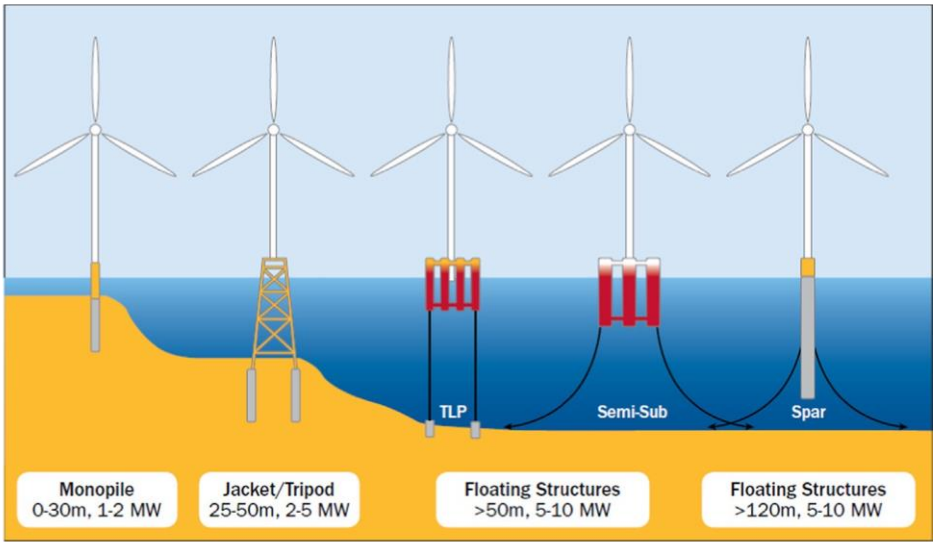


Figure 17 - Offshore wind support structures with their associated water depths [35]

FACILITATING THE DEVELOPMENT OF INTERNATIONAL GRID INFRASTRUCTURE

Wind speeds offshore are stronger and more stable than on land, making OWE potentially easier to integrate into the power generation mix than onshore wind. Still, the intermittent nature of wind and therefore power generation, means that its integration into an existing electricity grid is a critical step that requires back-up capacity from base-load generation and peaking plants. The main alternative power generation sources to back-up intermittent wind output are:

i) Natural gas: Easier to cycle than coal plants due to greater simplicity in controlling fuel supply and greater responsiveness of the direct combustion gas turbine systems compared to coal or biomass boiler-to-steam turbine systems.

ii) Hydro-electric power where available: Technically the most effective complement to renewable generation currently available, because it can be rapidly cycled, has zero operating emissions and has no loss of energy efficiency in the cycling process, and in the long term.

iii) New energy storage technologies: Ideal complement to OWE being fully flexible to efficiently store renewable electricity whenever there are surplus generation spill overs, and to release this stored energy when in demand. This allows to smoothen out the supply profile, but at present no technologies (outside of pumped-stored hydro) are close to overcome the combined required performances of durability and low cost.

iv) Demand response systems: A novel method of managing renewable intermittency actually primarily used as peak shaving that is under development thanks to the development of "smart" and automated grids [33].

DECREASING INSTALLATION, LOGISTIC AND TRANSPORT COSTS

Installation costs can account for approximately 30% of the overall project cost [35]. In fact, installing an OWF requires the transport and handling of multiple components that are typically very large, very heavy, but also very fragile. The logistics of OWTs have so far largely been borrowed from the onshore wind industry, but also from O&G offshore operations. Due to the limited supply of specialised vehicles and vessels, the logistics associated with OWFs usually involves high costs and time constraints.

Faster and safer installation and operations could be facilitated by a larger fleet of specialised vessels for OW. In parallel, the development of new processes for OWT subcomponents assembly done near ports, in coastal locations or at sea could deliver dramatic cost and time reductions. Waiting times can result in substantial revenue losses, whereas timely spare-parts supply, thanks to an optimized warehouse management, or sufficient repair capacity, thanks to trained staff, will shorten the logistic delay times.

Until now, O&M visits are carried out when the significant wave heights are less than or equal to 1.5-2m. As a result, access to the OWTs in the North Sea is estimated to be possible for only 100 days per year, with the remaining time of the year as non-productive time ('weather downtime'). Technological development such as ships with improved navigation, motion stabilizers and new systems for safe O&M personnel transfer (i.e. "mother ship" approach) will allow an increase of the safe working wave height up to 3 m and above, therefore increasing the number of days available for transfers up to 310 days per year [36, 37].

DECREASING O&M COSTS

OWT reliability is already high and will further improve. Nevertheless, sea operations are responsible for a large part of the total life cycle cost [38-40]. In fact, many reports showed that, depending on the source and the definitions used in the cost assessments, the O&M costs are around 14 to 30 % of the total cost of an OWF, approximately 55% of OPEX and its annual total cost varies between 15 and 45 €/MWh [39,41,42] (see Figure 18).

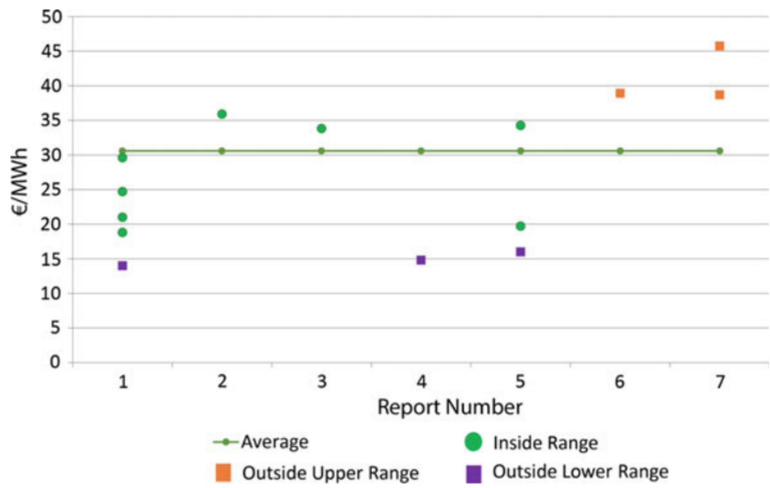


Figure 18 - Spread of the O&M cost of OWFs in different studies [43]

O&M costs are mainly due to spare-parts replacement and repair actions, but also by production losses due to downtime. The accessibility of a turbine in case of a failure is one main aspect affecting downtime.

As it can be seen from Figure 19, breakdown of OPEX in a OWF strongly depends on maintenance operations. In fact, individual OWTs currently require about five site visits per year: one regular annual maintenance visit, and three to four visits in case of malfunction [44]. This is almost as much as the cost of the wind turbines and about as much as the costs of construction and installation. Decreasing such costs is therefore an important challenge that requires to overcome many challenges.

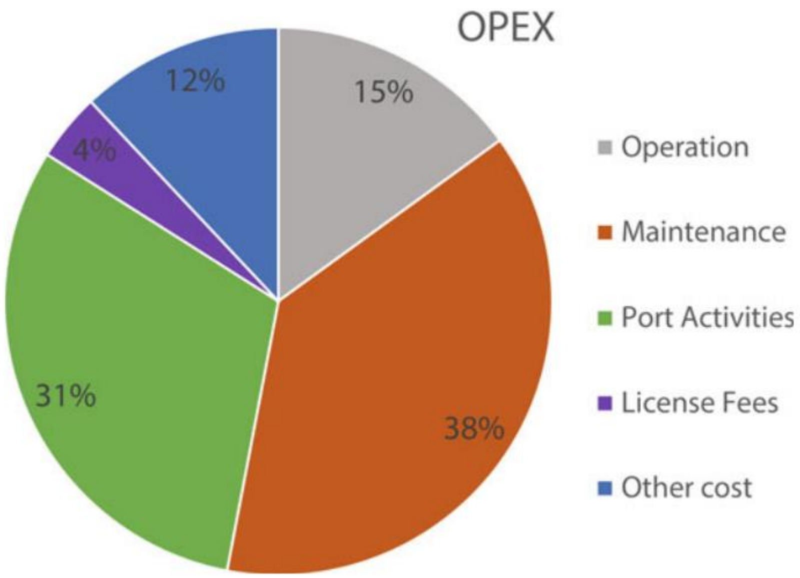


Figure 19 - Breakdown of OPEX in an OWF [45,46]

As well known, OW structures are exposed to harsh environment, and therefore they experience a complex stress regime, which mainly includes the following types of stress:
Corrosive stress.
Physical load.
Biological stress.
Improving substructure resistance to such types of stresses could yield a significant decrease of the OWE LCoE.

The corrosion stress is affected by many factors (dissolved gas concentrations in seawater, seawater salinities, etc.). Corrosion is therefore difficult to predict/simulate. Its effects are frequently underestimated by companies and consequently strongly impact project profitability. Due to the crucial importance of lower OWE LCoE, the issue of corrosion effects on offshore energy devices is an important and growing area of interest as device deployment and designs advance.

The emerging ORE sector is unlike the O&G industry in that structures are unmanned, and the commercial reality is that it cannot afford the luxury of designing for unrepresentative reliability levels. The only way in which the steel structure costs can be reduced significantly, is to embrace modern steel and fabrication techniques coupled with the proper anti-corrosion coatings and advanced reliability-based design approaches [47]. The challenge is to develop innovative materials and fabrication techniques that improve the resistance and lifetime of offshore structures.

The currently adopted design standards for OWT structures are the design codes and semi-empirical correlations developed by certification authorities such as Det Norske Veritas (DNV) and American Petroleum Institute (API) for the O&G industry using fatigue data collected from small diameter flexible pipes many years ago. Due to the significant numbers of fabrication, inspection and design techniques that have evolved recently, there is the need for an update to the existing design standards for wind structures to ensure their fitness for purpose [48]. The OW structural design is determined by the expected fatigue load. However, local defects like pitting attack due to corrosion, may act as initiation sites for fatigue cracks that will require further maintenance. For this reason, special attention should also be given during OWT design to the potential occurrence of local defects in the foundation and the tower structure. Corrosion and biofouling (mainly sulphate-reducing bacteria) threaten the robustness of offshore steel structures in highly corrosive seawater, thereby significantly increasing O&M costs and reducing component life (typical yearly corrosion rate of unprotected steel structures in contact with seawater is in 80-500 μm range) (see Figure 20).

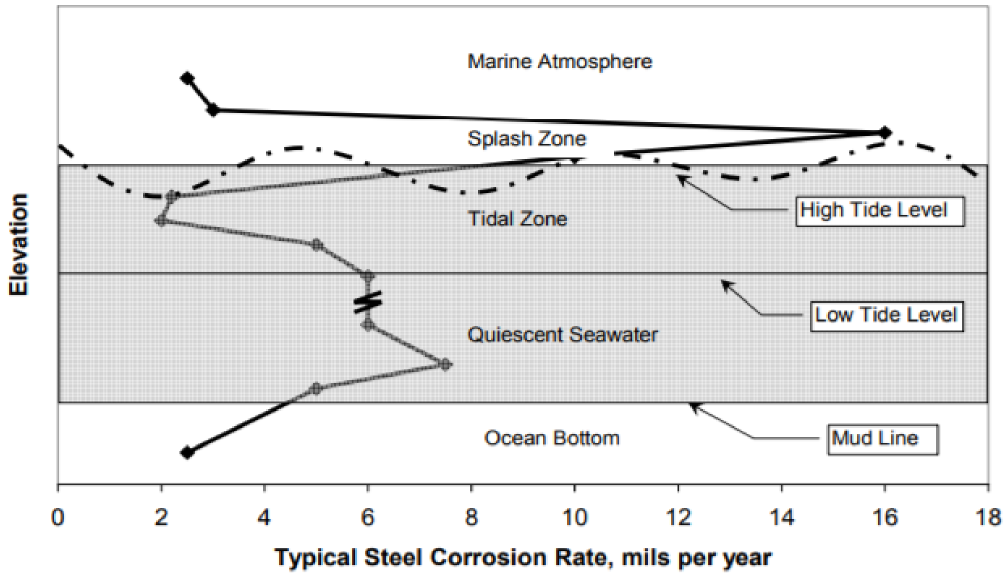


Figure 20 - Typical steel corrosion profiles for an offshore structure (1 mil = 25 micrometers) [49]

There is a lack of up-to-date, relevant information to support the cost effective optimal design of offshore structures. OWT substructures are responsible for a large part of the CAPEX of OWFs. These mainly consist of welded tubular members, similar to structures used for O&G applications. Therefore, a challenge is to design and carry out experimental aging tests on substructures subcomponents (e.g. welded tubular members) in appropriate marine environments to obtain data to update the design standards.

Long-term corrosion and damage risks are prevented by applying anti-corrosion coatings, and taking appropriate maintenance and when necessary repair actions. Through near misses, forced shutdowns, accidents etc., industries have realised that improper corrosion management can be very costly. Direct corrosion related costs estimated that anti-corrosion methods & services were worth globally more than $100 billion annually to the economy [50].

Another corrosion-related challenge is to better understand the actual effects of corrosion inside the offshore substructures (e.g. monopile), where cracks could potentially initiate. It is therefore important to also consider the effect of corrosion inside the substructures when estimating their expected operation lives. For example, the inside of currently installed monopile structures are generally not protected, either by coating or CP, as they were assumed to be airtight. However, in recent year it was discovered that this assumption does not hold, making internal corrosion protection necessary. Both coating and cathodic protection can be considered as solutions. However, such anti-corrosion measured needs to be carefully considered because there may be a significant increase in CAPEX.

Another challenge is to deploy inspection and monitoring techniques for the corrosion behaviour and applied anti-corrosion solutions. The use of better inspection techniques coupled with a good understanding of crack propagation behaviour allows to make an informed decision on the frequency of inspection, driving down costs. Optimised inspection and monitoring also allows to accurately determine the fitness for purpose [50].

COOPERATION AND CONTRACTING

The ORE industry is in its emergent phase, its supply chain is complex and its development remains uncoordinated, with unbalanced risk sharing and fragmented, non-standardised contracting practices prevailing among key value chain actors including developers, suppliers, service suppliers and government. As a result, there are resource congestions and bottle necks in delivery, both in terms of availability of adequately specified equipment, ports and vessels as well as skilled and qualified labour. As an example, lead times for turbines remain one of the longest in OW procurement, often taking two years or more. Suppliers look for joint commitments with developers but there is no feedback. Breaking this gridlock, and crucially, achieving greater integration and alignment of the supply- and demand-side business objectives will likely require greater communication and collaboration, but the success chances of decreasing OW LCoE are, to a large extent, determined by how the OW system (knowledge institutions, suppliers, developers, service providers, government, etc..) is built up and how it functions [51]. In fact, the words of standardization of OWF, and industrialization of OW components and interfaces are common as well as the challenge is to decrease OW LCoE, but to do so the system will have to share the know-how and work as much as possible adopting the open innovation approach [52].

4.4 Identification and classification of the companies

Industrial actors negotiate how to organize production, not just in-house but also in relation to external industrial partners. As different industries constituting a value chain may bring along different legacies and practices, their encounter is critical, particularly during the formative phase of a value chain. The development of a well-functioning value chain relies on mutual understanding and collaboration between the parties constituting the value chain. Renewable energy industries are particularly challenging to conceptualize as they do not evolve through pure market mechanisms, but are to a large extent subject to political decisions and regulations [53].

The ORE value chain is in a phase of formation where pivotal companies are trying to transform it into a mature one. Due to the fact that OE industry is still in the development phase, while the OW industry is in a more mature one, the following survey analysis refers only to OW.

OW has strongly evolved since the world's first OWF opened in Denmark in 1991 and its growth accelerated in the mid-2000s always confirming EU as the traditional leader [54]. Typically, the OW sector has been recognized as branching off from the onshore wind sector [55]. However, the combination of the terms 'offshore' and 'wind' reflects a sector relying on both wind and offshore industries.

The complete wind value chain (including that of OW) was for the first time studied in 2011 [56] and was divided in two main value chains that work closely together and form a bipolar value chain [57]:

- A deployment chain normally led by utility companies or other project developers - including planning, installation, operation and maintenance related to logistics, vessels and other marine supply services.
- A manufacturing chain led by wind turbine manufacturers – including everything that is considered key equipment (i.e. the design and manufacture and related components).

It is the deployment chain that make the OW sector different from the onshore one. The obvious reason is that offshore conditions are different and more demanding than the conditions onshore, and hence additional suppliers are involved [58]. OW also requires more financial resources, and hence more long-term planning and installation time. Investments are more often large scale and thus dominated by larger corporations [55].

The wind industry and offshore suppliers relate to and depend on each other. However, the OW sector is not just evolved out of prosperous combinations of existing assets from mature industries complementing each other. In fact, the OW industry grew out of shallow water, nearshore/coastal marine civil engineering practice and not only O&G industry. The structural designs that emerged are therefore somehow different from O&G structures, have different techno-economic drivers. Additionally, their maintenance has a very different cost base. Therefore, OW industry is also about coupling of two industrial sectors bringing industrial legacies along – respectively from onshore wind/turbine manufacturing sector and from maritime/off- shore O&G sector.

Concerning the OW value chain mapping, the ADMA Energy Pilot has gone through the first steps (Learn and Connect) of the VI methodology [58]. More in details, a database of around 200 pivotal companies from the OW sector was mapped together with the most relevant testing facilities and research infrastructures across EU regions. The mapping exercise allowed an overview of the core stakeholders, based on a critical analysis of the related strengths which exist across the regions, providing several key areas of common challenges and interests as a basis to further define cooperation areas and opportunities for value chain integration [59].

In report D2.2 of the NeSSIE project [60] the anti-corrosion solutions value chain (materials design companies, companies providing protective coating, companies offering services of corrosion inspection and monitoring, company providing services of corrosion assessment – see Figure 21) as well as ORE developers and other value chain actors were identified and defined. In this report it was decided to combine D2.2 value chain study with further OW value chain mapping studies [57]. Almost 50 companies were interviewed using the qualitative (open-ended) approach and more in details: a certification body, an OW farm owner/developer, 3 research centres and a knowledge provider company, 3 companies providing peculiar offshore services connected with corrosion (inspection routine maintenance (IRM) mainly through ROV and blasting surface treatment), and 30% of overall companies were components or subcomponents manufacturer and 30% provider of anti-corrosion solutions (10% of which cathodic protection).

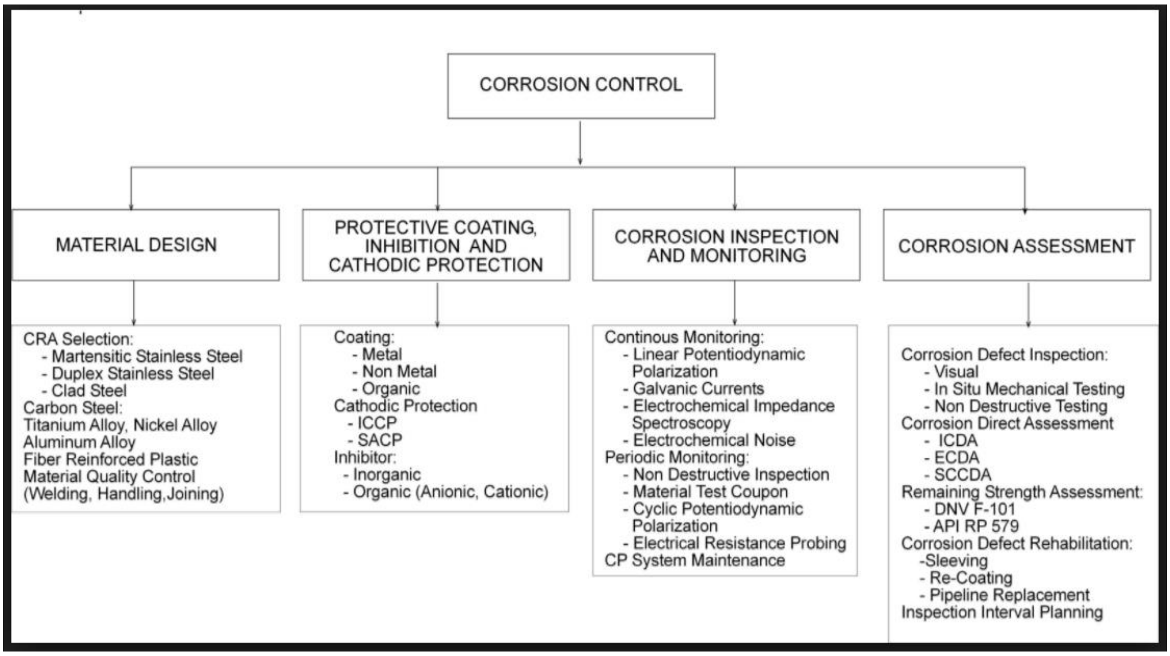


Figure 21 – O&G example of anti-corrosion value chain and corrosion management process

4. Survey

A survey is a market assessment tool designed to get information on a certain topic through providing questions to an entire group, or sample, of individuals. Due to the survey research versatility, businesses and researchers across all industries conduct surveys to uncover answers to specific, important questions. Survey research is an especially useful approach when a researcher aims at describing or explaining features of a very large group or groups.

This method may also be used as a way of quickly gaining some general information about a target audience to help prepare for a more focused, in-depth study using time-intensive methods such as in-depth interviews or field research. In this case, a survey may help a researcher identify specific individuals or locations from which to collect additional data.

The survey benefits lie in its cost-effectiveness, and that results are generalisable, reliable and versatile. As with all methods of data collection, survey research also comes with a few drawbacks – namely its potential inflexibility and results validity [61].

The NeSSIE company survey was conducted for exploring the specific innovation and business needs of different actors of the ORE value chain.

4.1. Survey preparation

Survey design takes a great deal of thoughtful planning and often a great many rounds of revision. A poorly phrased question can cause respondents to interpret its meaning differently, which can reduce that question's reliability, but assuming well-constructed question and questionnaire design, one strength of survey methodology is its potential to produce reliable results.
Starting from the experience of the ADMA Energy Pilot survey conducted in 2015, the following actions were done while preparing this survey:

- Identification of the survey aims (identify what exactly it is that we wish to know).
- Listing of information requested of the respondent (write the questions as clear and to the point as possible). The first versions of the survey were composed of approximately 20-25 questions grouped in three thematic sessions: respondent business, innovation and business needs and involvement within NeSSIE Project. After some iterations, it was decided to limit the questions to 10-15 and divide the survey in a preliminary session on the Company general information and the Company Market Sectors, followed by a session on the Company connection with corrosion solution technologies, services or materials and a final session on the potential interest of the Company in being involved in the NeSSIE project actions. This decision was taken also considering how long are respondents likely to be willing to spend time completing the survey.
- Building an indicative list of value chain companies to interview (number and type).
- Requesting feedback on the survey questions from all the partners and the Industry Advisory Board Members. Getting feedback from as many people as possible, especially people who are like those in your sample, increase the chances of coming up with a set of questions that are understandable to a wide variety of people and, most importantly, to those in our sample [61].

4.2. Methods of contacting the companies

In addition to constructing quality questions and posing clear response options, it is also necessary to think about how to present the written questions and response options to survey respondents. Respondents are more likely to provide open and honest feedback in a more private survey method. Methods such as online surveys, paper surveys, or mobile surveys are more private and less intimidating than face-to-face survey interviews or telephone surveys. Anyway, giving the survey respondents an opportunity to discuss the key topics and communicating them the survey topic and reasons, allows to dig deeper into the survey inciting topics within a broader perspective. Starting from these assumptions four methods of contacting the companies were used:

1. Sending an email with a short introduction to the NeSSIE project and the survey, kindly asking to fill-in it and giving the availability to support the respondent during the completion phase (quantitative interview approach – posing the same set of predetermined/standardized questions to every respondent in the same way (closed ended questions).
2. Doing a phone call with the respondent and directly supporting him/her in the survey completion phase (semi-quantitative approach).
3. Meeting the respondent and directly supporting him/her in the survey completion phase (qualitative approach – that means question are open ended and may not be asked the same way to every respondent).
4. Organising a workshop where inviting many companies to whom explaining the NeSSIE Project, showing the survey and discussing/filling-in it with many companies' contemporary during an open discussion (focus group – multiple respondent at the same time).

4.3. Example of a survey filled

Below, a survey filled in using the qualitative approach is shown. The company interviewed already participated in the previous ADMA survey therefore was both acquainted with the survey methods and the collaborative project approach. The discussion was very time-consuming, but really useful because the company highlighted for example that "there is a lot of potential for lower costs in coordination in the OW sector: constructing in the right place, not too much or too little, in the right order, and properly coordinated. A challenge is to optimize the project management activities". Besides, it confirmed how difficult is for a company to move from the offshore O&G sector to the OW sector. This hitch relies both on the different business models of the two sectors and on the different design and management approach of the OW sector. In conclusion, we think that the survey was useful for the company, because they were acknowledged on the Nessie project and on how is possible to develop collaborative EU projects on the OW sector, and it was useful for the Nessie partnership, because it both showed the importance of the survey qualitative approach and confirmed that the choice of interviewing only the companies that could be really interested in working/collaborating with NeSSIE project is the right one.

www.nessieproject.com

Company Survey NeSSIE

MARKET SECTORS

Please define the current market sectors you operate in

... is an integrated Group providing EPC (Engineering Procurement and Construction) services to Energy Industry worldwide.

Company Core Activity in the offshore energy

... operates within offshore Oil&gas. ... has built a comprehensive and specialized knowhow in supplying offshore platforms and modules such as Integrated Decks, Process Modules, Living Quarters, Utility Modules and Jackets, either in contracting complete offshore platforms on EPC basis or simpler fabrication contracts. ... works as main contractor of large scale manufacturing for offshore installations. Besides, ... owns an SME company (...) that designs offshore structures and takes care of the design of the oil&gas processing. ... supplies tailored and effective projects starting from feasibility to follow up on site for demanding International Clients including major oil and gas companies, fabricators and installation contractors.

Do you currently operate in markets/sectors outside of Oil and Gas?

Yes ❑ No X

If Yes please identify the sector

Offshore Wind Fixed ❑
Offshore wind Floating ❑
Wave ❑
Tidal ❑
Other, please specify...

If No, are you interested in future diversification opportunities?

Yes X No ❑

(If Yes, which Markets are you interested in?) Please state below.

... since 2 years is participating in bids for the construction of offshore wind farms in consortium with offshore wind turbines manufacturer. ... is interested in working within offshore wind sector in order to manufacture monopile and jacket foundations as well as electrical substation foundation. Besides, ...is interested in managing the overall manufacturing and installation procedures.

What do you consider to be the main risks to your business model in the coming future, and what strategies do you have in place to counter these risks?

The main risks of of our business is the increasing complexity of the offshore platforms and their always reducing manufacturing costs. Our strategy is to increase our efficiency in the manufacturing and to diversify our business starting to work within the offshore renewable sector.

Have you partnered in the past, or are currently partnering any Academic or regional/national/EU funded research projects?

Co-funded by the European Maritime and Fisheries Fund

We were partner in a Regional Research collaborative Project.

If so what were/are the projects? If you have not before collaborated with either, why not and what challenges do think your business would encounter?

The project title was on innovative carbon reduction technologies.

COMPANY CONNECTION WITH CORROSION SOLUTION TECHNOLOGIES, SERVICES OR MATERIALS

1. Is the corrosion process relevant in your business?

   Yes X No ☐

If yes please specify how.

We have to apply in the components we manufacture the corrosion solution technologies or materials requested by our clients. Besides, when we design offshore structure we design too the cathodic protection that we have then to apply.

2. What corrosion solution technologies do you use or do you supply?

Our clients require us to install cathodic protection and specific coatings for the splash zone.

3. A key reason highlighted in research of renewables market supply chains for the lack of cross technology take-up is the lack of affordability in general products/services conventionally applied to the oil and gas sector. How do you think your corrosion products/services/materials could practically benefit offshore renewable marine energy devices, i.e. fixed offshore wind, floating offshore wind, tidal stream and wave energy converter device arrays?

Our experience in the design and manufacturing of large scale components for offshore oil&gas sector comprising the corrosion solutions might decrease the costs of offshore wind turbines foundation.

Co-funded by the European Maritime and Fisheries Fund

4. What Specific Sub Sector of offshore corrosion mitigation do you work in?

Cathodic Protection X

When designing offshore structures we too design the cathodic protection elements.

Coatings

Paints (Biocide/Foul Release) X

Sprays ❑

Surface Plating ❑

When designing offshore structures we provide to the components manufacturer the data sheets of the special biocide paintings (avoiding marine growth and in particular the formation of mussels and other micro-organisms whose load needs otherwise to be considered when structural design calculations are performed) to be applied in the splash zone. When we act as manufacturer we receive painting cycles from the clients aimed at both protecting the components from the external fluids (marine water) and the internal fluids (see Kazakhstan for H2S) corrosion. As far as internal corrosion protection is concerned we mainly use bulk high performing materials or coatings of high performing materials.

Materials/Fabrication/Manufacture

Aluminium/Concrete X

Polymers/Composites ❑

Corrosion resistant Alloys ❑

We design and manufacture both underwater and topside (out of the water) offshore structures made in carbon steel

Services

Inspection, Monitoring and Assessment ❑

Other, please specify

Research

Corrosion Solutions ❑

Novel Materials ❑

5. Do you conduct internal research into new products/services in materials and corrosion?

   Yes❑No X

   (If yes - do you own patents that may interfere with the sharing of products/services, Please elaborate).

6. Did you ever you conduct internal research into new products/services in materials and corrosion?

   Yes❑No X

www.nessieproject.com

NESSIE PROJECT

(After introducing project NeSSIE to the clients)

After reading the earlier project introduction, what questions about the project NeSSIE itself can we help to answer?

How could we "use" the Nessie project to get in contact with companies working in the offshore renewable energy sector.

What, if any - involvement or awareness does your business have with regards to opportunities in the North Sea Basin for corrosion solutions in the growing offshore renewable energy sector? This would include future business considerations related to the rapidly changing market place as a result of climate change, national energy security policies and sustainability drives.

We are participating in bids for the installation of offshore wind farms in Norh Sea therefore we are interested in learning which specific corrosion solutions we might adopt.

7. Would you be interested in being part of NeSSIE going forward?

Yes X **No** ❑

If yes, please give a reasoning for your choice of participation and indicate how you would like to be involved: active demonstration project supplier, passive project progression information link only, etc...

I have to discuss it with the business development division and the offshore structure design division. We are interested anyway in being informed on workshops, deliverables, etc... We might be interested in participating in the demo as business modelling part concerning the costs for manufacturing the demo case structure.

8. Which areas of corrosion and materials are you interested in collaborating on?

We would like to be informed on the innovative solutions and materials going inside the market.

9. Would you be interested in taking on a lead role in the development of a demonstration project?

Yes ❑ **No** X

10. Given the questions and answers given earlier, what barriers (financial, economic, legal (regulatory), social, political) do you foresee if you were interested in participating as a technology/services/materials supplier to a NeSSIE demonstration project, as well as future offshore marine renewables device supply chains?

Our company works as manufacturer of large scale components and as providers of services therefore I foresee mainly economic and financial issues concerning the budget available for the NeSSIE demo project.

Any additional information you require on project NeSSIE, or questions you have on your potential involvement. (http://www.nessieproject.com/about-nessie)

Co-funded by the European Maritime and Fisheries Fund

4.4. Example of a focus group approach to fill in the survey

In 1960, in the North Adriatic Sea in front of Ravenna the first Italian and West European offshore methane reservoir it was discovered. In the last 50 years, Ravenna became and still is the most important Offshore O&G Italian industrial hub. Unfortunately, the North Adriatic Sea is not a windy area [62] (see Figure 18), therefore the Ravenna companies operating in the offshore O&G sector had not the possibility to exploit their long lasting offshore experience in the OW in the North Adriatic Sea.

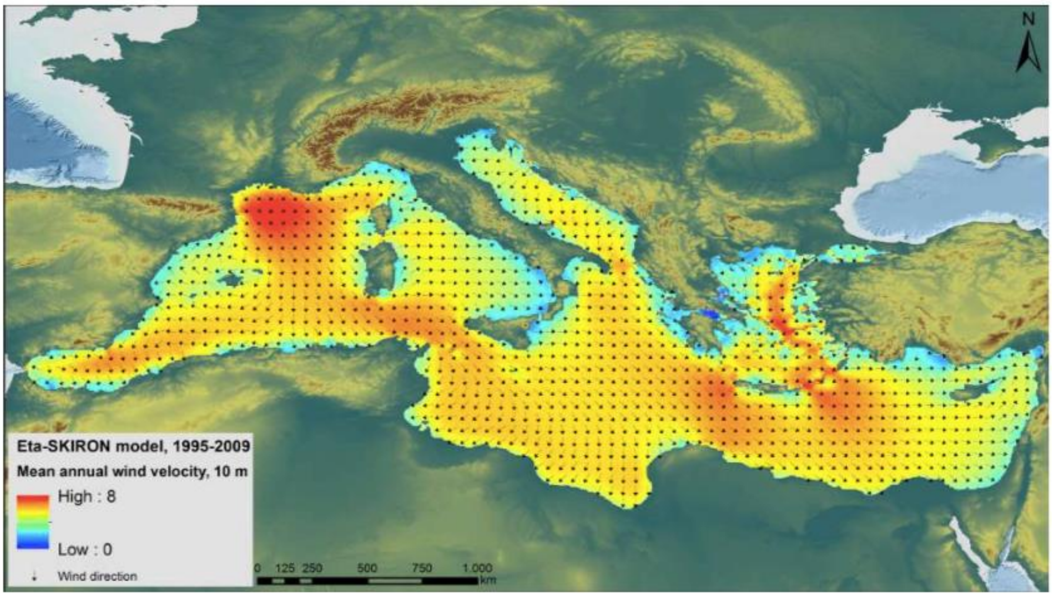


Figure 22 – Mean annual wind speed (m/s) in the Mediterranean Sea [63]

Nevertheless, such companies are working worldwide in the offshore O&G field, but still haven't started to expand and develop their business to the OW sector. Since some years, also thanks to OMC international events and ADMA actions, all the Emilia Romagna companies working within the offshore O&G field (grouped in the ROCA Association) have been strongly acknowledged toward the huge business of ORE. To continue down such a path, it was decided to interview the companies adopting the focus group approach. Therefore, a workshop was organized where the NeSSIE project was presented and the survey topics discussed.

Figure 23 – Picture of the Workshop organized in Ravenna to interview and fill-in the survey with many companies using the Focus Group approach

As it is possible to see from Figure 19 approximately 10-15 companies attended the workshop. In conclusion, the results were good. The surveys were filled in and the companies actively participated in the discussions that mainly focused on:

- The importance of corrosion in the offshore sector.
- The necessity to develop greener anti corrosion solutions.
- The importance of working on developing new design standard for the OW.
- The potential interest of the companies in gathering the activities of a demo case devoted to test innovative solutions within OW and Ocean Energies field.

Furthermore, it was decided to do other workshops approximately every 4-6 months to discuss NeSSIE actions and other potential activities necessary to support the companies in their difficult business diversification path within the ORE field.

5. Discussion of the Survey Results

The response rate and the quality of the answers was very high. All discussions were very positive and all the companies were very receptive to collaborating with the NeSSIE project. Depending upon the respondent characteristics (e.g. existence of an R&D or a Business Development division), the NeSSIE partners decided to apply a different method of contacting the companies to fill-in the survey. If analysis of survey results is aimed at identifying, describing and explaining patterns, it is important that all companies are surveyed in the same way. However, the aim of this survey was to identify needs instead of patterns, therefore the following discussion will also be based on presenting and discussing the needs rather than patterns.

As far as the methods of contacting the companies is concerned, it can be stated that the face to face (qualitative and focus group) approach allowed more organic direction to the conversations that would not have been possible through the email or phone call survey approach (quantitative approach). Obviously, the qualitative approach is more time consuming because the analysis of qualitative interview data typically begins with a set of transcripts of the interviews conducted, followed by reaching some conclusions condensing large amounts of data into relatively smaller information. Additionally, the quality of the results of the qualitative approach strongly relies on the quality of the interviewer to understand the respondent answers, as well as on the know-how of the respondent on the survey topic.

Concerning the workshop (focus group approach), the large amount of companies in one place at one time was also of huge benefit to develop stakeholder relationships in a quick and convenient manner. Prior research of the key companies to approach may sound an obvious strategy, but it was important to ensure a productive and effective approach strategy. Therefore, also if the focus group approach is more time consuming, its results are important not only for the survey, but also for spreading the ideas of developing the open innovation approach and promote collaborative projects.

In conclusion, in order to elicit useful responses to collaboration with project NeSSIE, face to face meetings appear key.

5.1. Innovation Needs

OW industry is still a relatively young technology and is eagerly looking for technical innovations because technical as well as business challenges are going forward. As with any young technology, the long road of OW, from its start to a mature product, can be described using the S-curve.

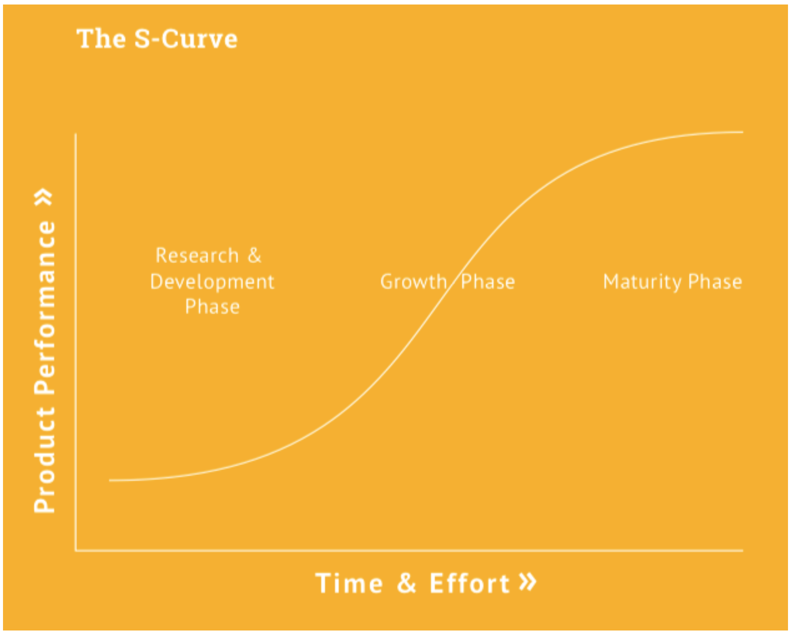


Figure 24 – Typical S-Curve

In the first part of the S-curve, the pure R&D phase takes place, often still in a laboratory or test environment. This phase consists of solving technical issues and developing workable pilot models. The following phases show a relatively steep growth. The last phase, consisting of adjusting and perfecting the technology into a mature product, ready to be marketed, is a relatively difficult phase, and the S-curve levels out as a result. The S-curve has many variants, depending on the ease with which a technology is developed into a completed product ready to be marketed [64]. It is important to underline that the most important insight that has dominated the field of innovation studies in the recent decades is the fact that innovation is a collective activity and takes place within the context of an innovation system. Therefore, to understand the sector's main needs, it is important to interview different actors of the innovation system (e.g. research centres, components manufacturer, service providers, etc…), as it was done in NeSSIE project.

When speaking of innovation within OW sector, is important to highlight the barriers that exist in the OW sector when introducing new solutions. Such barriers are mainly caused by the fact that the cost of failure of an innovation is far too high and might cause the failure of the overall investment (e.g. a new coating directly tested in an OW turbine if proved to be inadequate would require too expensive repairs/retrofit). Therefore, demonstration projects to test different innovations in their real live behaviour would be beneficial for the further entry into the OW market of such innovations. Attention will have to be given to proof that the test/demo is relevant for real life applications, in order to avoid the real risk that developers will not be convinced, and therefore will not adopt the innovation even after a demonstration project.

Several innovation needs were identified by means of the company surveys:

- Updated design guidance for OW structures
- New anti-corrosion coatings
- Innovative methods for substrate cleaning
- New corrosion resistant alloys
- Innovations relating to cathodic protection

Innovative technologies/sensors for inspection, monitoring, measuring corrosion and assessment of

offshore structures
Mapping of potential actions of cross-technology transfer
In the following, these innovation needs are discussed in more detail.

Updated design guidance for OW structures

As far as survey results are concerned, the certifying body did not highlight any innovation need, nevertheless companies highlighted the need of updated design guidance for OW structures, because in many norms there is a large “grey zone” with too much room for interpretation. Therefore, companies are worried for potential unrealistic demands and inspections costs that could threaten the competitiveness of OW sector. Due to this, it is of great importance for the OW industry development to get in contact with the certifying body because: i) they play a key role in approving constructions and installation methods of a project, ii) without certification, the OW farms are not “bankable”, that means that banks will not lend money to a project developer, or do so at very high interest rates, and iii) their vision at an early stage of the development of an innovation on the future “certification” or on the modifications necessary to obtain the certification influences the development process.

New anti-corrosion coatings

The research centres, generally named as the technology or know-how providers, are looking for: green anti-corrosion solutions, new materials for coatings and steel structure lifetime prediction models. Modern offshore constructions are more and more made of special alloys including high strength steel, stainless steel, aluminium and even titanium alloys for specific components. Low and unalloyed steel, however, must always be protected because of their low corrosion resistance to marine atmosphere. A generally used method is to apply surface coatings. A wide range of coatings exist, both metallic and organic. Very good results have been obtained, for example using thick thermal spray aluminium or zinc-aluminium coatings with or without additional paint layers. However, there is still a strong need for innovation. The main innovation needs are:

i) New more efficient coating application processes avoiding coating flaws.
ii) Coatings more resistant to damage (e.g. mechanical impact) therefore improving components lifetime and performances. As shown in some OWF inspection procedures reports, the effectiveness of corrosion protection is high (there are no serious corrosion problems). However, there are damages and anomalies mostly related to mechanical impact (e.g. in boat landing areas), or quality of the coating application and/or quality of the coating repairs. More in details, the reported anomalies comprise coating damages due to incomplete coating layers – mainly caused by defects during coating application procedures - or delaminating coating – mainly due to less effective coating repair.
iii) More effective coating repair procedures/materials.
iv) Repair coatings tolerant to humid/wet substrates, increased salt concentrations, lower application temperatures and imperfect substrate preparation.
v) Coating systems consisting of less coating layers, reducing the application cost considerably. A key requirement herein is reliability. One of the main reasons today for using multi-layers systems is that a defect in one layer does not immediately compromise the reliability of the entire system. Therefore, inspection techniques to guarantee the quality of an applied coating (absence of holidays, cracks, etc.) over the entire structure

are needed, especially in the case of single layer coatings.

vi) Development of long lasting, performant and environmentally friendly anti-fouling coatings.

vii) Coating solutions for bolted connections, flanges, corners and edges, difficult to reach areas, etc.

Innovative methods for substrate cleaning

Cleaning of substrates and surface preparation before coating application is still a very delicate operation strongly impacting corrosion process. Such procedures, in fact, influences the adhesion of the protective layers and coatings on the substrate during the application procedure without having any correlation with the performance of the coating itself. Grinding and blasting is mostly performed using "old" technologies, but other methods like high pressure waterjet, dry ice blasting or laser cleaning can be used if further developed both from the technical and economic (cost reduction) side.

New corrosion resistant alloys

Smaller parts can be made of uncoated special stainless steels, nickel alloys etc. The number of 'new' corrosion resistant alloys however is restricted: only the AMLoCor was found to be a new alloy for offshore applications. Therefore, an innovation need is to develop "new" and more performing corrosion resistant alloys.

Innovations relating to cathodic protection

The submerged section of Offshore foundations is virtually always protected using cathodic protection. This is a well-established technology, but several innovation needs specific to ORE remain:

i) Protecting the inside of monopile foundations using cathodic protection.
ii) Investigating the potential for protection against MIC and fouling.
iii) Optimal combination of cathodic protection with coating systems (both from a technological and economic point of view).

Innovative technologies/sensors for inspection, monitoring, measuring corrosion and assessment of offshore structures

In addition to these anti-corrosion measures, innovative technologies for inspection, monitoring and assessment of the OWT are necessary. Such technology would and will involve ROV and will most probably be based on adopting predictive maintenance technology (i.e. remote surveillance that can help in constant monitoring and real-time information about what is happening at a site). Therefore, an innovation need is the development of innovative sensors that will be installed in ROV for inspection and will be further used for predictive maintenance.

Coating flaws deriving from defects during coating application process can cause huge damage to the OW structure integrity. Therefore, an important step forward for the improvement of OW structures lifetime would be the development of a quality control system able to proof that there are no defects anywhere in the coating, over the entire surface of the structure.

Another issue raised is the possibility to measure corrosion in a way that its data are also relevant for other structures. In fact, coupons are used for corrosion measurement, but there is a spread on data gathered from coupons also within a single farm. Therefore, it is not possible to find trends in corrosion data that could be useful to improve corrosion protection. One proposal is to create a database with information from coupons coming from many different OWF to look for "useful" trends within this large database, that if necessary could also adopt a data anonymization process.

Below the water line, and likely also below the mud line, Microbiologically Induced Corrosion (MIC) takes place. It is however still unclear how important this form of corrosion is and whether it has a real impact on the structural integrity of offshore foundations. Therefore, the development of inspection and monitoring techniques to determine the extent and impact of MIC would be a first important step towards the development of a strategy on how to deal with MIC.

Mapping of potential actions of cross-technology transfer

To decrease the O&M costs, an innovative approach could be to exploit the side ground know-how that means applying technologies coming from other fields (cross-technology transfer) as, for example, aquaculture. In fact, combining OWE with offshore aquaculture to reduce the O&M costs by synergy effects of the combined operations. In fact, if the offshore wind and aquaculture sectors join forces, O&M activities can be coordinated and shared together and thus costs saved.

5.2. Business needs

The ORE value chain is still immature, therefore there is the possibility for companies to enter within such market also if coming from other sectors.

Networking actions

All the interviewed companies coming from offshore O&G sector highlighted the common business need to expand their business within ORE sector. More in details, many of the respondents would like to network with ORE pivotal companies both to show their know-how and their products portfolio; in fact, pivotal companies mainly decide the materials and components requirements/specifications thus getting your product approved by them means "entering" into the ORE market from the main door.

Promoting collaboration between companies and research centres

Another business need highlighted by many respondents to the survey, as well as in [51], is the need to increase the collaboration with other companies and research centres. This is mainly due to the low degree of vertical integration in the OWT market causing little integration across the value chain. Nevertheless, the sector is multidisciplinary. By combining the strengths of companies and researchers, developments were and will be achieved that most likely would have not have been achieved otherwise, or much later. This panorama might change with the increasing number of FLOW, which could prompt more integration across the value chain [41, 64]. A solution might be to build a platform that bridges between national collaboration initiatives to support international R&D programmes and business development activities.

More communication between companies along the ORE value chain

Akin to this need, there is also the need to increase the communication both horizontally and vertically in the value network between suppliers, original equipment manufacturers (OEMs), service providers, contractors, developers and operators. Complexity, infancy of value chain and poor communication in turn have their own effect to resource congestions and bottle necks in delivery, both in terms of availability of adequately specified equipment. Besides, the increase of the collaboration and communication between the value chain actor would facilitate the establishment of a clear value proposition that would increase the efficacy of the OW sector when dealing with stakeholders.

Staff training

Trained staff is another business need to capture the cost reduction opportunities. In fact, current education and training does not provide people with all the right and updated skills, qualifications and certificates to work on the major offshore sites. To keep up with the required sector developments, companies will need to permanently invest in capacity building and training to ensure that sufficiently skilled O&M personnel are available. A rough calculation suggests that one O&M job will be created for every two turbines installed. To meet that demand, operators and developers will have to set up offshore training centres and training programs collaborating with research centres and universities.

Uniform specifications for subcomponents characteristics

The first offshore wind farm, Horns Rev (D), suffered from a major coating failure of eighty wind turbine foundations. The coating on the transition pieces broke down and resulted in unexpected repair and maintenance costs. The reason was a combination of wrong coating selection and improper application of the coating. This pointed out that there was a lack of conformity and of communication between the manufacturer, coating applicator and coating supplier. Detailed and standardized rules for protection against corrosion of offshore structures are still currently lacking. Therefore, there is a business need for an accepted uniform specification.

6. Conclusions

This report aimed at identifying the industrial challenges and the technological as well as research needs on corrosion in offshore energy structures through a survey approach. Such information will help the actors of the ORE value chain to establish a better understanding about the critical factors to overcome, and will help the NeSSIE partners to better design the demo projects business cases. In order to get the information from the different actors, it was decided to design a survey that was implemented using the quantitative (mainly by email) and qualitative approach (focus group and one-on-one meetings).

After a study of the literature concerning the main challenges to decrease ORE LCoE, the report progressed identifying which actors would have been interviewed through the survey. It then moved to designing the questionnaire for the survey and describing how the information were collected from the different actors. In the end, the results were discussed.

The results discussion showed that the corrosion solution management strategies need to be strongly improved in order to decrease the OW LCoE. Such improvements require a strong R&D activity on innovative anti-corrosion materials (greener and more efficient) and on their application as well as repairing procedures. In parallel, there is the need to: a) perform experiments in demonstration projects aimed at testing innovations in real conditions, b) improve modelling methods to predict offshore structure lifetime and c) develop innovative methods for quality check control systems. In terms of O&M activities on field, the development and application of predictive maintenance methods is of great importance, as well as a combination of optimized designs with monitoring of the offshore structure degradation mechanisms.

This report confirms what stated in many EU documents/reports: there is a strong need to increase the private-public collaborations, because decreasing the ORE LCoE requires a lot of R&D work. Reducing costs of technology is never the result of solely R&D because findings from laboratories or the drawing board must always be developed starting from the industrial needs and then be tested for their practical usability.

In terms of innovation needs, there is a huge potential to exploit cross-technology actions from offshore O&G to ORE, but such a process is not as easy as it might appear. Its success requires good planning of open innovation initiatives.

As far as the NeSSIE demonstration projects are concerned, this report illustrated that there is a strong need to identify which technologies are more convenient to test within the demo projects.
In conclusion, through this report we showed that:

- Qualitative survey approach may serve as a model for an approach that provides a good basis for a young industry to accelerate its path toward becoming a mature one thanks to the "open" access to the different actors' needs.
- EU leadership in ORE technology cannot be simply maintained, but further R&D, education/training and innovation is necessary. So far, EU leadership will be maintained if the ORE vale chain actors' desire to keep their own know-how and technologies confidential will

not prevail over the opportunity to develop a more efficient ORE "ecosystem" through collaborative projects.

To reduce OWE and OE LCoE it will be also necessary to access to low cost source of finance. In order to do so, the financiers' perceived risk will have to be decreased also through transparently testing the innovative technologies in demo projects

7. References

[1] M.E. Porter, Competitive Advantage, 1985, The Free Press, New York.

[2] R. Teixeira Pinto, Multi-terminal dc networks—system integration, dynamics and control [Ph.D. thesis], 2014, The Netherlands: Delft University of Technology, https://repository.tudelft.nl/islandora/object/uuid%3A9b0a88cf-c2c6-43d3-810d-b64a211ab419.

[3] Renewable energy in Europe 2017, European Environment Agency (EEA) Report n. 3/2017, ISSN 1977-8449, 2017.

[4] Offshore wind in Europe, Walking the tightrope to success, Ernst&Young et Associes, 2015, https://www.ewea.org/fileadmin/files/library/publications/reports/EY-Offshore-Wind-in-Europe.pdf.

[5] Blue Energy Action needed to deliver on the potential of ocean energy in European seas and oceans by 2020 and beyond, COM/2014/08 final, 2014, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014DC0008.

[6] Ocean Energy Forum, Ocean Energy Strategic Roadmap 2016, building ocean energy for Europe.

[7] Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, 2015, EU COM(2015)6317.

[8] Ocean Energy Europe, Strategic Research Agenda for Ocean Energy, European Technology and Innova on Platform for Ocean Energy (TPOcean), November 2016.

[9] G. Sannino, G. Pisacane, Ocean Energy exploitation in Italy: ongoing R&D activities, ENEA Technical Report, 2017, ISBN 978-88-8286-355-5.

[10] D. Magagna, R. Monfardini, A Uihlein, JRC Ocean Energy Status Report 2016 Edition, Joint Research Centre, 2016, doi:10.2760/164776.

[11] SI Ocean, Wave and Tidal Energy Market Deployment Strategy for Europe, 2014.

[12] E. Topham, D. McMillan, Sustainable decommissioning of an offshore wind farm, Renewable Energy, 102, 2017, 470-480.

[13] Global Wind Energy Council (GWEC), Global Wind Report Annual Market updated 2015, Accessed April 2016.

[14] WindEurope, The European Offshore Wind Industry – Key Trends and Statistics 2016, Published January 2017, Brussels.

[15] S. Rodrigues, C. Restrepo, E. Kontos, R. Teixeira Pinto, P. Bauer, Trends of offshore wind projects, Renewable and Sustainable Energy Reviews, 49, 2015, 1114-1135.

[16] European Environment Agency (EEA), Renewable energy in Europe 2017, Report n. 3/2017, 2017, ISSN 1977-8449, 2017.

[17] P. Dvorak, The promises and challenges of the offshore wind industry, 2017, http://www.windpowerengineering.com/offshore-wind/promises-challenges-offshore-wind-industry/).

[18] WindEurope, Record-low Bids in Offshore Wind Shouldmake Policy Markers Rethink Post-2020 Ambition Levels, 28 April 2017, Brussels, https://windeurope.org/newsroom/news/record-low-bids-in-offshore-wind-should-make-policy-makers-rethink-post-2020-ambition-levels/.

[19] BVG Associates, Unleashing Europe's offshore wind potential - A new resource assessment, June 2017.

[20] ORE CATAPULT7, Floating wind: technology assessment, ORE_CATAPULT, 2015.

[21] https://www.offshorewind.biz/2018/02/15/worlds-first-floating-wind-farm-outdelivers/?utm_source=emark&utm_medium=email&utm_campaign=daily-update-offshore-wind-2018-02-16&uid=69924

[22] Australian Renewable Energy Agency, Commercial Readiness Index for Renewable Energy Sectors, 2014.

[23] A. MacGillivray, H. Jeffrey, C. Hanmer, D. Magagna, A. Raventos, A. Badcock-Broe, Ocean Energy Technology: Gaps and Barriers, Published by SI Ocean, 2013,

http://www.marineenergywales.co.uk/wp-content/uploads/2016/01/Gaps-and-Barriers-Report-FV.pdf.
[24] DG RTD, DG Energy, Unit G.3 - Renewable Energy Sources, Study on Lessons for Ocean Energy Development, Final Report, 2017, doi 10.2777/389418.
[25] D. Magagna, A. Uihlein, Ocean energy development in Europe: Current Status and future perspectives, Int. J. of Marine Energy, 11, 2015, 84-104.
[26] R.A. Arinaga, K.F. Cheung, Atlas of global wave energy from 10 years of reanalysis and hindcast data. Renew Energy, 39, 2012, 49–64.
[27] A. Uihlein, D. Magagna, Wave and tidal current energy – A review of the current state of research beyond technology, Ren. and Sust. Energy Reviews, 58, 2016, 1070-1081.
[28] T.D. Corsatea, D. Magagna, Overview of European Innovation Activities in Marine Energy Technology, Publications Office of the European Union, Luxembourg, 2013, doi:10.2790/99213.
[29] Annual Report 2013, Implementing Agreement on ocean energy systems, IEA-OES, Lisboa, 2013, http://www.ocean-energy-systems.org/documents/82577_oes_annual_report_2013.pdf.
[30] Annex IV: Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal, and Current Energy Systems, 2014, https://report2014.ocean-energy-systems.org/ongoing-collaborative-projects/assessment-of-environmental-effects-and-monitoring-efforts-annex-iv-/.
[31] J. Giebhardt, P. Kracht, C. Dick, F. Salcedo, Report on grid integration and power quality testing. Deliverable 4.3 final, 2014, MARINET.
[32] Ten-Year Network Development Plan 2014, 2014. <https://www.entsoe.eu/major-projects/ten-year-network- development-plan/tyndp-2014/Pages/default.aspx>.
[33] M. Stark, M. Bermudez-Neuebauer, Accenture, Changing the Scale of Offshore wind, 2013.
[34] Mott Macdonald, R.C. Thmoson, G.P. Harrison, Life-cycle costs for Offshore Wind, Proceedings Life-cycle costs for Offshore Wind Workshop, 2016.
[35] P. Higgins, A. Fley, The evolution of offshore wind power in the United Kingdom, Renew. Sustain. Energy Rev, 37, 2014, 599-612.
[36] J. Paterson, F. D'Amico, P.R. Thies, R.E. Kurt, G. Harrison, Offshore wind installation vessels – A comparative assessment for UK offshore rounds 1 and 2, Ocean Engineering, 148, 2018, 637-649.
[37] O. Salo, S. Syri, What economic support is needed for Arctic offshore wind power?, Renewable and Sust. Enrgery Reviewx, 31, 2014, 343-352.
[38] T. Michler-Cieluch, G. Krause, B.H. Buck, Reflections on integrating operation and maintenance activities of offshore wind farms and mariculture, Ocean and Coastal Management, 52, 2009, 57–68.
[39] R. Martin, I. Lazakis, S. Barbouchi, L. Joahnning, Sensitivity analysis of offshore wind farm operation and maintenance cost and availability, Renewable Energy, 85, 2016, 1226–1236.
[40] C. Rockmann, S. Lagerveld , J. Stavenuiter, O&M costs of Offshore Wind Farms and Potential Multi-use Platforms in the Dutch North Sea, pp. 97-113, in Aquaculture Perspective of Multi-Use Platforms in the Dutch North Sea, B.H. Buck, R. Langan, Springer 2017.
[41] M. Scheu, D. Matha, M. Hofmann, M. Muskulus, Maintenance strategies for large offshore wind farms, Energy Procedia 24, 2012, 281 – 288.
[42] S. Shenton, A novel offshore wind transfer technique: experiences from the Beatrice Demonstration site, 2016, https://ore.catapult.org.uk/wp-content/uploads/2016/08/A-novel-offshore-wind-transfer-technique.-Experiences-from-the-Beatrice-Demonstration-Site-4.pdf.
[43] R. Miedema, Research: Offshore Wind Energy Operations & Maintenance Analysis. MSc Thesis, 2012, Hogeschool van Amsterdam.
[44] http://www.noordzeewind.nl/en/project-en/.
[45] R.A. Board, Value breakdown for the offshore wind sector, 2010, Report commissioned by UK Renewables Advisory Board.
[46] S. Lagerveld, C. Röckmann, M. Scholl, A study on the combination of offshore wind energy with

offshore aquaculture. IMARES Report C056/14, Retrieved August 2, 2016, http://edepot.wur.nl/318329.

[47] F.P. Brennan, A framework for variable amplitude corrosion fatigue materials tests for offshore wind steel support structures, Fatigue & Fracture of Engineering Materials & Structure FFEMS, 37, 2014, 1–5.

[48] A.W. Momber, P. Plagemann, V. Stenzel, Performance and integrity of protective coating systems for offshore wind power structures after three years under offshore site conditions, Renew. Energy, 74, 2015, 606–617.

[49] J. Ault, The Use of Coatings for Corrosion Control on Offshore Oil Structures, Ocean City, http://www.elzly.com/docs/The_Use_of_Coatings_for_Corrosion_Control_on_Offshore_Oil_Structures.pdf.

[50] O. Adedipe, F. Brennan, A. Kolios, Review of corrosion fatigue in offshore structures: Present status and challenges in the offshore wind sector, Renew. Sustain. Energy Rev., 61, 2016, 141–154.

[51] P.D. Andersen, N.E. Clausen, T. Cronin, K.A. Piirainen, The North Sea. Offshore Wind Service Industry: Status, perspectives, and a joint action plan, Ren. and Sust. Energy Reviews, 81, 2018, 2672-2683.

[52] A.J. Wieczorek, S.O. Negro, R. Harmsen, G.J. Heimeriks, L. Luo, M.P. Hekkert, A review of European wind innovation system, Ren. and Sust. Energy Reviews, 26, 2013, 294-306.

[53] J. Essletzbichler, Renewable energy technology and path creation: a multiscalar approach to energy transition in the UK, Eur. Plan. Stud. 20-5, 2012, 791–816.

[54] M. Steen, G.H. Hansen, Same sea, different ponds: cross-sectorial knowledge spillovers in the North Sea, Eur. Plan. Stud. 22, 2014, 2030–2049.

[55] J. Markard, R. Petersen, The offshore trend: Structural changes in the wind power sector, Energy Pol., 3, 2009, 3545–3556.

[56] R. Lema, A. Berger, H. Schmitz, H. Song, Competition and cooperation between Europe and China in the wind power sector, IDS Working Paper, 2011, 377.

[57] S. Ponte, T. Sturgeon, Explaining governance in global value chains: a modular theory-building effort. Rev. Int. Pol. Econ., 21, 2014, 195–223.

[58] A. Karlsen, Framing industrialization of the offshore wind value chain – A discourse approach to an event, Geoforum, 88, 2018, 148-156

[59] ADMA Vanguard Initiative, A Technology Roadmap of the Vanguard Initiative's pilot Advanced Manufacturing for energy related applications in harsh environments, 2016.

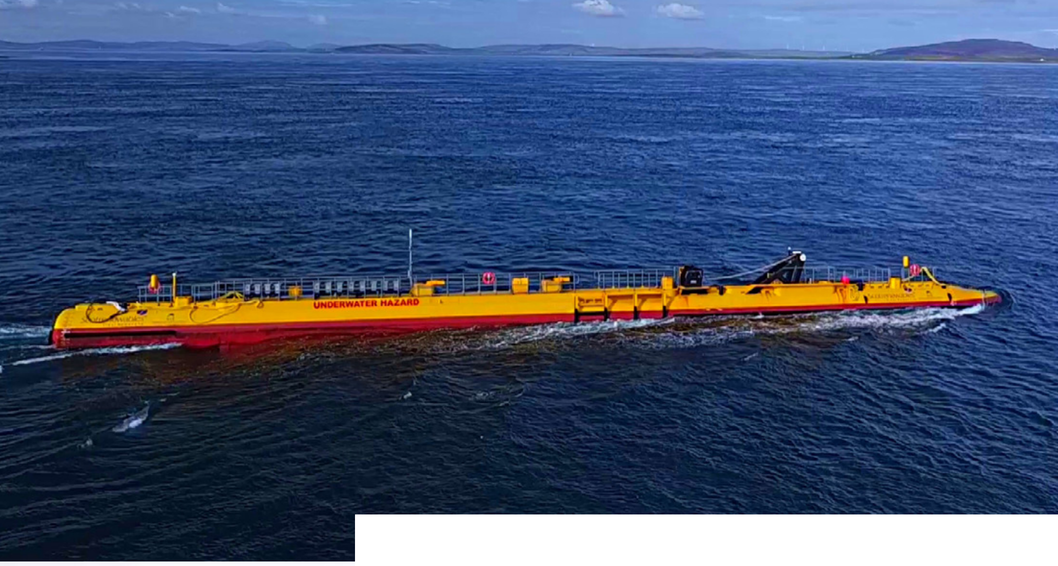
[60] M. Laurie, N. Van Velzen, NeSSIE D2.2 - Assessment of Economic Opportunity, 2018.

[61] Saylor Academy, Principles of Sociological Inquiry: Qualitative and Quantitative Methods, 2012, https://saylordotorg.github.io/text_principles-of-sociological-inquiry-qualitative-and-quantitative-methods/index.html.

[62] European Environment Agency (EEA), Europe's onshore and offshore wind energy potential, Report n. 6/2009, ISSN 1725-2237.

[63] F. Boero, F. Foglini, S. Fraschetti, P. Gortup, E. Macpherson, S. Planes, T. Soukissian, The CoCoNet Consortium, Towards coast to coast networks of marine protected area (from the shore to the high and deep sea), coupled with sea-based wind energy potential, Scientific Research and Information Tech, 6, 2016, 1-95.

[64] R. de Vos, FLOW - Competitive through cooperation, http://www.flow-offshore.nl/images/flow-openbaar/FLOW_Book-11_EN.pdf, 2016.



NeSSIE

North Sea Solutions for Innovation in Corrosion for Energy

nessieproject.com