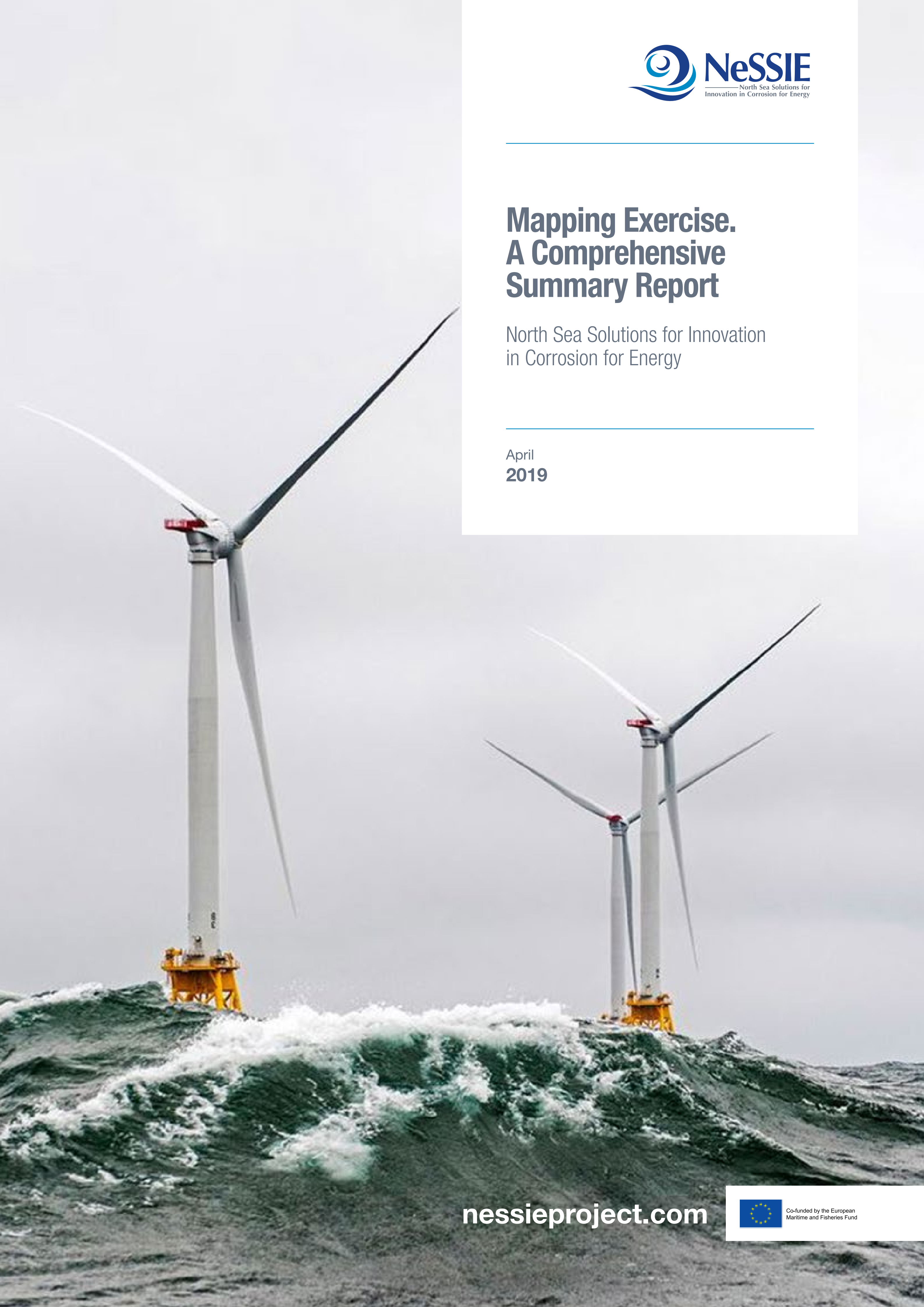

# Mapping Exercise. A Comprehensive Summary Report

North Sea Solutions for Innovation in Corrosion for Energy

April
**2019**

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 2.5).

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*Source: NeSSIE Project – cofunded by the European Maritime and Fisheries Fund (EMFF)* – *www.nessieproject.com*

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# 2 Abbreviations and Acronyms

| | |
|---|---|
| ACS | Anti-corrosion solution |
| ADMA | Advanced Manufacturing for Energy Related Applications in Harsh Environments |
| CAPEX | Capital expenditure |
| DP | Demonstration Project |
| EU | Europe |
| LCoE | Levelized Cost of Energy |
| Nessie | North Sea Solution in Corrosion for Energy |
| NSB | North Sea Basin |
| OE | Ocean Energies |
| O&M | Operations and Maintenance |
| OPEX | Operational expenditure |
| ORE | Offshore Renewable Energies |
| OW | Offshore Wind |
| R&D | Research and Development |
| RE | Renewable Energy |
| RES | Renewable Energy Sources |
| TE | Tidal Energy |
| VI | Vanguard Initiative |
| WE | Wave energy |
| WP | Work Package |

## 3 Executive Summary

The value of investments in renewable energy sources (RES) has increased rapidly over the last decade and in the last five years it outstripped that in fossil fuel generation. In Europe (EU) this was due to the combination of a strong: i) decrease of the Levelized Cost of Energy (LCoE) from RES, ii) increase of the reliability of renewable energy (RE) technologies, iii) policy pressure to reduce carbon dioxide emissions and iv) policy incentives to increase the share of RE in the EU energy mix consumption. Offshore renewable energies (ORE) represent the largest known untapped resource that can contribute to an EU sustainable energy supply. To maintain EU leadership in ORE market, whose value is estimated in more than 50 bln€/year up to 2050, it is necessary to continuously support the development of ORE devices and projects.
The issue of corrosion effects on ORE devices is an important and growing area of interest as device deployment and design advance, and focus falls on device performance maintenance and lowering costs.

Within the NeSSIE project, WP2 has been aimed at:
i) providing the structure to map the current situation in relation to anti-corrosion solutions (ACSs) and the use of new materials in ORE,
ii) identifying business and innovation needs as well as the economic value along the complete ORE value chain concerning service life and specifically ACSs and new materials,
iii) mapping the funding options available for supporting the delivery of the demonstration projects (DPs) in this area across the public and private sector,
iv) identifying and analysing the best practice of DPs development in ORE.

The aim of this report is to comprehensively summarize the results of WP2 showing its importance within the NeSSIE project development. This document (deliverable D2.5) starts with a short summary of each WP2 deliverable followed by a discussion of the outputs of WP2 as a whole and how they build on each other and how they ultimately feed in to the later WPs and in the NeSSIE Roadmap.

In conclusion, this report will highlight the importance of getting a clear multidisciplinary - scientific, technical/technological, economic/commercial, financial and normative - and updated map of the state of the art of a technology when designing its development roadmap and 3 DPs within its field. Besides, we gathered from all the industrial value chain actors many inputs on the challenges faced by the sector, later used in NeSSIE activities such as the ones in WP3.

# 4 Introduction

This report is a summary of all the outputs obtained in Work Package (WP) 2 of the North Sea Solution in Corrosion for Energy (NeSSIE) project.

NeSSIE is an EU-funded project that developed a roadmap and three investment plans for the establishment of public-private partnerships to apply this knowledge in ORE. NeSSIE transformed challenges coming from the offshore energy industry into industrial applications and business opportunities in the North Sea Basin (NSB) promoting a greater strategic cooperation in the offshore energy value chain.

NeSSIE promoted and supported the development of collaborative DPs, through the establishment of strategic cross-sectoral public-private partnerships in the NSB starting from previous work undertaken within the Vanguard Initiative (VI) Pilot in Advanced Manufacturing for Energy Related Applications in Harsh Environments (ADMA).

NeSSIE partnership is aimed at:

- increasing the know-how on the reliability of the offshore structures,
- delivering new business and investment opportunities in the ORE sector,
- developing a roadmap and three investment plans for the delivery of three bankable, investment-ready DPs in the NSB. These DPs will test ACSs and new materials for use in the wave, tidal and offshore wind energy sectors.

WP2 fits into the overall NeSSIE WP2/WP3 scheme as illustrated in Figure 1.

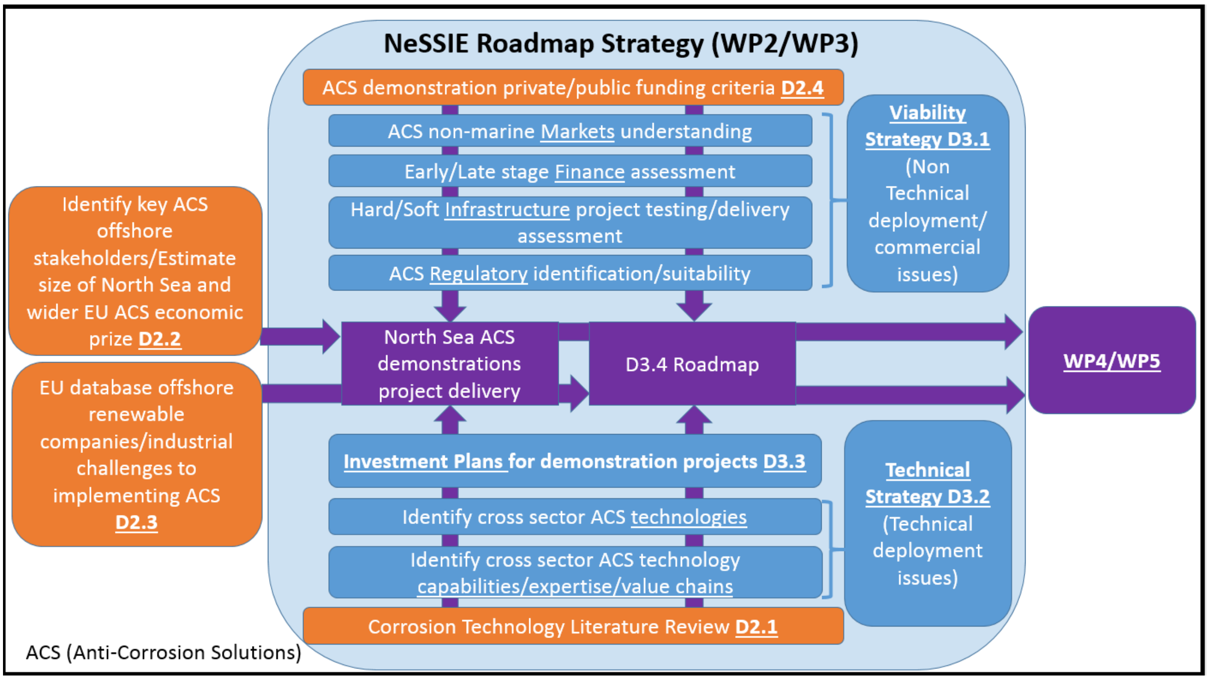


Figure 1 – *D2.3 position in the wider WP2/WP3 NeSSIE project [1]*

The main results that were obtained in WP2 were to map:

a) the current activities and challenges on ACSs, new materials and procedures based on a desktop study of the scientific, technical and patent literature,

b) the corrosion solutions employed by other industries outside the marine industry,

c) the economic opportunity relating to novel materials and ACSs in the NSB,

d) the business and innovation need of the companies working within offshore energies field in the different NeSSIE regions concerning service life of offshore structures,

e) the private and public funding options available for supporting research and development R&D) projects

in this area.
This report will summarize each output of WP2 and then discuss:
a) the importance of the desktop study as a first phase planning in the design process of a R&D project,
b) the main results coming out from all the outputs highlighting how they build on each other and how they ultimately feed in to the later WPs and the NeSSIE Roadmap.

### *4.1 Desktop study*

**Desktop study:** a study that is carried out purely through research, rather than physical investigations, that means that it can be done sitting at a desk collating (gathering and analysing) information currently available (printed or on internet) on the topic to gain a broad understanding of the field. This may be a preliminary study carried out before more detailed physical investigations are carried out, or it may be a standalone study carried out instead of a physical investigation.
In very general terms, a desktop study is likely to be less time consuming and less expensive than a physical investigation. Desktop studies, providing an initial understanding of a subject or situation (first line identification), identify potential risks and inform the detail, scope and methodology of subsequent investigations, or it can be a first phase planning and assists to precisely focus the design phase. To validate the information present in a desktop study it is important to cite the references. Such references could come from different sources such as for example scientific papers, patents, technical studies, norms, etc..

# 5 Work Package 2 Outputs

According to current projections of the world electricity demand, electricity is set to remain the fastest-growing final form of energy worldwide, growing by 2.1% per year over the 2012-2040 period. The renewables-based electricity generation is projected to triple over 2013-2040, overtaking coal to become the largest source of electricity. According to the new policies scenario, 33% of the world electricity generation by source will come from renewables in 2040.

In this fast-growing movement, offshore renewable energies (ORE) are estimated to play a major role, driven by both political, environmental and economic factors. A significant part of this ORE will come from offshore wind (OW) farms [2]. In fact, there already are OW farms that will be commissioned after 2020 that have closed prices ranging 55-95€/MWh.

To continue the development of ORE, the cost of installing and maintaining these structures needs to be decreased further.

A significant part of the costs is the result of the harsh conditions in which these structures need to operate and, more specifically, the resulting corrosion. More in detail, Operation and Maintenance (O&M) costs are typically around 15 - 30% of the total life-cycle cost of an OW farm [3]. In fact, offshore structures are subjected to several damage mechanisms including corrosion and fatigue; so protective strategies against corrosion should be considered as are essential to reach the expected service life for which a structure was designed.

Due to the fact that different protection systems can be used to delay and mitigate corrosion initiation and its related consequences such as safety, structural integrity and service life, this chapter will highlight the main outputs of WP2 of the Nessie Project whose aim was:

i) to map, and in some cases interview, the value chain actors (create a list of companies involved or interested in ORE),

ii) to map the ACSs applied within the offshore energy field and the funding options for supporting R&D within this field,

iii) to understand the main corrosion related challenges directly from the sector value chain actors.

### 5.1 State of the Art Study on Materials and Solutions against Corrosion in Offshore Structures

The aim of this report, whose title is "State of the Art Study on Materials and Solutions against Corrosion in Offshore Structures" and is downloadable from the NeSSIE internet site, was to review the state of art in terms of ACSs and corrosion resistant materials suitable for application in ORE structures.

The review was the result of a desktop study (technical & scientific & commercial literature, patents and standards, interviews with value chain actors) and was mainly focused on OW, wave (WE) and tidal energy (TE) structures. In order to present the market updated data, it was complemented with input from industry experts and have been updated through the upload of new online version up to the end of the project, due to the sector's continuous development.

The report focused on corrosion issues and was therefore mainly concerned with metallic materials used in marine environments, but also reviewed the innovative materials and ACSs under development (see figure 2). Nevertheless, some attention was paid to composite materials and concrete.

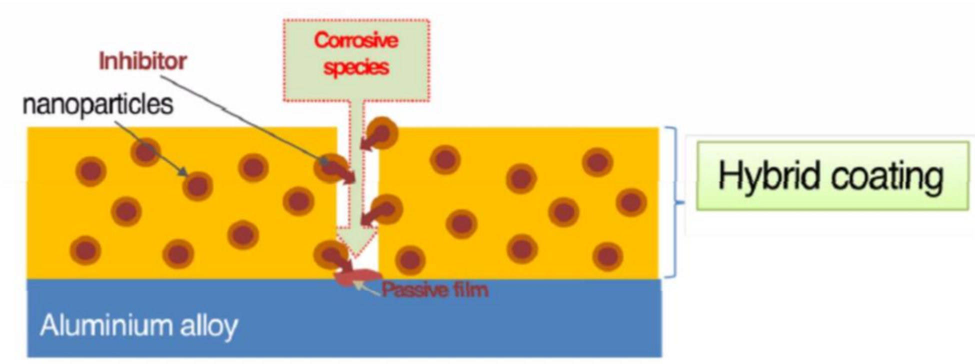


Figure 2: *Corrosion healing mechanism of a hybrid sol gel coating with nanoparticles [4]*

The report described the main corrosion phenomena, mechanisms and forms highlighting the different intensity of corrosion attack taking place in the various areas of an offshore structure (see figure 3).

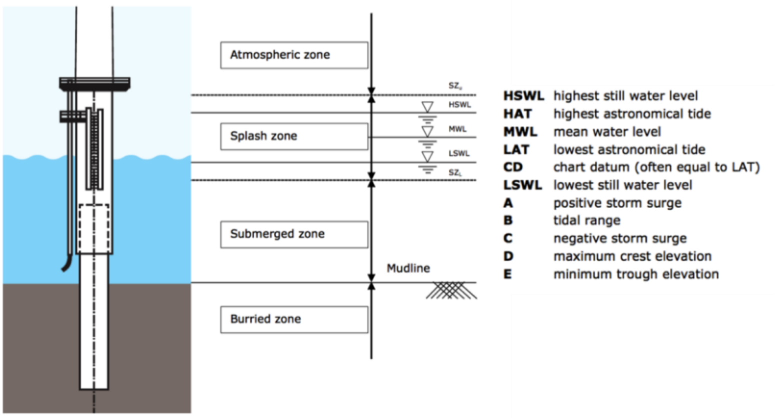


Figure 3: *Schematic representation of levels and zones in seawater environment [5]*

The report identified and analysed the: i) international standards and guidelines relevant for the design and operation of ORE structures and materials, ii) protection strategies for corrosion and fatigue mitigation, iii) corrosion related challenges in the OW and ocean energy (OE) sector.

The report was then complemented with a study on the most recent patents on ACSs applied to the offshore energy sector and with remaining corrosion issues that were identified such as for example possible innovative anti-corrosion strategies. Finally, international standards and guidelines relevant for the design and operation of offshore renewable energy structures, materials and protection strategies for corrosion and fatigue mitigation were presented.

By presenting an overview of new and existing corrosion mitigation strategies, this report will be useful to: i) prepare the way to find innovative ACSs that will reduce the cost of ORE; Ii) form a baseline for the current state of the art study on corrosion issues in the offshore industry and for further work in WP2, WP3 and WP4.

It follows a summary of the main conclusions concerning:

*i) the corrosion resistant materials used in offshore structures:*

Modern offshore constructions are more and more made of special alloys including high strength steel, stainless steel, aluminium and even titanium alloys. The final material solutions adopted are the compromise between the final weight and the service-life of the structures trying to optimize the capital (CAPEX) and operational expenditure (OPEX) costs. Although most cast iron grades have a good corrosion resistance to water and atmospheric conditions, they are not resistant to chlorine containing environments. Low and unalloyed steel must always be protected because of their low corrosion resistance to marine atmosphere. Nevertheless, stainless steel and nickel alloys cost is much higher than the unalloyed and alloyed steel, however smaller parts or components of offshore structures can be made of these materials due to their good corrosion resistance. Furthermore, titanium has increasing applications in marine structures over the last years despite its higher cost compared to steel, due to its complete immunity to corrosion by seawater, its heat transfer capability, and its high corrosion fatigue limits in both low and high cycle fatigue. Aluminium alloys could be used in marine environments without coatings due to their superficial and natural oxide layer, but generally a supplemental protection is needed taking care to pre-treat the surface. Concerning the innovative corrosion resistant alloys, the most used is AMLoCor.

*ii) the current corrosion mitigation/protection strategies used in offshore wind structures; in fact, using corrosion resistant materials is not always possible being not cost efficient or because they may still degrade requiring additional protection as a safety measure:*

Within the active corrosion protection methods, the impressed cathodic corrosion protection is becoming more popular in the OW industry for external protection. Concerning passive corrosion protection methods, the described ones are: metallic – with attention to different application techniques (e.g. Zn/Al thermal sprayed coatings work like a sacrificial anode), organic – with attention devoted to phosphate conversion coatings - and composite coatings. Besides, development on rubber linings and chemically bonded phosphate ceramic coatings used for protecting carbon and mild steel equipment as well as chemically bonded silica ceramic coatings used to protect a variety of metal substrates are described. Concerning R&D in coatings, the research focus is on environmentally friendly coating systems, with the ability to behave and adapt in response to environmental demands, and in the last years several types of organic-based coatings have been developed including anti-fouling paints, self-healing, composites or nano-based coatings. Common to all the coatings is the necessity to carefully cleaning substrates before their application, as it strongly influences the adhesion of the protective layers and coatings on the substrate. To do so grinding and blasting is mostly performed, but other methods like high-pressure water jet can be used.

## *5.2 Assessment of the economic opportunity*

This report assesses the potential economic opportunity in EU that could be delivered if novel ACSs found in traditional marine sectors are applied in the ORE sector. It was designed as an introduction to the problems caused by corrosion in existing offshore industries, and the opportunity that existing expertise presents to emerging ORE technologies on a qualitative and quantitative basis. The intention of this report, whose title is "Assessment of Economic Opportunity Report" and is downloadable from the NeSSIE internet site, was to economically evaluate the anti-corrosion expertise employed by other industries outside the ORE, applied to the ORE sector and therefore indicating the economic opportunity for ACSs within the ORE sector.

The report starts with a literature review on existing utilised offshore materials, corrosion mechanisms and employed solutions. In order to evaluate the materials expertise and innovative solutions employed by industries operating in the NSB offshore sector, the relevant value chain actors were first identified - key private companies (service, provider, and manufacturers), research organisations/collaborations, testing facilities and applicable standards/regulatory bodies. In addition, a short list of planned wind, tidal and wave projects operated, or planned to operate by Developers within the NeSSIE timeframe was identified.

In detail, four key supply chains were identified: 1. Protective layerings including environmentally benign paints, sprays and coatings; 2. Cathodic protection; 3. New materials and their associated fabrication, manufacturing and assembly processes and 4. Corrosion monitoring, assessment and repair services. A non-exhaustive and project-relevant filtered dataset of supply chain companies delivering these solutions to established industries across the NSB region was then constructed.

In order to provide real world context of the practicalities of applying corrosion solutions to marine devices and to assess the potential economic opportunity of applying novel materials and direct corrosion services/products to ORE across the NSB region, the report: i) listed the planned OW, TE and WE project operated, or planned to operate, landscaping investigations and lessons learned from existing ORE projects on ACSs and ii) reviewed and summarized ORE industry development roadmaps from the UK/EU region.

The report showed that the issue of marine structure corrosion was found to be a common one amongst a diverse set of offshore users and established industry supply chains. Besides, an accompanying Scottish Enterprise diversification study was further able to illustrate just how established supply chains can diversify their business model to deliver the cost reductions that ORE developers are desperately seeking.

To calculate the economic worth of ACSs to developers and solutions vendors, a number of assumptions taken from the oil and gas, maritime and offshore renewables sectors were made. The calculations covered the UK and wider EU, and utilised projected capacity taken from various renewables roadmaps.

The scenarios investigated the range from the reduction of ORE project CAPEX to increased CAPEX with the application of novel ACSs compared to business as usual solutions, yet in all cases considered the reduction of OPEX and contribution towards maintaining device performance. As it can be seen from Table 1 Scenario 1, reducing CAPEX leads to developer savings of up to £9.2bn in the UK and £32.7bn in the wider EU by 2030. to £12.8bn and £74.6bn in the UK and EU, respectively, by 2050.

| | | | TOTAL WAVE & TIDAL | | | TOTAL FIXED & FLOATING WIND | | | TOTAL OFFSHORE MARKET | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capacity | Developer Saving | Vendor Value | Capacity | Developer Saving | Vendor Value | Capacity | Developer Saving | Vendor Value |
| | | | MW | NPV10 £M | NPV10 £M | MW | NPV10 £M | NPV10 £M | GW | NPV10 £bn | NPV10 £bn |
| Scenario 1 | UK | 2020 | 350 | 208 | 283 | 8,060 | 2,507 | 3,043 | 8.4 | 2.7 | 3.3 |
| | | 2030 | 6,000 | 1,538 | 1,984 | 19,477 | 7,703 | 9,181 | 25.5 | 9.2 | 11.2 |
| | | 2050 | 15,000 | 2,345 | 2,907 | 45,000 | 10,486 | 11,459 | 60.0 | 12.8 | 14.4 |
| | EU | 2020 | 350 | 206 | 307 | 23,493 | 10,276 | 13,146 | 23.8 | 10.5 | 13.5 |
| | | 2030 | 25,282 | 5,949 | 10,311 | 66,488 | 26,831 | 33,218 | 91.8 | 32.8 | 43.5 |
| | | 2050 | 188,000 | 14,219 | 22,403 | 460,000 | 60,353 | 50,891 | 648.0 | 74.6 | 83.3 |
| Scenario 2 | UK | 2020 | 350 | 6 | 118 | 8,060 | 266 | 1,154 | 8.4 | 0.3 | 1.3 |
| | | 2030 | 6,000 | 114 | 829 | 19,477 | 913 | 3,506 | 25.5 | 1.0 | 4.3 |
| | | 2050 | 15,000 | 364 | 1,224 | 45,000 | 1,493 | 4,397 | 60.0 | 1.9 | 5.6 |
| | EU | 2020 | 350 | 5 | 130 | 23,493 | 730 | 4,979 | 23.8 | 0.7 | 5.1 |
| | | 2030 | 25,282 | 445 | 4,463 | 66,488 | 2,570 | 12,810 | 91.8 | 3.0 | 17.3 |
| | | 2050 | 188,000 | 2,431 | 9,712 | 460,000 | 6,296 | 23,881 | 648.0 | 8.7 | 33.6 |
| Scenario 3 | UK | 2020 | 350 | -25 | 161 | 8,060 | -22 | 1,566 | 8.4 | -0.05 | 1.7 |
| | | 2030 | 6,000 | -102 | 1,130 | 19,477 | 67 | 4,753 | 25.5 | -0.04 | 5.9 |
| | | 2050 | 15,000 | 49 | 1,662 | 45,000 | 444 | 5,957 | 60.0 | 0.5 | 7.6 |
| | EU | 2020 | 350 | -27 | 176 | 23,493 | -712 | 6,756 | 23.8 | -0.7 | 6.9 |
| | | 2030 | 25,282 | -617 | 5,981 | 66,488 | -968 | 17,343 | 91.8 | -1.6 | 23.3 |
| | | 2050 | 188,000 | 128 | 13,006 | 460,000 | -2,578 | 32,261 | 648.0 | -2.5 | 45.3 |

Table 1 - *Summary Economic Opportunity ACSs for ORE*

In Scenario 3, the investigated increase in CAPEX through the introduction of novel ACSs in comparison with the business-as-usual case, can cause a cost to the developer of £0.04bn and £1.6bn in the UK and wider EU, respectively, by 2030. Considering the results to anti-corrosion solution vendors, the three scenarios result in a range of value chain availabilities between £17.3bn and £43.5bn in the wider EU, by 2030; with these numbers more than doubling to £33.6bn and £83.3bn by 2050.

The future market size of the UK and wider EU ACSs were shown strongly positive and aligned well with existing market sizes in established oil and gas, and marine supply industries, with the investigated scenarios being on the optimistic side when determining the value of corrosion mitigation in the ORE sector.

In conclusion, what this report has researched is that there is:

i) a quantifiable potential benefit to all parties, and capabilities on both sides of the corrosion solution equation,

ii) an increasing need to support mechanism to facilitate materials and corrosion expertise transfer between sectors.

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

This report, whose title is "Business and Innovation Needs. Servicing and Maintaining Offshore Structures in the Energy Sector" and is downloadable from the NeSSIE internet site, aims at identifying a set of business and innovation needs within the corrosion topic through surveying the companies working within ORE sector. Such aim will result in:

i) a better understanding of the critical factors to decrease LCoE costs in ORE.

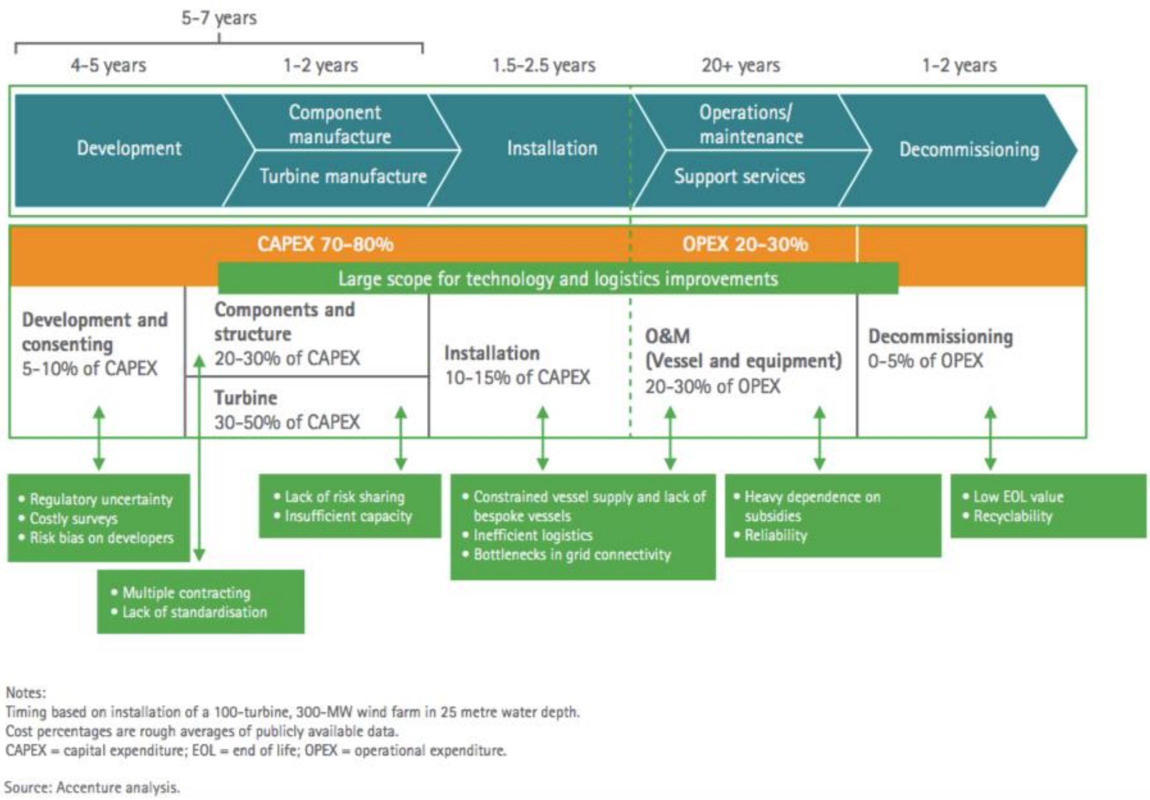


Figure 4 – *Offshore wind project life cycle*

ii) Planning of appropriate innovation strategies to connect the value chain with developers and end users.

iii) support in the development of the three investable DPs.

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. In fact, in order to increase the chances of coming up with a set of questions on the business and innovation needs that are understandable to a wide variety of people and, most importantly, to those in our sample, many pivotal and value-chain companies in the ORE field, all the partners and the NeSSIE Industry Advisory Board Members were contacted to get feedbacks on the survey questions. This document will then describe how the survey data were collected and discuss the main business and innovation needs collected.

More in details, the companies' needs can serve as a guideline for further development of ACSs and can be a tool to make strategic plans for the future decrease of the LCoE of the ORE sector. Companies were contacted in different ways: i) through email and asked to fill in the survey, ii) organising one-on-one meetings to discuss and fill in the survey, iii) making a technical workshop to discuss the corrosion issue and then jointly filling in the survey.

The key output was to collect quality data from companies and each NeSSIE partner had the flexibility within its region to use the approach that best suited their company base. To increase the industry engagement and get out of the box companies ACSs needs, in fact, not always the "easy" approach of an email is sufficient, but a more time-consuming and tailor-made approach is strongly recommended. The survey results were very positive and all the companies were very receptive to collaborating with the NeSSIE project and discuss not only on corrosion, but also on other offshore energy issues. In Figure 5 it is possible to see the results of a state-of-the-art study on the main challenges to decrease LCoE costs in OE.

| 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 5 - *Main priority challenges for OE Development [6]*

The discussion with the companies 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, the need emerged to: a) perform experiments in DPs 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 confirmed, as stated in many EU documents/reports, that 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 DPs are concerned, this report illustrated that there is a strong need to identify which technologies are more convenient to test within the DPs.

In conclusion, through this report we showed that:

- qualitative survey approach may serve as a model for an approach that provides:

i) fastest way to get insight in the technology and its challenges thanks to the combination of a desktop study and a survey to the experienced companies within the field of interest,

ii) 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 innovation "ecosystem" through collaborative projects.

Besides, to reduce OW 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 DPs.

## 5.4 *Review of Public and Private Sector Investments in Offshore Renewable Energy*

DPs are a phase of the innovation process in which several actors jointly test a given technology for many purposes such as to accelerate its introduction into a (new) market, to illustrate that the technology is up scalable or to test how it works in field conditions. Hence, DPs are a crucial tool for companies to facilitate learning and reduce risk associated with innovation. DPs are too a tangible way of demonstrating the utility of a technology to potential users, investors and a vital instrument for policy makers to direct and encourage the sustainable development. This report, whose title is "Review of Public and Private Sector Investments in Offshore Renewable Energy" and is downloadable from the NeSSIE internet site, is aimed at supporting the NeSSIE DPs design phase. To do so, it will highlight the importance of DPs in the renewable energy innovation process through analysing the scientific literature and some examples of DPs within the renewable energy sector and describing the main funding opportunities for DPs. More in details, to support the optimal "strategic" design of the NeSSIE DPs this report:

a) analyses the previous experiences of DPs within the development process of new technologies in the RE sector through a state-of-art study of the scientific literature (see Table 2).

| **Means of categorization** | **Types** | **Source** |
|---|---|---|
| **Specific aim** | a) <u>Prototyping demonstration projects</u>: To develop new prototypes and turn/improve prototypes into viable product version.<br>b) <u>Organizing demonstration projects</u>: To develop a production organisation capable of producing large(r) quantities or larger-scale of the prototypes-turned-into-products.<br>c) <u>Market demonstration projects</u>: To find and explore (a) market(s) for the new prototype-based products. | [7] |
| **Organizational form** | a) <u>Cooperating private organisations</u>: this organisational form is absent in the DP literature. This might be due to those private firms' fully-funding DP ambition to retain the results without publication. DPs may generate knowledge spillovers which benefit other firms at the expense of those involved in the projects. Even though this may be beneficial to society at large, it may delimit the incentives for firms to contribute to the development of the projects.<br>b) <u>Cooperating public organisations</u>: mostly in case of fundamental research.<br>c) <u>Cooperating public and private organisations</u>: this organisational form develops thanks to public grants and has three principal types of participant: a) Universities and RTOs which develop knowledge, competence and prototypes in sustainable energy, b) private firms which turn prototypes into products in (protected) market settings, c) public organisations which provide funding to cover (some of) the costs and efforts made by public and private organisations. | [7] |
| **Learning effects** | a) <u>Technical</u>: enable scientists and technicians to learn how to technically develop sustainable energy prototypes.<br>b) <u>Organisational</u>: enable actors to cooperatively-organise the sequential improvement and commercialisation process of new prototypes in RE (e.g. deciding which organisations and investors to involve, how to lower costs and balance cost/reward ratios for all participants, which technical standards to apply). The sequential improvement is a reason why DPs frequently last several years and should have an international, global character to accelerate the technical as well as social learning processes, and large-scale diffusion and adoption of sustainable energy technologies.<br>c) <u>Policy</u>: teach policy officers how to develop public energy policy (regulation and legislation) which stimulates the development, production and commercial exploitation of prototypes-turned-into-products in RE. | [8] |

| | | |
|---|---|---|
| | d) <u>Market</u>: provide experience to commercial professionals to bring RE prototype-based products to the market. DPs are "protected" spaces in business and society where niche markets can be created and build socio-technical innovation scenarios for RE exploitation on the market (create a positive public opinion about the new RE technologies). | |
| **Locations** | <u>Laboratory</u>: with universities and public research centres as the leading organizations.<br><u>Real world site</u>: with private firms leading supported by RTOs because firms want to improve/test and then commercialize the product.<br><u>Market place</u>: in case of a market DP this is located where the marketing dept. of the firm decide that it is the best location to show it to the market. | |

Table 2 – *Demonstration Projects classification [adapted from [7]]*

b) Analyses the different funding opportunities for DPs (a detailed study on this issue was performed in NeSSIE Report 3.1).

c) Analyses examples of DPs within ORE in the partners regions already ongoing or under development.

d) Discusses the fundraising process adopted in DPs development.

Depending upon the DP's aim, its development has different timing and funding needs. In any case the DP design phase is fundamental for the uptake of the innovation to the market. During the DP design phase, it is necessary to define its value proposition, the team that will be involved, the business plan and how to implement a co-design and an open innovation approach during the DP overall life cycle. Besides, many authors, as well as the NeSSIE partners experience, highlighted that there are main reasons for success or failure of DPs:

a) User involvement: important at all stages of DPs to facilitate learning and to continuously check whether the work being performed in the DPs is indeed representative for "real conditions".

b) Government support: crucial because it can influence the diffusion of innovation increasing public acceptance indirectly by indicating to potential adopters the direction of public funding, policies and priorities.

c) Dissemination of results and evaluation information should be included in the project design taking into consideration confidentiality requirements.

d) Careful planning: it is necessary to take account of market readiness, user participation and financial sustainability.

ORE technologies are capital-intensive, require protracted periods of experimentation and market demand has often yet to emerge. As shown in figure 6 it exists different funding option within the innovation process or market uptake of a certain technology. Corporate or private stakeholders find it difficult to fully engage in ORE experimentation due to uncertain financial/competitive returns. Hence, government must play a lead role in the initiation of such DPs.

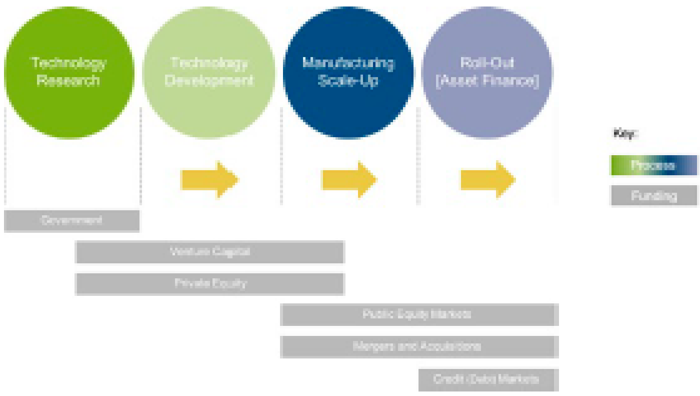


Figure 6 - *Different funding mechanism for a market-uptake of a Technology [9]*

In doing so government must involve:

1) the private sector stakeholders from the beginning of the R&D process adopting the open innovation approach because value is created through the interaction and mutual collaboration between people, organisations and technologies.

2) The appropriate team to manage the DP (e.g. business development team) in order to efficiently exploit the results both to the private sector and to the "community".

In conclusion, DPs being either solution testing or research infrastructures, are beneficial assets for the territory by being a trigger for knowledge/value creation. Besides, when designing the DP phase, it is crucial to consider an inclusive approach and to set up and further monitor the business and technology plan development to be ready to implement the appropriate correcting actions.

### *5.5 Discussion on Work Package 2 Outputs*

WP2 mapped the current activities and challenges on ACSs - both materials and procedures – from a scientific, technical and economic point of view through a multi action-based approach based on:
i) literature studies: both paper-based and attending scientific conferences,
ii) technical reviews: both paper-based and attending sectorial exhibitions,
iii) technical interviews: providing surveys and doing meetings with ORE and offshore energies value chain companies.
It then analysed the private and public funding options available for supporting R&D projects in this area in order to support the three NeSSIE under-development DPs in becoming bankable and investment-ready.

As described in the definitions (chapter 4.1 of this report), a desktop study providing a first line identification of a subject can assist to precisely focus the design phase. Within NeSSIE project activities no physical investigations were performed; in fact, the final aim to develop three DPs in the NSB within ORE sector was reached through collating information first from the literature – scientific, technical and patents-based - and then discussing them with the ORE value chain actors.
To identify/define the ACSs challenges of the ORE sector, to create a collective and credible message on the issues to tackle and further discuss these with the value chain actors, WP2 provided the “foundation” for the technical and economic discussion.
To proactively discuss the challenges with the different value chain actors, to investigate the potential of the company’s knowledge in another market and support them in the definition of the 3 DPs WP2 was fundamental to know the market requirement both from a business and a scientific/technological perspective.
Besides, the WP2 main results were necessary to start and promote the knowledge transfer process between different value-chain actors of the offshore energy field; in fact, it gave the possibility to the NeSSIE partners to discuss with:
i) the companies about the “market-opportunity” provided by ORE sector in order to identify “windows” of business opportunity,
ii) the research centres about the market needs to support them in exploiting their know-how also in short term projects developed with the companies,
iii) the policy maker about the financial measures to promote the ORE development creating a supportive environment.
In few words, WP2 supported the NeSSIE partnership in creating the awareness and deepening the knowledge of ACSs economic importance within the ORE sector, showing to the different actors the importance of the open-innovation approach within the ORE sector development.
Such results increased the credibility of the technical and non-technical challenges identified and therefore were important to achieve the NeSSIE mission through the definition of the more efficient “instruments” that were further developed within the NeSSIE Roadmap for ACSs in the ORE Sector and used within the identification/definition and development of the three NeSSIE DPs.

# 6 Conclusions

WP2 was aimed at:

1) setting the technical and economic baseline for the Roadmap that has been developed in WP3,
2) provide the basis for the discussion with the value chain actors than was performed in WP4,
3) support the development of the DPs business and technology plans that were produced in WP3, WP4 and WP5.

The main results that were obtained in WP2 were to map:

a) the current activities and challenges on corrosion solutions, new materials and procedures based on a desktop study of the scientific, technical and patent literature,
b) the corrosion solutions employed by other industries outside the marine industry,
c) the economic opportunity relating to novel materials and ACSs in the NSB applied to the ORE sector,
d) the business and innovation need of the companies working within offshore energies field in the different NeSSIE regions concerning service life of offshore structures,
e) the private and public funding options available for supporting R&D projects in this area.

In conclusion, WP2 results were not only key to identify and prioritise the ACSs challenges in the NeSSIE roadmap, but were also the basis to involve the value chain actors within the NeSSIE project and support them in the definition of the 3 DPs.
Furthermore, due to the fact that WP2 studies were performed by a multidisciplinary team its report will be a good baseline for a deep knowledge of the ACSs for all the ORE value chain actors and will serve as a model for other consortia to address common technical challenges in ORE technology development.

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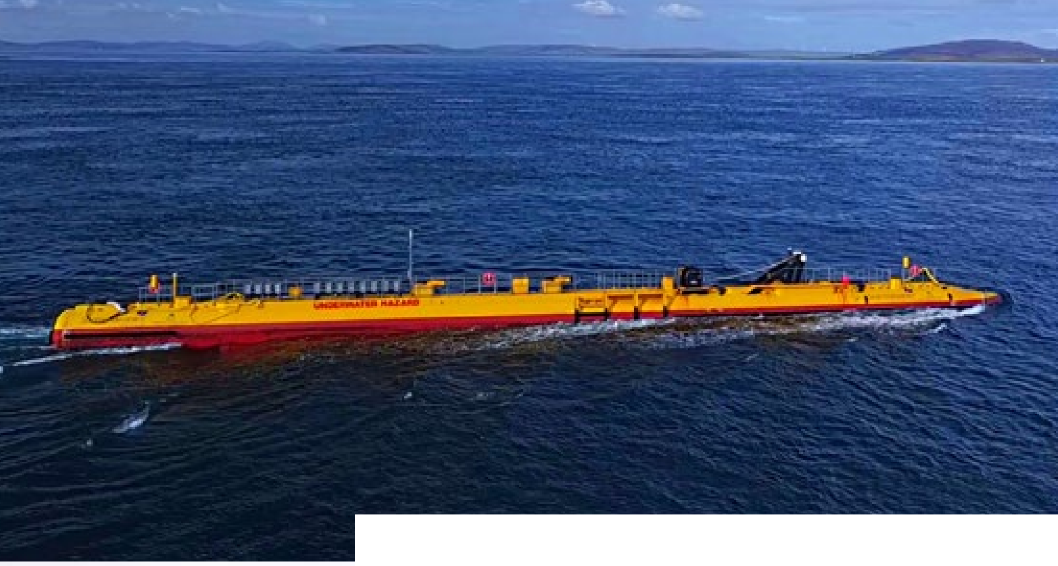

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