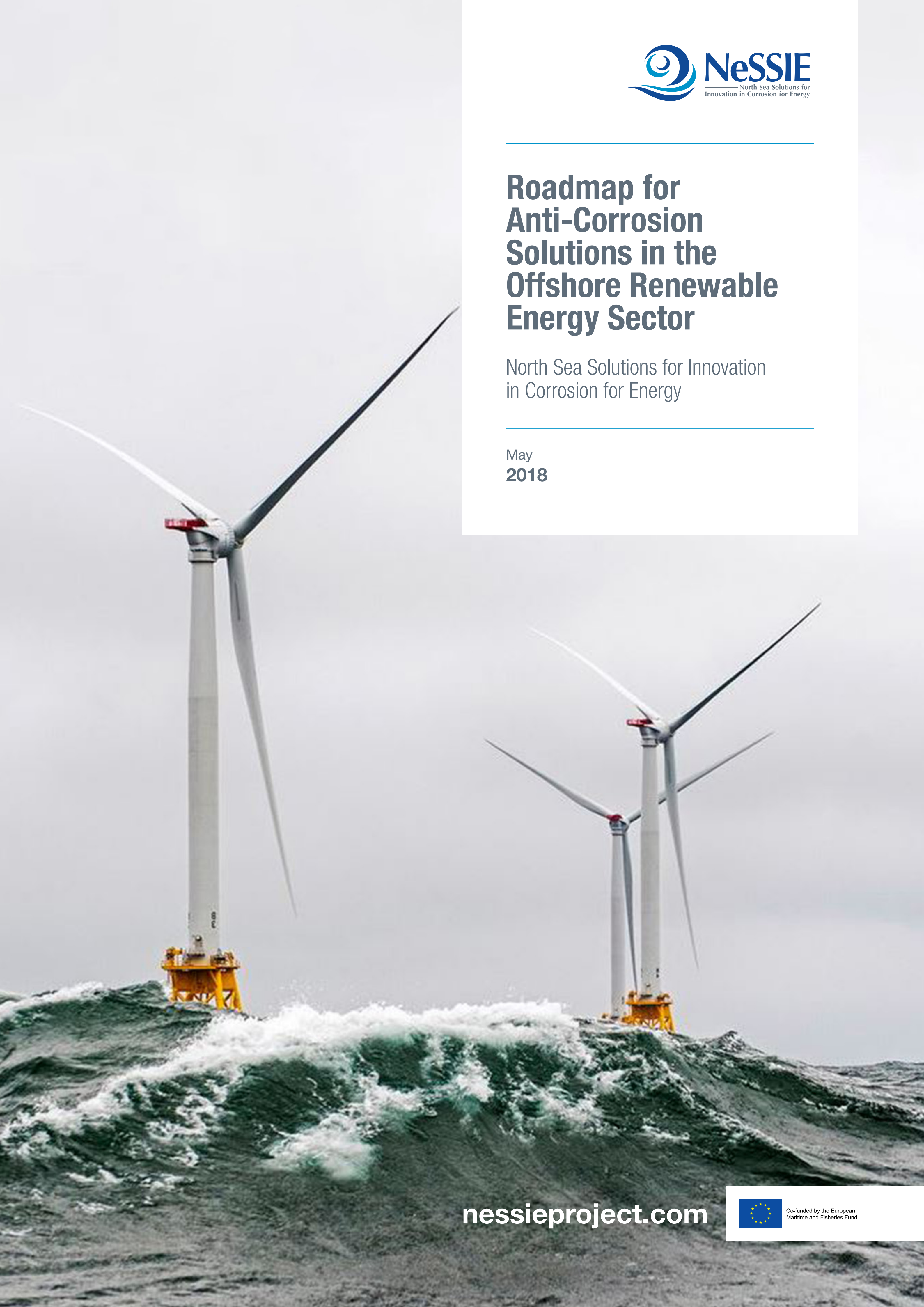
NeSSIE
North Sea Solutions for Innovation in Corrosion for Energy

# Roadmap for Anti-Corrosion Solutions in the Offshore Renewable Energy Sector

North Sea Solutions for Innovation in Corrosion for Energy

May
**2018**



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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).

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## Acronyms

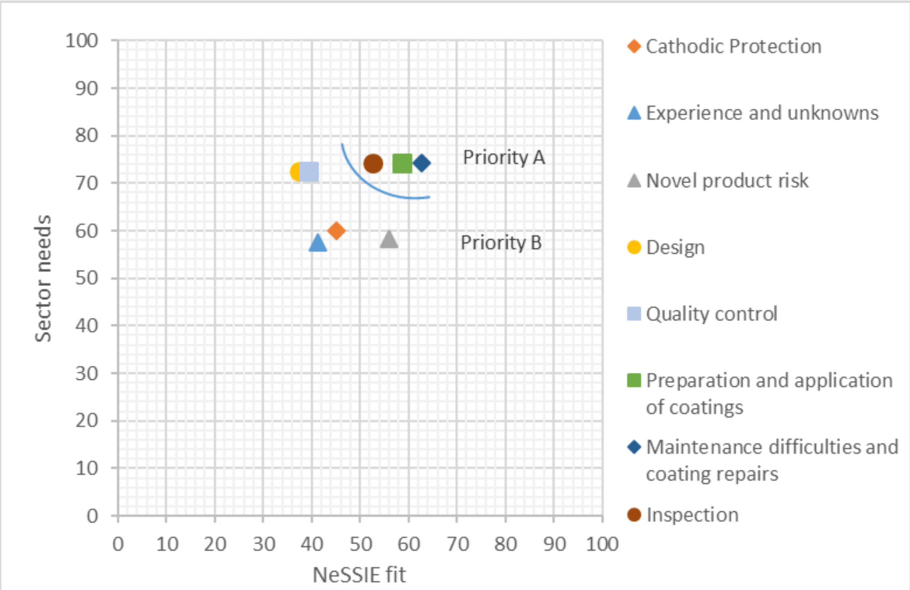
| | |
|---|---|
| ACS | Anti-corrosion Solution |
| CP | Cathodic Protection |
| LCOE | Levelised Cost of Electricity |
| MSP | Marine Spatial Plan |
| NeSSIE | North Sea Solutions for Innovation in Corrosion for Energy |
| NREAP | National Renewable Energy Action Plan |
| O&M | Operation and Maintenance |
| OEM | Original Equipment Manufacturers |
| OPEX | Operating Expenditure |
| ORE | Offshore Renewable Energy |
| SME | Small to Medium size Enterprise |
| WP | Work Package |

# 1 Executive Summary

The NeSSIE project aims to deliver high-value manufacturing opportunities to the North Sea basin and wider EU supply chain of Anti-Corrosion Solutions (ACSs), aiding the Offshore Renewable Energy (ORE) sector goal to reduce the cost of offshore renewables. Through the exploration of cross-sector knowledge transfer from the established marine sectors as well as innovative solutions, NeSSIE identifies opportunities and focus areas for development of ACSs applied to ORE.

This 'Roadmap for Anti-Corrosion Solutions in the Offshore Renewable Energy Sector' presents the research undertaken within the preliminary stages of the NeSSIE project, outlining the current landscape of ACSs with regards to the technology, market, finance, infrastructure and regulation already in place. From this existing landscape, key challenges have been identified which affect the commercialisation of ACSs within the ORE sector.

A prioritisation identified the key challenges to focus on in terms of both sector needs and the NeSSIE project aims; these are outlined in Figure 1. The key challenges identified with the highest priority (Priority A) are the challenges that will benefit the most from the NeSSIE demonstration projects.




| NeSSIE Priority | ACS Challenge |
|---|---|
| A | Preparation and applying coatings |
| | Maintenance difficulties and coating repairs |
| | Inspection |
| B | Quality Control |
| | Novel Product Risk |
| | Cathodic Protection (CP) |
| | Design |
| | Experience and unknowns |

*Figure 1 – NeSSIE prioritisation of the main ACS Challenges*

Based on the identified challenges, a set of recommendations to various key stakeholders, such as policy makers and device developers, has been produced. The potential impact of the NeSSIE project on the current landscape of ACS technology, market, finance, infrastructure and regulation is also discussed. These recommendations are a key output of this work.

Through generating corrosion issue awareness, providing connections between different sectors and assisting in the development of demonstration projects, NeSSIE will encourage the development of ORE with the application of ACS and novel materials to tackle corrosion and reduce the cost of energy as ORE move towards commercialisation. By doing so, this will create job opportunities and generate industrial growth.

# 2 Introduction

## *2.1 Background*

This report is the culmination of the research done within NeSSIE to identify and address the challenges in the development of anti-corrosion solutions (ACSs) applied to the offshore renewable energy (ORE) sector, namely the NeSSIE Roadmap. Using the mature North Sea offshore sector manufacturing/services base and networks as a basis, the NeSSIE Roadmap will identify the anti-corrosion expertise already in place, identify new innovative materials being used, and recognise appropriate manufacturing techniques and existing mitigation systems. This roadmap will act as a model for wave, tidal and offshore wind in the North Sea basin and other sea basins to address common technical challenges within ACSs, and as an example of transforming the associated manufacturing opportunities into industrial application.

A strategic analysis approach (by means of roadmaps, deployment strategies, market and technology reviews) to understanding and developing the wider offshore renewable energy (ORE) sector is well recognised in the industry. Examples of this include the ORECCA project [1], Commonwealth Blue Economy series 4 report [2], The Carbon Trust's Floating offshore wind review [3] and SI Ocean wave and tidal energy market deployment strategy for Europe [4]. Like these studies, the NeSSIE Roadmap will ultimately identify the priorities and provide recommendations required to overcome the integration of offshore anti-corrosion systems into North Sea basin offshore renewable energy (ORE) systems, namely wave, tidal and offshore wind energy.

NeSSIE builds on the partnerships formed in the Vanguard Initiative Energy Pilot to build robust, high-integrity manufacturing value chains for marine offshore energy applications by identifying common areas of expertise, identifying common challenges and developing networks to support innovative technology/service developments. An industry survey was carried out in early 2016 under the Vanguard Initiative [5], with the participation of 83 European companies involved in the development of advanced manufacturing solutions for harsh environments. This survey included a section devoted to the identification of the main industrial challenges that companies face in their business activities and on the important challenges for the upcoming years, shown in Figure 2. One of the key identified challenges was 'Corrosion in water and corrosion protection' for marine operating devices, as such devices have been traditionally made using steel, which is highly susceptible to corrosion salt water.

It is worth noting that the participants identified corrosion as one of the main industrial challenges, second only to cost reductions in operation and maintenance. Interestingly, corrosion is highly connected to O&M costs, a study by the oil and gas industry reports 25-33% of maintenance costs are corrosion related [6]. The analysis of the survey responses shows that 60% of respondents currently consider it a relevant industrial challenge for their business activities.

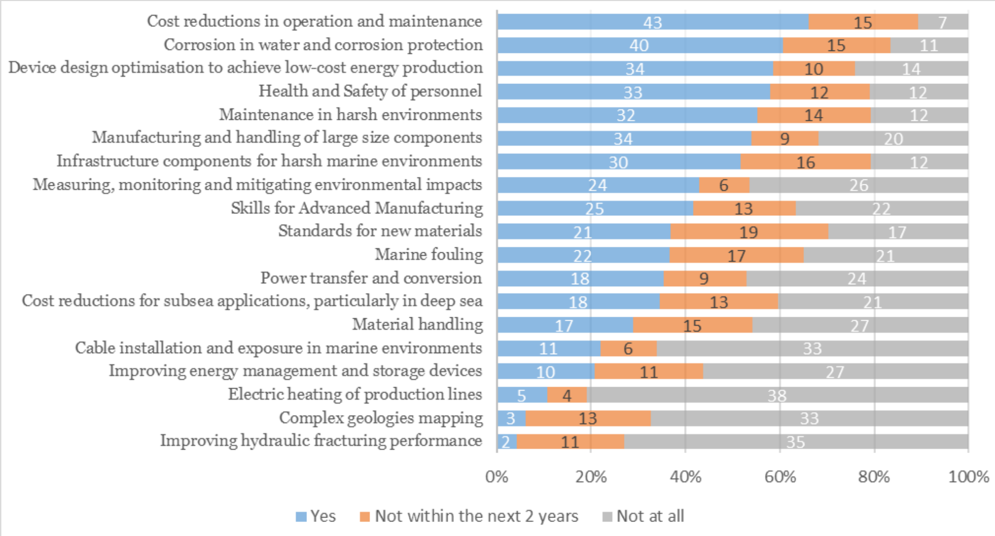



*Figure 2 – Relevance of industrial challenges for Advanced Manufacturing (ADMA) for energy applications in harsh conditions [5]*

## 2.2 NeSSIE Roadmap Vision

Within the ORE sector, there is a focus on reducing the lifetime costs of offshore renewable energy technology components, and making devices cheaper to construct, install and operate – thus lowering their levelised cost of electricity (LCOE) generation. Anti-corrosion systems have the potential to improve ORE devices' energy conversion efficiency, availability, survivability and reliability, whilst at the same time significantly reducing operational expenditures (OPEX) associated with operation and maintenance (O&M) activities.

NeSSIE aims to deliver high-value manufacturing opportunities to the North Sea basin and wider EU supply chain of ACSs, aiding the ORE sector goal to reduce the cost of ORE, creating job opportunities, and generating industrial growth.

A roadmap identifies the path forward; it provides an overview of the focus points and priorities to tackle the challenges in the development and reaching the set goal. The vision of this 'Roadmap for Anti-Corrosion Solutions in the Offshore Renewable Energy Sector' follows the aim of NeSSIE; identifying the high-value manufacturing opportunities to the North Sea basin and wider EU supply chain of ACSs in order to reduce the cost of ORE.

## 2.3 Roadmap Structure

To determine the pathway towards commercialisation for ORE including the application of ACSs, the roadmap is divided into three sections: the landscape, route and vision. This is illustrated in Figure 3.

Firstly, a general status overview is given including the non-technical challenges and the existing ACSs with their challenges for the ORE development, this sets the landscape. Secondly, the route towards commercialisation follows by addressing the highest priority challenges. Finally, the roadmap concludes with recommendations as to how to obtain the high-value manufacturing opportunities mentioned in the vision. Translating this method to the chapters, the structure of the roadmap is as follows:

- Section 3 discusses the current ORE landscape with the application of ACSs, based on the research completed on the current ACS technologies [7] and on the non-technical challenges. The key observations from this research in order to develop ACS in the ORE sector are discussed.
- Section 4 discusses the identified ACS challenges, based on the technology research and surveys performed. The key technical and non-technical challenges concerning ACSs are identified and a prioritisation is completed to indicate the challenges with highest priority with respect to both the ORE sector and the NeSSIE project goals.
- Finally, Sections 5 and 6 discuss the recommendations and conclusions from this work respectively. Based on all of the challenges identified for this report, recommendations are made in Section 5 to facilitate the ACS development and the ORE sector towards commercialisation. Section 6 concludes the research completed for this roadmap on ACSs for NeSSIE.

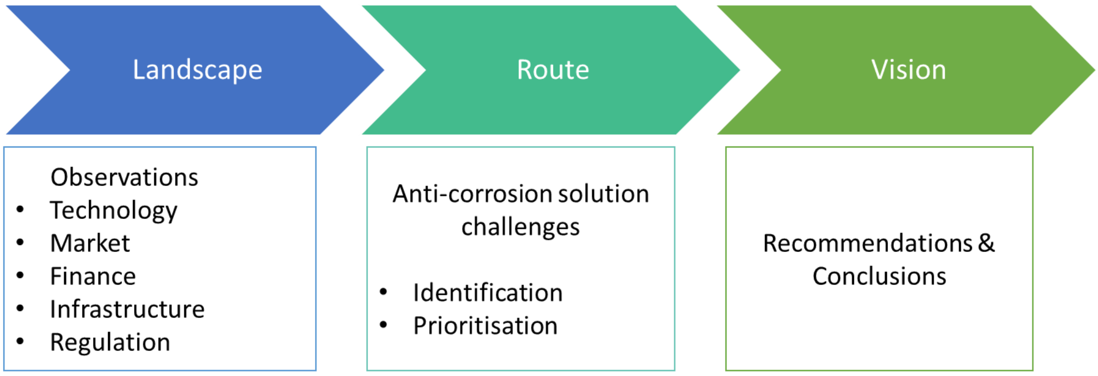



*Figure 3 – NeSSIE Roadmap Structure*

The roadmap builds upon the previous work produced by the NeSSIE project partners, as illustrated in Figure 4. Research done within NeSSIE on mapping of current corrosion solutions and new materials in the offshore sector [7] as well as the potential economic opportunities [8] feeds into the roadmap. The additional information required to develop the roadmap is outlined in the non-technical challenges for deployment [9].

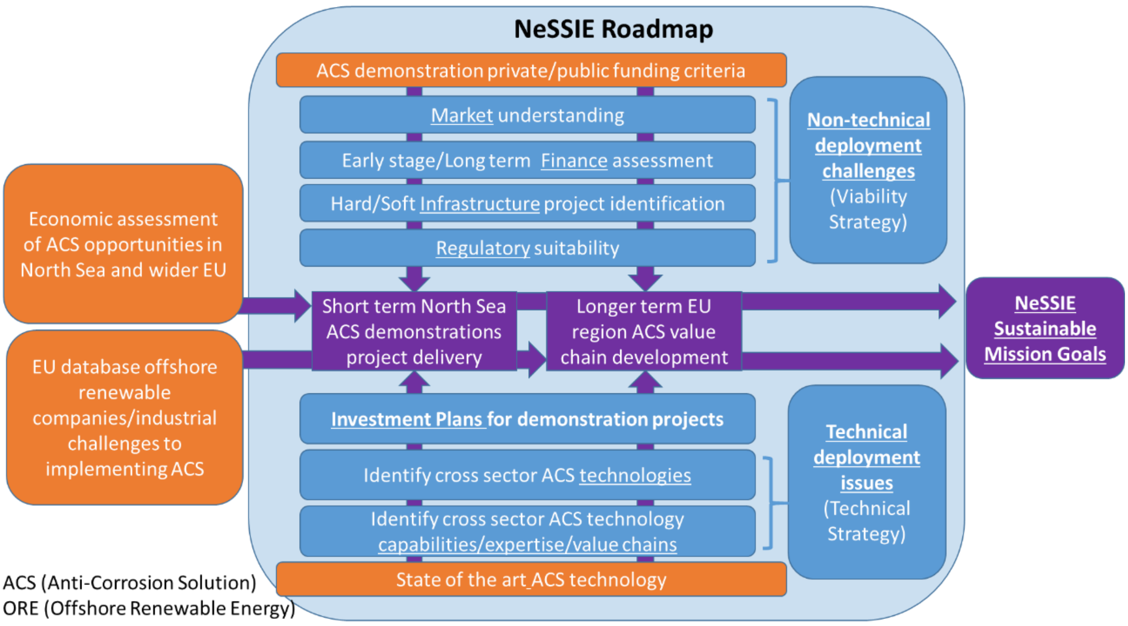



*Figure 4 – NeSSIE Roadmap Strategy – inputs from previous NeSSIE deliverables*

# 3 Landscape

This chapter investigates the technology, market, finance, infrastructure and regulation observations relevant to the development of ACS and new materials in the ORE sector. It follows previous research of NeSSIE, which discussed the current anti-corrosion solution technologies used in offshore structures [7] and the non-technical challenges of ACS in the ORE sector [9]. Below, the technical and non-technical observations regarding NeSSIE, for the development of ACS in the ORE sector, are discussed. This is the first step in the roadmap approach, as indicated in Figure 5.

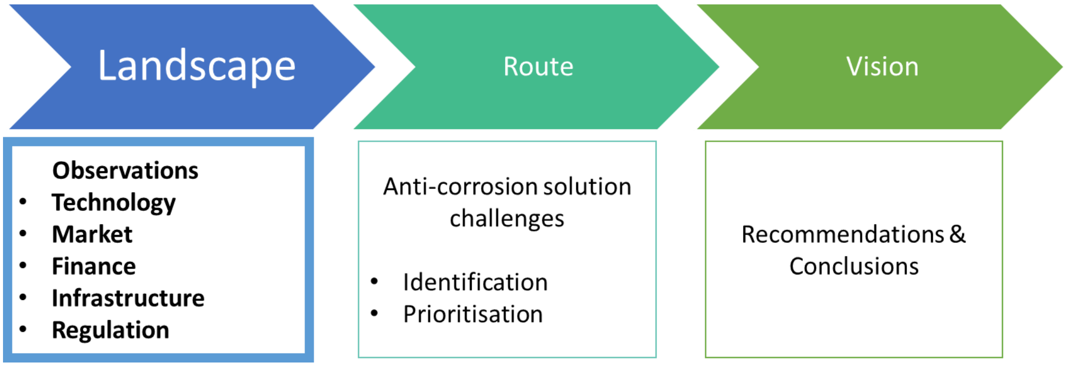



*Figure 5 – NeSSIE Roadmap Structure: Landscape*

## 3.1 *Technology observations*

Previous NeSSIE research provides an overview of the current materials and solutions for corrosion in offshore structures. These have been categorised into four key areas:

1. Protective coatings including environmentally benign paints, sprays and coatings;
2. Cathodic protection;
3. New materials and their associated fabrication, manufacturing and assembly processes;
4. Corrosion monitoring, assessment and repair services.

These solutions have to be considered on a project by project basis, with the wide-ranging technologies available within wave, tidal stream and offshore wind projects. The main technological challenges as identified for ORE can be categorised in the performance, predictability, manufacturability, installability, operability, survivability, reliability and affordability. Each technology will have different specific challenges and the applied ACS will affect this as well. The observation made regarding the technological challenges is displayed in Figure 6 and is discussed below.

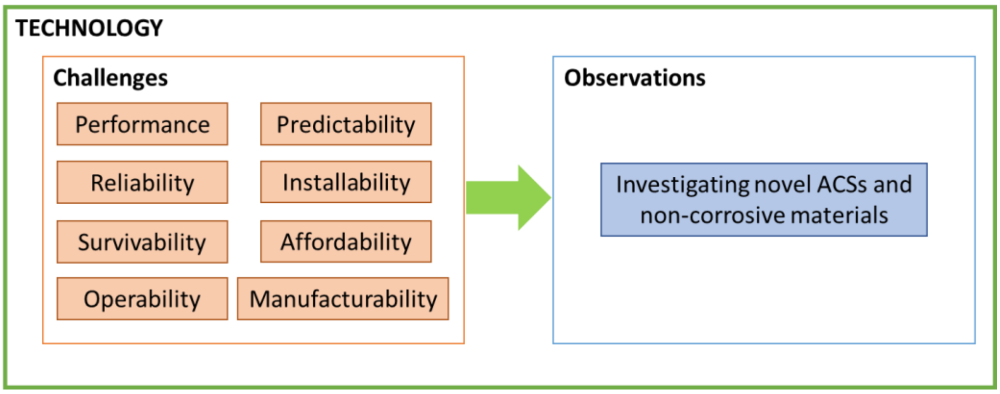



*Figure 6 – Technology challenges and observations*

### *3.1.1 Investigating novel ACSs and non-corrosive materials*

Modern offshore constructions are now more often being made of special alloys including high strength steel, stainless steel, aluminium and even titanium alloys. Low- and unalloyed steel however must always be protected because of their low corrosion resistance to marine environment. Currently, the best results are obtained by thick thermal spray aluminium or zinc-aluminium coatings, with or without additional paint layers. Smaller parts can be made of uncoated special stainless steels or nickel alloys. The number of innovative corrosion resistant alloys however is restricted. Table 1 – List of examples of corrosion protection as discussed in previous NeSSIE research on the state of the art of ACSs Table 1 provides the corrosion protection systems discussed in the NeSSIE ACS state of the art report [7], this is an indicative overview of solutions that are currently used. This is not an exhaustive list of solutions, for example, non-corrosive materials is not included here. Novel ACS and non-corrosive materials for application in the ORE sector should be further explored to investigate potential improvements.

| Anti-Corrosion Solutions | Examples |
|---|---|
| **Cathodic Protection** | Active |
| | Passive |
| **Metallic coatings** | Hot dip galvanizing |
| | Thermal Spraying |
| | Nickel coatings |
| **Organic coatings** | Epoxy and polyurethane coatings |
| | Polyurea coatings |
| | Powder coatings |
| **Hybrids** | Phosphate conversion coating |
| | Chemically Bonded Phosphate Ceramic coatings |
| | Film Galvanizing Systems |
| | Silane coatings |
| | Sol-gel coatings |
| **Alternative corrosion control measures** | Precautionary measures |
| | Protective caps and shields |
| | Sheating |
| | Dehumidifiers |
| | Sealing and joints |

*Table 1 – List of examples of corrosion protection as discussed in previous NeSSIE research on the state of the art of ACSs [7]*

## 3.2 Market observations

The marine energy market has a great growth potential; with the global installed capacities in 2017 of approximately 8MW and 17MW for wave and tidal energy respectively [10] and a combined capacity potential of 337 GW by 2050 [5]. Offshore wind has seen significant growth in recent years, with the prospect of a cumulative installed capacity of about 25 GW in the Europe by 2020 [11].

The market potential for applying ACSs and novel materials in the ORE sector has been identified in previous NeSSIE work on the economic opportunity [8]. However, there are several market challenges for ACSs to reach their full impact on OREs with the combination of different factors playing a role, as identified in the report on the non-technical challenges [9]. The following paragraphs will discuss some opportunities to address these challenges in the form of market observations for the application of ACSs and novel materials within the ORE sector (Figure 7).

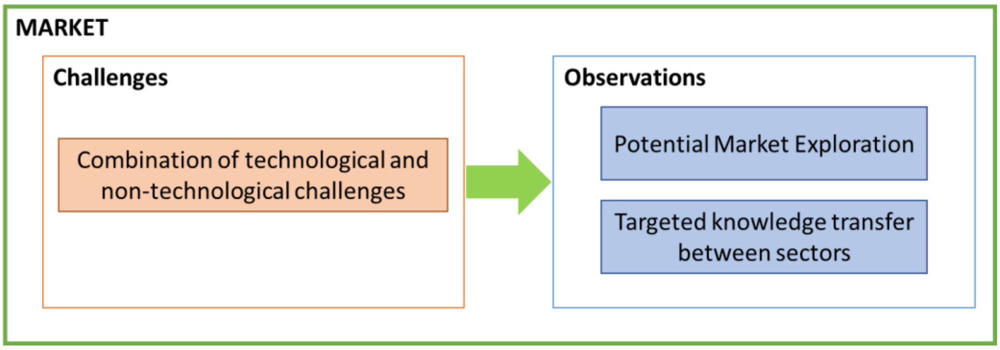



*Figure 7 – Market challenges and observations*

### *3.2.1 Potential market exploration*

ORE may benefit from the knowledge of mature offshore sectors such as oil and gas or shipbuilding, as these sectors have a long history in dealing with corrosion issues. The Scottish Enterprises 'Oil and Gas diversification opportunities' report [12] is a good example of how established supply chains are being encouraged to diversify into the growing offshore renewables markets. Oil and gas is one of many sectors with offshore corrosion experience.

The previous absence of a significant market for ACSs in the ORE sector, due to the early stage of wave and tidal energy, has meant that business development in offshore renewables has not been a core priority for companies with expertise in ACSs in the oil and gas and maritime sectors. However, with offshore wind developing several GW of capacity in Europe and the oil price crash, the opportunity has become evident. High oil prices until 2015 (over $100 per rent crude oil barrel compared to slightly over $50 in 2017) meant that the oil and gas industry was not focused on cost reduction of ACSs. Therefore, novel materials and improved ACSs were not a primary focus of R&D for the oil and gas industry. Regarding the ACS applications within the ORE sector, even though corrosion is a well-known issue in the marine environment, other challenge areas such as technology performance have been the main research focus. However, R&D of materials such as composites, concrete, polymers or aluminium that have improved corrosive resistant characteristics could be beneficial for all sectors, as mentioned in the technology observations.

For offshore wind and marine energy developers, the primary new materials and corrosion management requirements are to aid in realising cost reductions and ensuring array performance levels. For ACS vendor supply chains, the diversification opportunities in ORE were shown to be economically significant for different scenarios in the NeSSIE report on the assessment of the economic opportunity of ACSs [8].

In addition, research towards new ACSs and non-corrosive materials should be performed to ensure a suitable solution, as not all existing solutions that are applied in the established marine sectors will perform under the conditions experienced by offshore renewables.

### *3.2.2 Targeted knowledge transfer between sectors*

The Wave and Tidal Energy Market Deployment Strategy for Europe [4] states that LCOE reduction could be achieved by developing common R&D actions with offshore wind. All three energy areas share common interests such as grid infrastructure, equipment, operations and maintenance procedures, as well as project development and permitting processes. As part of the SI Ocean consortium, an in-depth analysis of synergies between the wave, tidal and offshore wind sectors has been developed by the Joint Research Centre (JRC) [13]. The study indicated that wave and tidal projects could have component and project synergies of up to 42% with offshore wind. This highlights the value of projects such as NeSSIE which pursue diversification and foster knowledge transfer between these different sectors.

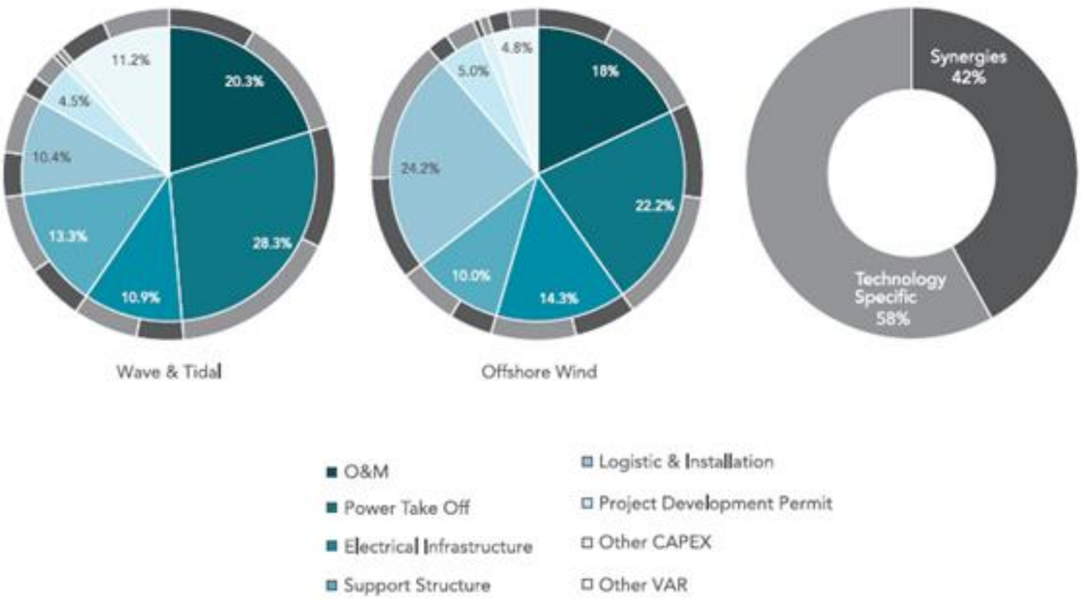



*Figure 8 – Synergies between wave and tidal energy and offshore wind [4]*

Offshore renewable developers are involved in tackling several complex technological challenges with limited resources, as discussed in section 3.1. As corrosion has not been a focus of the sector, the knowledge about the available ACSs is often incomplete, especially in the case of new coatings and materials. Interaction among different maritime sectors is critical to avoid this issue. The cross-sector interdisciplinary workshop, as discussed in Section 4.3, showed that industry stakeholders acknowledge that there is a need to integrate knowledge on corrosion mitigation throughout the whole lifetime of the system and products. Corrosion needs to be taken into account from the design phase.

The involvement of the companies in a multi-sectoral approach is critical as the knowledge of the mature sectors such as oil and gas or shipbuilding is not always suitable for transfer to offshore renewables. For example, on oil and gas platforms, corrosion protection systems are generally under permanent inspection, which is not the case on offshore wind towers. Thus, where on oil and gas platforms areas of deteriorated coating can be recognised and repaired comparatively easily, such repairs are not feasible on offshore wind energy towers resulting in a relevant challenge for industry.

This shows the need to boost cross-sector interaction and collaboration in terms of knowledge sharing, networking and development of new common research options. This could be achieved through collaborative projects, with a consortium including partners from different sectors, and through cross-sector workshops.

## 3.3 Finance observations

The following observations can be made for the development of demonstration projects, based on the gathered information on ORE funding. This is based on the non-technical challenges identified in the NeSSIE project research [9], indicating that there is a need for improvement in public funding coordination, for appropriate funding in all development stages up to commercialisation, and for clear communication from the ORE technology developers on their development process. These challenges and the observations following them are shown in Figure 9 and discussed below.

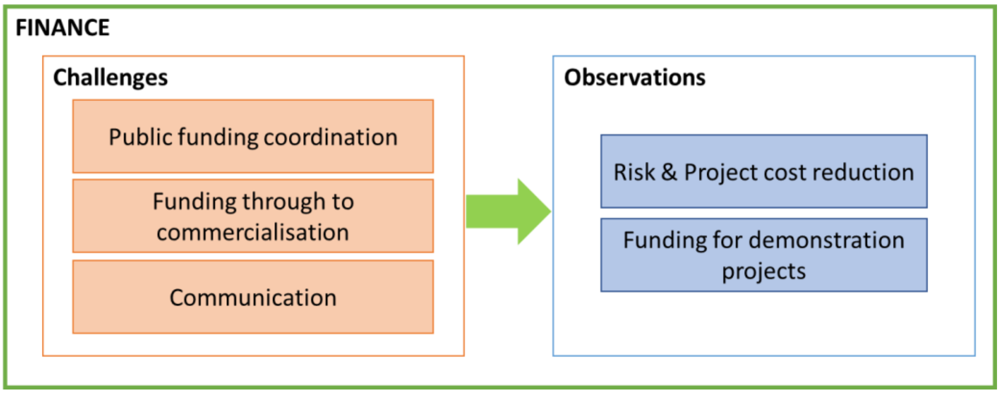



*Figure 9 – Finance challenges and observations*

### *3.3.1 Risk and project cost reduction*

Technology risk reduction is necessary to secure funding for projects. Demonstration of a technology at different stages and specific focus points are required to reduce the risks when moving towards commercialisation. By improving the conditions of different project aspects, such as operation and maintenance, the cost of energy of the technologies can be reduced. With a focus on corrosion, NeSSIE demonstration projects can reduce this risk by indicating the performance and reducing the cost of energy.

Focussing on one issue, such as corrosion, does not eliminate the possibility of investigating other aspects within the same demonstration project. To reduce the investment required to deploy demonstration projects, the demonstration of innovative corrosion related solutions could be added to existing demonstrators of other technological concepts. This would eliminate the need to build separate demonstrators and incur additional cost. A similar approach is employed at the East Anglia ONE wind farm in the UK, where a specific test turbine site was allocated within the commercial farm to promote innovation [14].

### *3.3.2 Funding for demonstration projects*

A report by the Ocean Energy Forum [15] highlights the importance of upfront capital funding for the development from demonstration to pre-commercial stage. Potential funding options are mentioned as: Member States budgets, national revenue from the Emission Trading System, EU structural funds, EU demonstration programmes such as ERA-Net co-fund, Innovation Fund and the European Fund for Strategic Investments. The report also mentions insurance for the project development. This could come from several different sources, similar to the upfront capital funding options, for example: National (Green) Investment Banks, European Investment Bank (EIB) (programmes such as InnovFin), Member States budgets, national revenue from the Emission Trading System and/or the European Fund for Strategic Investments. To be able to achieve upfront capital, a combination of different funding sources is needed. In this funding mixture of demonstration projects, the role of public institutions is key, as the level of risk is assumed too high for private investors without any additional funding confidence.

Sources of both public and private funding have been discussed in more detail in the NeSSIE report on the non-technical challenges in developing ORE projects [9]. Such funding sources can also be used to reduce the price risk associated with electricity markets. An example of this would be the Feed-in tariff with Contracts for Difference (CfD) scheme in the UK, where payments to generators take the form of a top-up to a set strike price from the fluctuating market price of electricity. Strike prices are currently set by a competitive auction; with total spend on the scheme limited by the Levy Control Framework [16].

## *3.4 Infrastructure observations*

The infrastructure challenges concerning the development of ORE include the combined use of marine space, the absence of appropriately skilled workers and sufficient grid capacity, as identified in the NeSSIE report on the non-technical challenges of ORE project development [9]. This section explains the infrastructure observations to address these previously recognised challenges, shown in **Errore. L 'origine riferimento non è stata trovata.**.

Technical synergies and commonalities identified in the 2011 ORECCA Roadmap [1] between the different offshore technologies allow a shared perspective when considering the hard and soft infrastructure required to deliver ACS solutions.

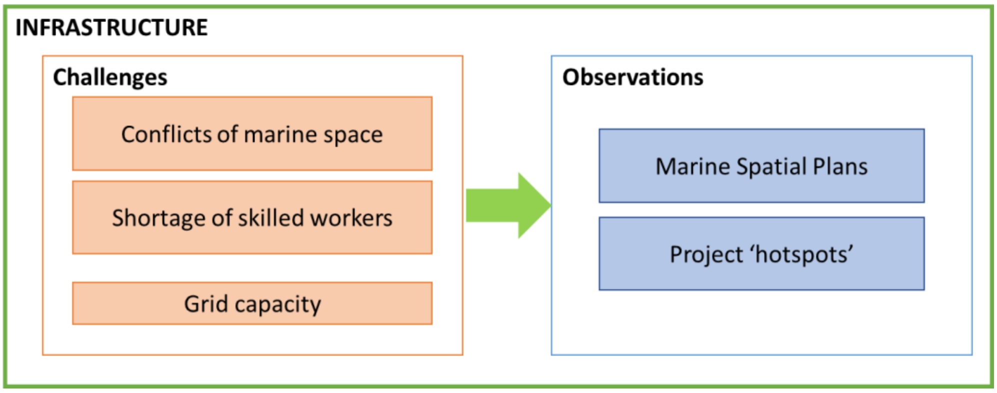



*Figure 10 – Infrastructure challenges and observations*

### *3.4.1 Marine Spatial Plans*

Marine Spatial Plans (MSPs) are useful for identifying demonstration project locations. MSPs aim to highlight and characterise spatial opportunities to future offshore renewables developments to private developers and public licencing bodies. For example, the Pilot Pentland Firth and Orkney Waters MSP [17] has identified and designated areas for marine renewable energy project development. These allocated areas do not impose the exclusive use of marine renewables. However, this regional plan provides an insight in preferred sites based on the documentation of existing hard infrastructure, activities and sensitivities determined by the Sustainability Appraisal [18] of these locations and their surroundings. As the coastal waters are governed by the Crown Estate, these designated marine renewable development areas have Crown Estate Agreements for Lease, at a 'planned development at the licensing stage' [17]. This initial identification of preferred marine renewable energy deployment areas is useful for the NeSSIE demonstration projects.

### *3.4.2 Project 'hotspots'*

The existing oil and gas infrastructure and strong North-Western Europe wind resource, accompanied by the decline in oil and gas production in the North Sea and raise in oil price between 2009 and 2016 have proven advantageous to the offshore wind supply chain in the region [19]. Oil and gas providers in the area have been increasingly remodelling their operations to diversify into the fast growing offshore wind sector. Oil and gas installation/logistics vessels, heavy fabrication yards and service companies have actively increased facility investments geared towards dedicated support for offshore wind structures, such as Equinor (previously Statoil) with the floating wind energy project Hywind [20].

Tidal and wave energy technologies could take advantage of the success of offshore wind development in the North Sea basin countries, as there is experience from the diversification pathway to hard infrastructure access. In fact, for tidal turbines there is significant design and manufacturing overlap with offshore wind turbines already. The similarity in the required infrastructure and components between the different offshore technologies and sectors has been recognised as a key explanation for diversification; the oil and gas companies recycling and extending their usage of existing resources for the development of offshore wind farms [21]. There is an opportunity to apply this to the different renewable technologies. Figure 11 emphasises various oil and gas, and offshore wind operational hard infrastructure synergies that exist between the two sectors.

Hard infrastructure availability and existence is clearly of key importance when considering the long-term development of supply chains to translate oil and gas ACSs to the rapidly growing offshore renewables sector. The previous mentioned ORECCA Roadmap [1] highlights mobilising necessary facilitating infrastructure around hotspots where large amounts of high intensity renewable resource exist, i.e. ports, vessels and transport infrastructure. Using this reasoning for NeSSIE demonstration projects and value chains, it is deduced that the locations for ACS supply could benefit from these existing high intensity hotspots. The demonstration projects will need manufacturing and assembly facilities and knowledge as well as monitoring services present at the regional clusters. In terms of soft infrastructure, training programmes to ensure skilled workers can be set up in these locations as well. Equally important are strong power and transport networks, access to testing facilities and onshore to offshore logistical support equipment and facilities. A list of examples of these hotspots in the North Sea basin have been identified in the NeSSIE report on the non-technological challenges [9].

Other hotspots are open sea test centres. The location of the demonstration projects is heavily influenced by the availability of open sea test centres for pre-commercial devices. Where there is a preference for supply chains in close proximity to the demonstration site, in the case of strong transport infrastructure near testing centres, a case can be made to source wider EU NeSSIE demonstration supply chain partners from outside of the test centres regions. However, in a pre-commercial cost competitive project environments, the use of distant supply chains would need to be convincing and not purely involve economics for short-term demonstrations. At a longer timeframe, sustainable wider EU supply chains feeding into North Sea basin offshore renewables projects is a realistic and achievable outlook.

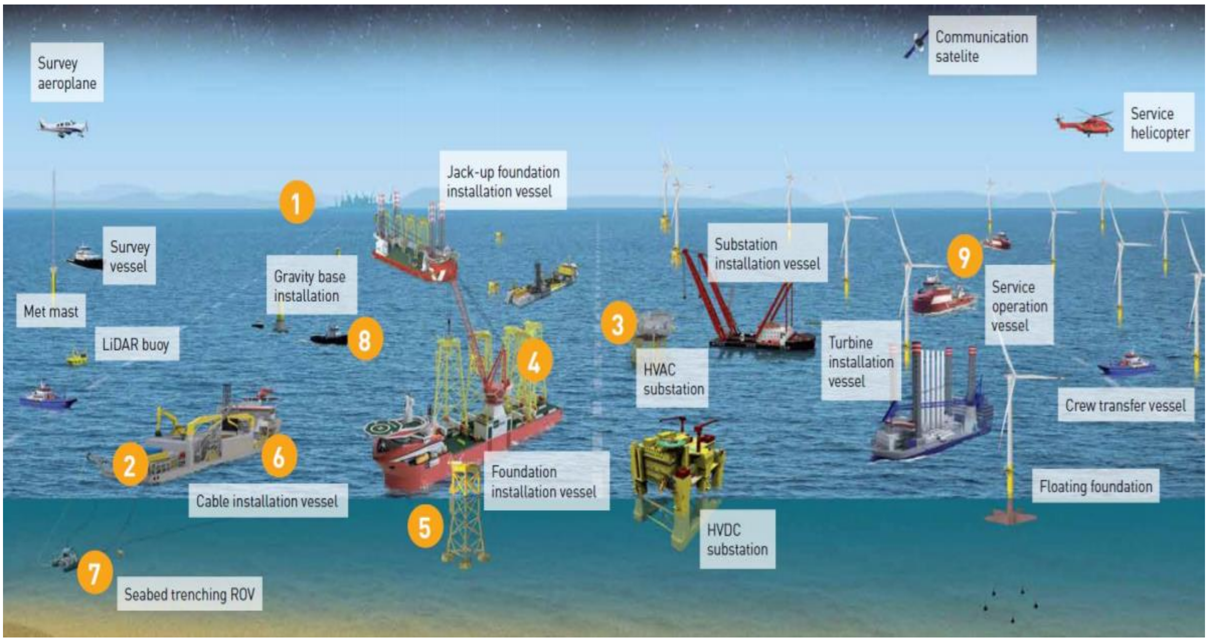



*Figure 11 – Oil and gas, and offshore wind sector synergies [22]*

## 3.5 Regulation observations

To ensure a smooth development process, a clear regulatory path is required. The regulatory challenges identified in the NeSSIE report on the non-technical challenges [9] have a connection in that they often refer to uncertainties associated with the offshore sector. Key uncertainties have been identified in consenting and licensing, and environmental impact. The observations are therefore focussed on reducing these uncertainties (Figure 12).

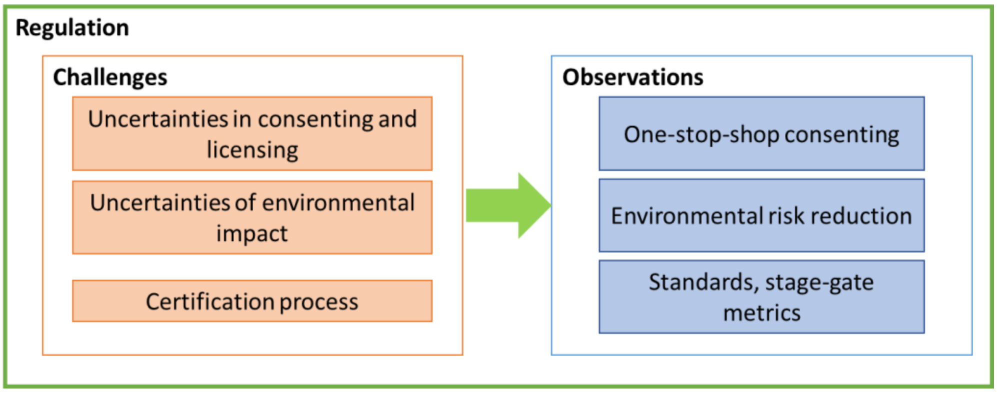



*Figure 12 – Regulation challenges and observations*

### 3.5.1 One-stop-shop consenting

Developers of marine renewable energy technologies have indicated a one-stop-shop framework as ‘the most desirable consenting process’ [23]. This framework refers to having one sole contact point for all necessary licences, therefore simplifying the consenting process. Consenting approaches such as for marine energy in the UK [24] and the tender process for wind energy in the Netherlands [25] can be taken as examples and are recommended to be implemented for marine energy in the North Sea basin countries. NeSSIE can take advantage of these existing processes.

#### *3.5.2 Environmental uncertainty reduction*

Environmental Impact Assessments are performed to investigate the impact of renewable energy projects. With the deployment of marine energy projects being at a preliminary stage and therefore relatively short periods in the water, the (long-term) environmental effects need to be investigated further. The assessments are currently done based on the ‘best available’ scientific knowledge [26]. This high uncertainty of the effects of deployment on the marine environment means a high risk is associated with implementation. It is of importance to gather as much information of the environmental impact before, during and after the deployment of the demonstration projects to reduce the uncertainties existing in this field. Monitoring services are of great value here. As monitoring is also of great importance to corrosion issues, this is of interest to NeSSIE. In addition, the environmental impact of ACSs and materials need to be taken into account, monitored and assessed.

#### *3.5.3 Standards, stage-gate metrics and certification*

The state of the art study of ACSs by NeSSIE [7] also provides a survey of the main standards and guidelines reported in order to collect references for all of the materials and procedures that are currently used in offshore systems. These standards and guidelines are currently commonly used in other sectors such as oil and gas. Offshore renewable energy generation sectors such as wind and marine will have different requirements in terms of standards and guidelines. Standards for the offshore renewables sector are not complete; especially those regarding ACS are not yet well defined, as they still in the early stages of development.

Standards and certification of processes and technologies ensure reliability of a product or service. The assessment, monitoring and comparison of developing technologies can assist in reducing the risk of deployment and therefore increase investor confidence. However, it is of importance to avoid developing and implementing unrealistic demands. Stage-gate metrics can play an important role for demonstration projects as they focus on the different stages towards commercialisation. To be able to tackle the corrosion issue, it needs to be taken into account at an early design stage. Integrating corrosion aspects in the stage-gate metrics would ensure that corrosion is incorporated in a holistic design approach.

# 4 ACS Challenges

The aim of NeSSIE is to deliver high-value manufacturing opportunities to the North Sea basin and wider EU ACS supply chains. To achieve this aim the current challenges that occur with the existing ACSs need to be addressed. Therefore, these ACS challenges are identified and assessed as to which challenges need to be tackled first to ensure industry roll-out through a prioritisation exercise. This is part of the path forward or route of the roadmap, as shown in Figure 13. This section discusses the challenges identified, the prioritisation method, the validation of this method and the potential solutions for these challenges.

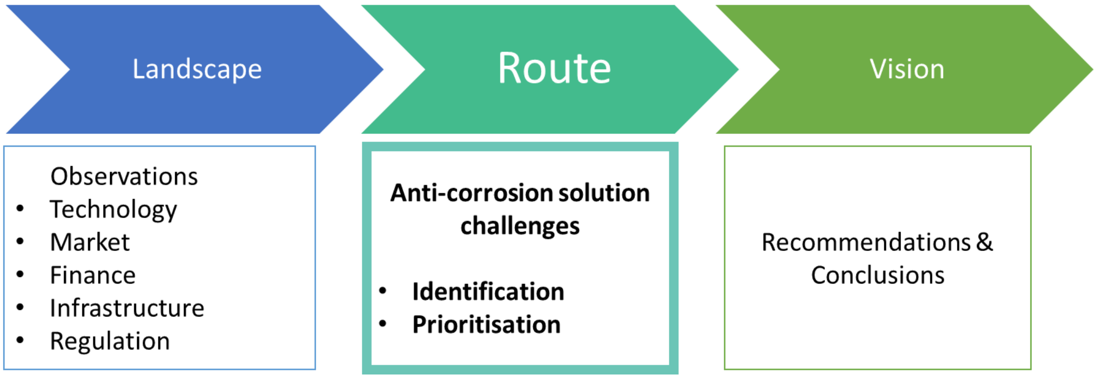



*Figure 13 – NeSSIE Roadmap Structure: Route*

## 4.1 *Identification of key ACS challenges*

Through surveys and interviews with the industry, mainly ORE developers, the challenges associated with ACS have been identified. These challenges were categorized in eight key challenges, which are presented in Table 2 and summarised in the following sub-sections. It should be noted that the initial challenge identification is mainly based on the experience of offshore wind farm developers.

| Key Challenges | Examples |
|---|---|
| Cathodic protection | Hydrogen embrittlement, cathodic disbondment |
| Experience and unknowns | Regulation, knowledge transfer between sectors, corrosion below the mudline after installation |
| Novel product risk | Consolodation of the market, variance in test data/reliability tests |
| Design | Unable to protect/coat certain designs, material selection, use of high strength construction steels |
| Quality control | Unrealistic demands, inspection criteria and procedure not well defined |
| Preparation and applying coatings | Preparation of surface to get required roughness bring difficulties: not all areas can be blasted, thicker paint layer more susceptible to cracking (welds/corners) |
| Maintenance difficulties and repairs | Locations that are more susceptible to damage (boat landing, flanges, edges and corners), weather windows, application conditions (wet surfaces, temperatures too low) |
| Inspection | Costly, undiscovered damage |

*Table 2 – Key ACS challenges*

#### *4.1.1 Cathodic Protection*

Cathodic protection (CP) is not able to protect the structure against the corrosion reaction when the current is too low to be sufficient, referred to as under-protection. On the other hand, over-protection can also be an issue with CP; this occurs when the anode generates more current than necessary to protect the metal from corrosion and can result in different problems such as hydrogen embrittlement and cathodic disbondment.

Hydrogen embrittlement can occur when hydrogen is built up, leading to fracturing of the metal. In cases of over-protection and a damaged coating, as CP is often the secondary protection system, cathodic disbondment is a phenomenon that can occur. The adhesion between the anti-corrosion coating and the structure is destructed.

#### *4.1.2 Experience and unknowns*

Due to the relative lack of knowledge in certain areas of the ORE sector, some R&D areas need further investigation to establish the impact of corrosion. An example is the rate of corrosion below the seabed, the so-called mud line, about which very little is known. The assumption is made that microbiologically induced corrosion (MIC) occurs in the first meter below the seabed, and that no corrosion occurs further down than 1m. Research towards MIC is another topic of interest.

Another topic that requires further research is the effect of pile driving, on fixed offshore wind structures, and specifically on the coatings. In addition, the deployment of novel materials in the harsh environment and the long-term effects as well as the interaction between different materials are topic areas that require further research.

#### *4.1.3 Novel product risk*

The development of new products comes with uncertainties and therefore risks. Test-plates, often referred to as coupons, installed on marine devices to measure corrosion do not properly represent the structure itself. The coupons are not always electrically connected, or with the same potential, and have different spatial properties to the structure such as thickness, edges and shape. These coupons are more susceptible to corrosion than existing offshore structures due to the potential of cracking or delamination of anti-corrosion coating at these locations. In addition, coupons located at different locations within a single wind farm park display large variations in corrosion. This proves difficult for the track record of a solution. The lack of track record and name recognition of novel solutions is perceived as risky, as cost of failure is high.

Additionally, consolidation of the mature market is perceived as a main risk for novel products. Customers are rarely willing to pay premium price for a custom-engineered product, as they are competing with low-cost solutions. This can reduce the potential of a new product to roll-out, for example for a new paint or novel material.

#### *4.1.4 Design*

The design of a device should take into account the corrosion protection method in the early design stages, whether by investigating non-corrosive materials (such as composites) or considering the requirements for ACS applications (for example with coatings).

In the case of coatings, the structure needs to fulfil certain requirements. An example of such a requirement would be that the whole structure should be able to be painted, as often the paint cannot be applied in all angles or holes due to the inability of the paint systems to be put in certain positions.

Other issues with design have occurred with material selection, for example in the case of bolts. If the bolts are made of a more reactive metal (meaning with a lower atomic number, therefore being less noble) than the structure, the contact between these metals can result in galvanic corrosion, where the bolts act as the sacrificial anode and corrode more rapidly.

In addition, in some cases the need for maintenance and inspection has not been considered at the design stage, complicating the execution and increasing the related costs.

#### *4.1.5 Quality Control*

Certification is required to ensure the quality of a product or service. Therefore, it is of importance to ACS as bad workmanship can significantly affect the performance of the ACS and drive up cost. A lack of quality control during fabrication has been a source of corrosion, leading to significant costs during project execution and operation.

However, the certification process of ACS, specifically for the coating process, comes with difficulties due to unrealistic demands of the standards. Currently, the control process is perceived to have a 'spot check' approach rather than a holistic system check.

Another example of standards being misrepresented in practice can be found with the preparation process for coatings. Certain materials, such as stainless steel, cannot be blasted with the same iron grit as the rest of the structure. However, practice has shown that, in certain cases, blasting stainless steel with iron grit followed by adequate coating gives very good results. However, as this is a deviation from the standards, it is not allowed. Such examples of deviations from standards resulting in important cost reductions, without apparent loss of performance, should be further validated and after a positive evaluation, taken up in standards.

In some cases, standards are inexplicit. An example is the specification of weld seams to be 'smooth', however a clear measurable definition of smooth is absent. Another example is the requirement of reworking small defects to comply with the requirement for 'no paint defects', which can result in a high cost and a lower effectiveness of the coating.

#### *4.1.6 Preparation and application of coatings*

The preparation and application of coatings are extensive procedures and this complexity comes with various challenges.

The surface of a structure needs to be of a certain roughness to ensure adequate adhesion of the coating. However, different types of steel in the same structure need different types of blasting preparations, which increases the complexity of the process and therefore the chances of defects.

Typical coating systems consist of three paint layers, leading to high labour costs. Specific locations, such as welds, corners and edges, need to be manually applied with a brush to ensure coverage, yet this can lead to a too high thickness layer, resulting in the necessity of reworking. The coating system thickness should not be too high to avoid cracking or delamination (for example with zinc rich coatings).

Another problem with the application of paints occurs with solvent free paints, as they cannot be applied with a brush due to their high viscosity. The spray application system for these paints can become quite heavy, bringing difficulties for the applier.

#### *4.1.7 Maintenance difficulties and coating repairs*

In general, the high cost of maintenance in offshore facilities is seen as a key challenge to the sector. Maintenance with regard to corrosion prevention is often related to the damage of anti-corrosion coatings. This damage can occur during use of the device, when vibrations and forces cause slight displacements. For offshore wind, this damage to coatings is often found between the flanges, resulting in corrosion.

In addition, offshore wind maintenance vessels need to land on the (secondary) structure. The friction that occurs with these boat landings damages the coatings, requiring repair. Repairing the coatings offshore, similar to preparing and applying coatings on land, is labour and time intensive, and therefore a costly activity. Due to the offshore environment, the need for the right weather conditions can prolong the process. If, due to weather conditions, there is too much time between applying coating layers, cleaning of the surface needs to be repeated to clear salt deposits.

Finally, the quality of the repaired coatings is often found to be lower than that of the original coating, resulting in more frequent repair following the initial repair process.

#### *4.1.8 Inspection*

The inspection of the installed devices is a costly activity. High costs are related to the deployment of manual labour/workforce and the deployment of maritime vessels, with high dependence on weather windows and availability of the inspection vessels.

There have been instances where corrosion damage has gone unnoticed. An example of unnoticed damage occurred with polyurea coatings, which have high strength and flexibility characteristics. Corrosion of the metal structure had occurred beneath the coating, leaving a shell of coating without any structural strength.

### *4.2 Prioritisation method*

The prioritisation exercise for NeSSIE is based on the prioritisation method used in the Marine Energy Technology Roadmap by the Energy Technologies Institute (ETI) and the UK Energy Research Centre (UKERC) in 2014 [27].

A set of criteria has been created which can be divided in two categories, namely 'Sector needs' and 'NeSSIE fit'. The criteria are valued with an importance factor between 1 and 10 based on the NeSSIE partner's experience. The importance factor gives a weight to a criterion, indicating the importance that a challenge fulfils that criterion. Each challenge is then given a score for each of the criteria, being low, medium or high. This indicates the potential impact that solution of the challenge can have on the criterion. The impact of a challenge on each assessment criterion is then translated to a value of 1 to 3, from low to high respectively. The final score of a challenge is established by multiplying the impact of each criterion by the importance factor of these criteria, and normalising the sum of all criteria within that challenge to 100.

### 4.2.1 Criteria

The assessment criteria for the prioritisation exercise are shown in Table 3. The importance factor, as described in the previous section, is indicated in the Appendix.

In addition to these criteria, the timeframe and location of potential solutions are of importance within NeSSIE. The project is focussed on delivering three investable projects in the North Sea basin by its end, namely May 2019. This means that the requirements of 'Time' and 'Location' are criteria for the selection for the demonstration project.

| Assessment Criterion | Description |
|---|---|
| Sector urgency | Is rapid development a priority to the sector development? Does it solve a common problem? |
| Impact on cost reduction CAPEX | What is the CAPEX cost reduction potential? |
| Impact on cost reduction OPEX | What is the OPEX cost reduction potential? |
| Impact (technical) risk reduction | How much would a solution to this challenge contribute to the risk reduction of ocean renewable energy projects? |
| Impact demonstration project on the sector development | How much would demonstration projects contribute to the sector development? |
| Ambition and innovation content | To what extent is the solution to this challenge an innovative technology/method? |
| Future market deployment | Does a solution to this challenge have a deployment potential (within Europe/globally)? |
| Sustainability; value to economy, environment, social factors | Does a solution to this challenge have additional value? For example to the economy, environment and/or social factors such as job creation. |
| Cross-sector transferability | How readily adaptable is a solution to this challenge to the sector? Would this solve other problem (in other sectors?) |

| | |
|---|---|
| (yellow) | Sector needs |
| (blue) | NeSSIE fit |

*Table 3 – Assessment criteria*

### 4.2.2 Classification

Based on this priority assessment, as explained under the prioritisation method, the priority challenges within NeSSIE have been identified and are shown in Figure 14 and Table 4. The prioritisation has resulted in three challenges categorised as Priority A. These are the top three challenges for NeSSIE to focus on, as they have shown to have the highest combination of sector need and NeSSIE fit, are the 'Preparation and application of coatings', 'Maintenance difficulties and coating repairs', and 'Inspection' challenges.

It is important to note that this does not mean that the challenges with Priority category B are not important for the application of ACSs in the development of the ORE sector. Moreover, this is most likely an indication that the challenge is less in alignment with the NeSSIE objectives. In addition, some of the challenges identified as Priority B will still arise within the Priority A topics. Solutions that will be investigated through NeSSIE will most likely encompass a combination of these challenges. An example would be that a novel single coating solution will address the 'Preparation and application of coatings', and the 'Maintenance difficulties and coating repairs' challenges, but will also encounter aspects of the 'Novel product risk' challenge.

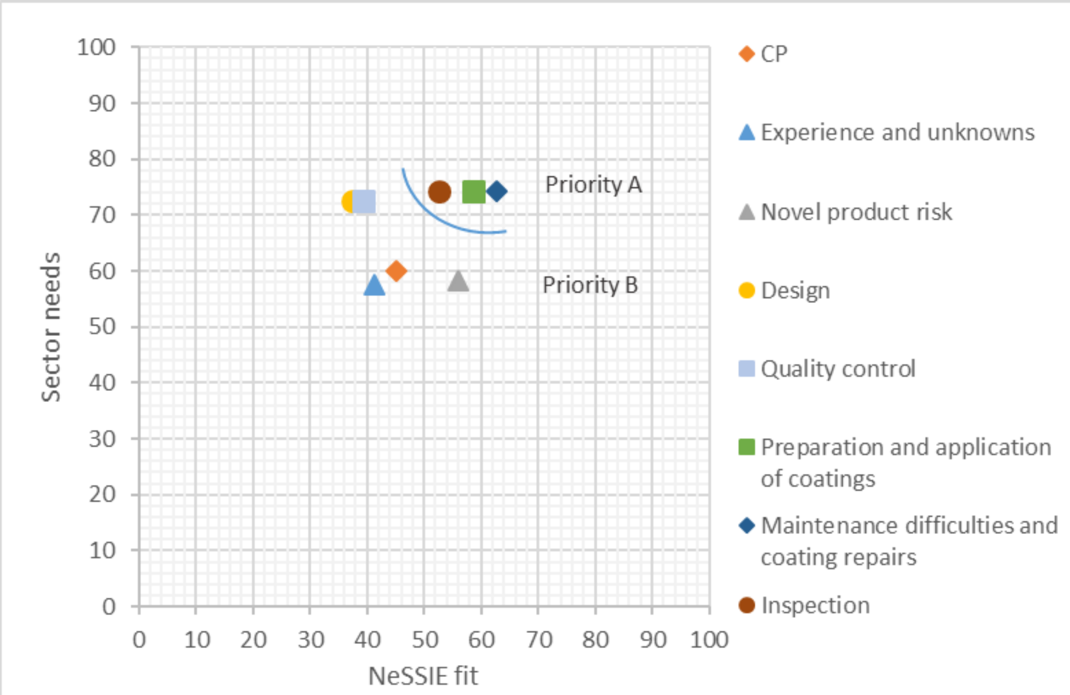



*Figure 14 – Prioritisation of the identified key challenges based on 'Sector needs' and 'NeSSIE fit' criteria.*

| NeSSIE Priority | Challenge |
|---|---|
| A | Preparation and application of coatings |
| | Maintenance difficulties and coating repairs |
| | Inspection |
| B | Quality Control |
| | Novel Product Risk |
| | Cathodic Protection |
| | Design |
| | Experience and unknowns |

*Table 4 – Challenge priority categories*

Another important point to consider with this prioritisation is that evidently the challenges that are currently encountered most in the sector are perceived to have a high priority. However challenges that are categorised having the lowest priority, namely 'Design' and 'Experience and unknowns', could be perceived of less relevance as the true effect of challenges in these key challenges is unknown, or even certain challenges in these categories are not encountered yet and therefore not perceived as a challenge.

As mentioned, the challenges that are not in the highest priority might not become the main focus of the demonstration projects, yet aspects of these challenges will be encountered when tackling the highest priority challenges. In addition, these challenges will be included in the recommendations to ensure an extensive approach to reduce corrosion issues in the ORE sector.

## *4.3 Validation*

The identified challenges and the prioritisation have been validated through feedback from the NeSSIE partners internally, and through communication with companies active in the offshore renewable, oil and gas, and corrosion sectors by means of a workshop around the challenges in the offshore renewable energy sector and potential for knowledge sharing between the different sectors.

The identified challenges and prioritisation were presented at a cross-sector interdisciplinary workshop intended to promote collaboration between ORE and existing offshore sectors such as oil and gas. This was intended to provide additional context to the work, gaining new perspectives and expertise and filling in key knowledge gaps.

The feedback from project partners, the NeSSIE industry working group and the attendees of the cross-sector disciplinary workshop are included in the discussion and recommendations in the following sections.

## *4.4 Examples of solutions to the ACS challenges*

Within project NeSSIE, solutions for these identified challenges will be investigated. As mentioned before, there will be a focus on identifying solutions for the challenges classified in category A. However, the solutions will most likely encompass several of the identified challenges.

| Key Challenges | Potential Solutions |
|---|---|
| Preparation and Application of coatings | Coatings tolerant to low surface roughness, single layer coating system |
| Maintenance difficulties and coating repairs | ACS for locations with high risk of damage (boat landing/chains), single layer coating system |
| Inspection | Drones, unmanned vehicles (UVs) |
| Quality control | Adjustment of standards through feedback from industry, industry representation in stardard development, experience and extensive training programmes for certifiers |
| Cathodic protection | Novel survey/monitoring services, introduce materials that decelerate cathodic process |
| Novel product risk | EU/Government support for research and demonstration projects |
| Design | corrosion issues taken into account throughout the whole design process |
| Experience and unknowns | Training programmes, research/testing |

*Table 5 – Potential solutions of the identified key ACS challenges*

# 5 Recommendations

As the main challenges encountered with ACSs related to ORE deployment have been identified, including the highest priority challenges based on the sector needs and the relevance to NeSSIE, this chapter will follow up on this analysis by introducing the steps forward, providing recommendations for key stakeholders and discussing the landscape observations which the NeSSIE project will address (Figure 15).

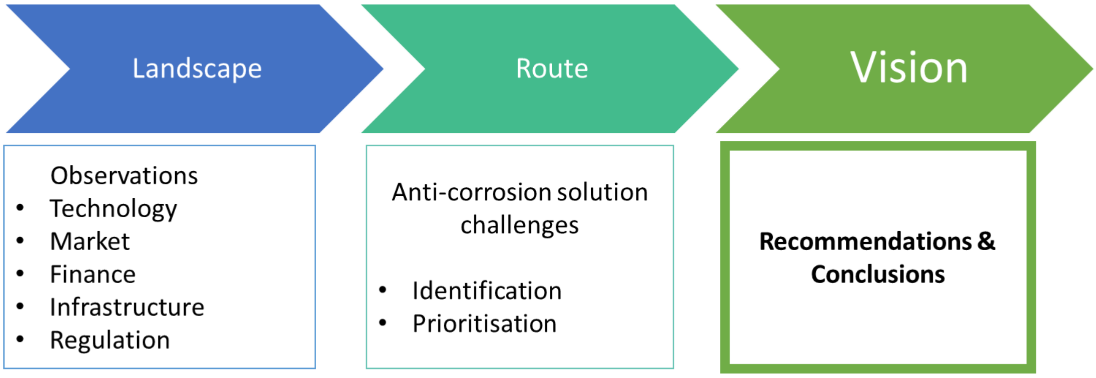



*Figure 15 – NeSSIE Roadmap Structure: Vision*

NeSSIE seeks to build strong value chains within the EU, supporting the ORE sector to progress towards commercialisation. Considering the timeline presented in Figure 16 in which the different ORE technology development stages are shown, NeSSIE will assist in the development of the ORE sector by focussing on the issues relating to corrosion for the roll-out of offshore renewables.

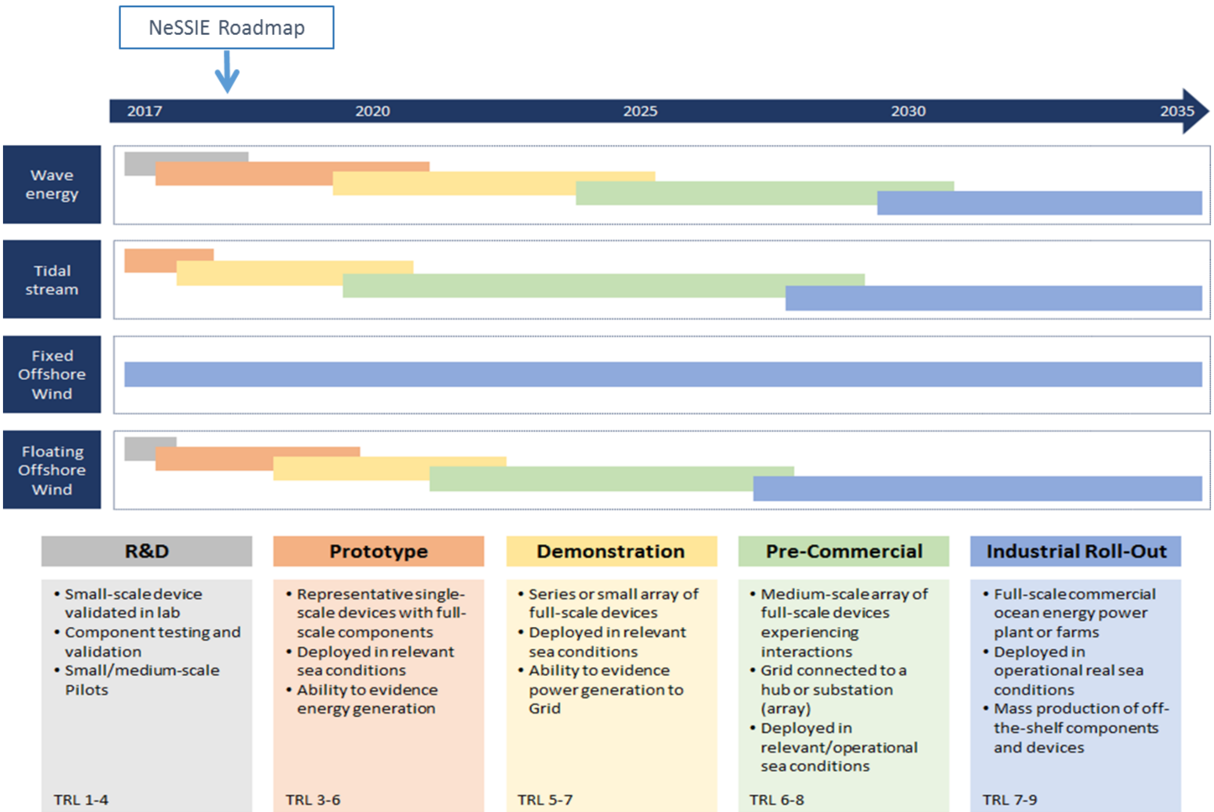



*Figure 16 – ORE development timeline and NeSSIE project timeline*

## 5.1 Landscape recommendations

Considering the landscape categories as investigated in the NeSSIE report on the non-technical challenges [9] and the further analysis in this roadmap, it is now possible to form guidance on the optimal criteria required for short-term demonstration projects and long-term supply chain developments on which NeSSIE is focussed.

### 5.1.1 Technology observations

Regarding the technology aspects of ACS within ORE development, NeSSIE demonstration projects can provide:

- Opportunities for testing of ACSs and novel materials within the demonstration projects to tackle the corrosion issue in the ORE sector, investigate improved solutions and support their path to the market.

### 5.1.2 Market observations

Development of new and improved ACSs as well as services and their application could decrease the initial CAPEX, improve the device performance, reduce the risk of critical failure and improve the reliability and operability by reducing maintenance downtime. With the investigation of ACSs and the assistance in developing demonstration projects, NeSSIE can indicate and support:

- Diversification opportunities for the established sectors to the ORE sectors, as well as investigating novel solutions that are beneficial to all sectors;
- Cross-sector knowledge transfer: the interaction among the different sectors is critical to encourage diversification, to create awareness of the existing ACSs in the developing ORE sectors and to identify necessary adjustments for ACSs between the sectors.

### 5.1.3 Finance mechanism observations

Due to the early stage of development and the associated uncertainties, wave and tidal energy projects come with high risks. This results in difficulties with reaching the required investment for such projects. Fixed offshore wind has progressed to the commercial stage, building capacity to achieve the targets set for carbon reductions and renewable energy within the EU.

Regarding financial aspects of ORE development, NeSSIE demonstration projects can fulfil the following roles and should consider the following:

- Demonstration projects can play a role in reducing the perceived risks by indicating the performance of technologies. Consider project collaborations to increase the efficiency and impact of the project outcome of the capital intensive demonstration projects;
- Upfront capital is of great importance for the demonstration projects, public funding options are the main option due to the high risks.

### 5.1.4 Infrastructure observations

Regarding hard and soft infrastructure required for the development of ORE demonstration projects, the following aspects are of importance to NeSSIE:

- MSPs give a good insight in the potential locations for demonstration projects;
- Demonstration projects would profit from industrial ‘hotspot’ locations, i.e. ports and test centres, for optimal offshore logistics and manufacturing expertise diversification. Training programmes to ensure skilled personnel can be located at these locations as well;

- Standards, stage-gate metrics and certification can reduce the risks of demonstration projects by ensuring reliability of a process and/or product. Unrealistic demands should be avoided.

#### *5.1.5 Regulation observations*

Within the EU, regulations are all encompassing. With many procedures in place, the consenting and licensing can be difficult. NeSSIE can contribute to a better experience of developing ORE projects, if it addresses the following points:

- A one-stop-shop licensing framework for marine energy deployment is valuable to the development of projects, and is therefore recommended;
- Reducing the uncertainty of the environmental impact of ORE is of importance to the development of projects, monitoring on demonstration projects plays a significant role in this.

#### *5.1.6 Anti-corrosion solution observations*

NeSSIE has provided an overview of the challenges that are currently being encountered in the ORE sector with existing ACSs. The prioritisation based on criteria that indicate the sector needs as well as the relevance to NeSSIE, identifies the issues to focus on within the NeSSIE project:

- Preparation and applying coatings;
- Maintenance difficulties and repairing coatings;
- Inspection.

Wherever possible, these and the other identified main challenges have been included in the recommendations to the stakeholders.

### *5.2 Stakeholder recommendations*

The stakeholders of the value chains relevant in the NeSSIE project, as shown in Figure 17, have previously been identified in the economic opportunity report [8]. The relevant stakeholders with the application of ACSs in the ORE sector are considered are policy makers/regulatory bodies, value chains/OEMs, technology/device developers, research institutions, testing facilities and certification bodies.

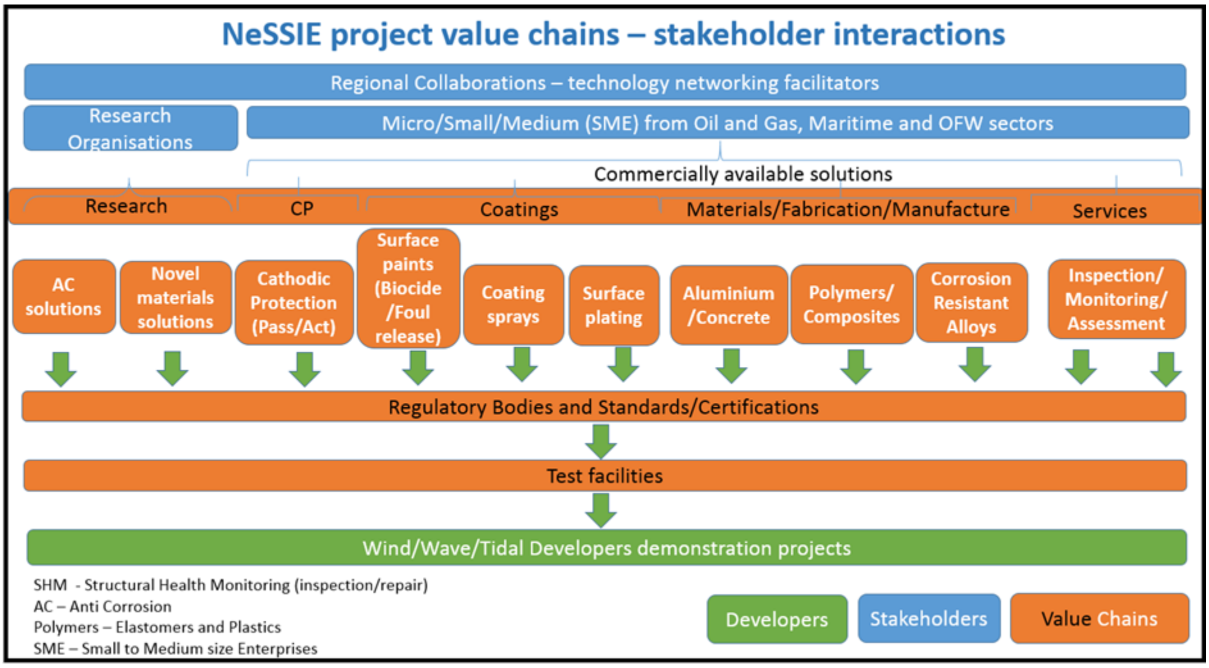



*Figure 17 – NeSSIE project value chains and stakeholder interactions*

This section will provide the recommendations for the relevant stakeholders. The recommendations were formed based on the landscape status, the identified challenges, internal feedback from the partners and feedback from industry. A close collaboration between the different stakeholders is of importance to ensure the implementation of these recommendations. Figure 18 provides an overview of the set of NeSSIE recommendations and the stakeholders that are involved in the implementation of these recommendations.

### *5.2.1 Policy makers/Regulatory bodies*

The NeSSIE report on economic assessment of the opportunity of the application of improved corrosion solutions in the ORE sector shows the potential value to offshore renewable developers and the ACS providers with the industrial roll-out of ORE [8]. It was found that in tackling corrosion with the use of ACS ORE developers could save up to €84bn and that the European ACS supply chain could gain up to €82bn by 2050. This also provides an indication that the further development of these sectors creates value to the economy. To be able to achieve this potential value, the support of policy makers is key.

As identified in the status overview, for the roll-out of offshore renewables the policy makers need to facilitate the one-stop-shop consenting, the development of Marine Spatial Plans and coordinate funding throughout the path towards commercialisation. The latter should focus on providing funding programmes for developers to make use of for testing at the testing facilities, which is of direct importance to NeSSIE, as well as on supporting the complete path towards commercialisation. Start-stop financing and the lack of funding after demonstration projects should be avoided to survive the 'valley of death' in the development of novel products.

### *5.2.2 Value Chains/Original Equipment Manufacturers (OEMs)*

A key aim of the NeSSIE project is the facilitation of knowledge transfer between the different marine sectors to build on prior experience and encourage the application of best-practise. In the research process of NeSSIE it was determined that there is a need for clear communication of the existing challenges in the ORE sector and the steps forward in the development of the sector. This can be used to connect with existing established marine sectors, as this provides diversification opportunities in these sectors. In addition, knowledge transfer should extend further than the marine sectors; for example, applications to protect materials could potentially be taken from the aerospace sector.

It should be noted that a simple copy of ACS best practise in one sector might not automatically be suitable for application in the ORE sector due to some substantial differences in deployment conditions, such as the highly aerated water conditions of tidal and wave resource locations and the moving components. By creating opportunities where ORE developers and solution providers are made aware of the existing challenges and solutions, the transfer areas can be identified.

### *5.2.3 Technology/Device Developers*

Developers of offshore renewables structures should be aware of corrosion and should take it into account at early design stages. The NeSSIE economic opportunity assessment [8] found a potential significant cost saving for technology savings with the application of improved ACSs and novel materials in the ORE sector.

The lack of including ACS in the design stage was identified as a key issue potentially causing a great deal of additional expense to developers throughout the ORE project. Corrosion issues can be mitigated or even avoided if technology developers incorporate this in the design process. An example would be to include a simulation of corrosion in complex geometries to determine the corrosion in the potential ORE structures at the design stage. Sharing information and collaboration in data capturing can play an important role in avoiding repeating mistakes and accelerated ORE deployment.

#### *5.2.4 Research Institutions*

Considering ORE, there are various different areas where research is required to obtain additional knowledge with regards to corrosion in the offshore environment. Experience and unknowns was one of the identified key challenges in Section 4, referring to the need for continued research in certain areas. These include the impact of corrosion below the mudline, microbiologically induced corrosion, impacts of pile driving on coatings and the site specific impacts on ORE corrosion such as temperature, location, salinity depth and light exposure. Research institutions can play a key role here in supporting technology development.

#### *5.2.5 Test facilities*

The work done at testing facilities is of key importance in the progress towards commercialisation, specifically for the wave and tidal energy technologies. These 'hotspots', both in terms of facilities and experience, form a fundamental and encouraging starting ground for growth. Moving forward, longer term operational testing is required to investigate the impact of corrosion on ORE structures, particularly wave and tidal generation as very little long term testing has been undertaken on such devices. It is expected that corrosion could impact wave and tidal devices in the long term in a very different way to existing offshore structures, as marine energy devices operate with submerged moving parts in a more heavily aerated environment within the tidal stream and the splash zone.

#### *5.2.6 Certification bodies*

Challenges within the quality control process were also categorized as a key challenge in Section 4. Within the NeSSIE prioritisation process, this challenge was not classified with the highest priority. This can be attributed to the aim of NeSSIE, to identify and develop demonstration projects, and the relative low impact those will have on the certification process. To reduce risk of the application of ACSs in the ORE sector, standards, specifically for the offshore wind, wave and tidal energy technologies, need to be developed.

Due to the early stage development of wave and tidal energy, stage-gate metrics have been introduced. To ensure corrosion issues are taken into account at an early stage and therefore mitigated, corrosion could be integrated in these stage-gate metrics.

Quality control forms a guidance to developers, ensuring the quality of a product, therefore standards and stage-gate metrics can increase the awareness of the developers on the subject of corrosion.

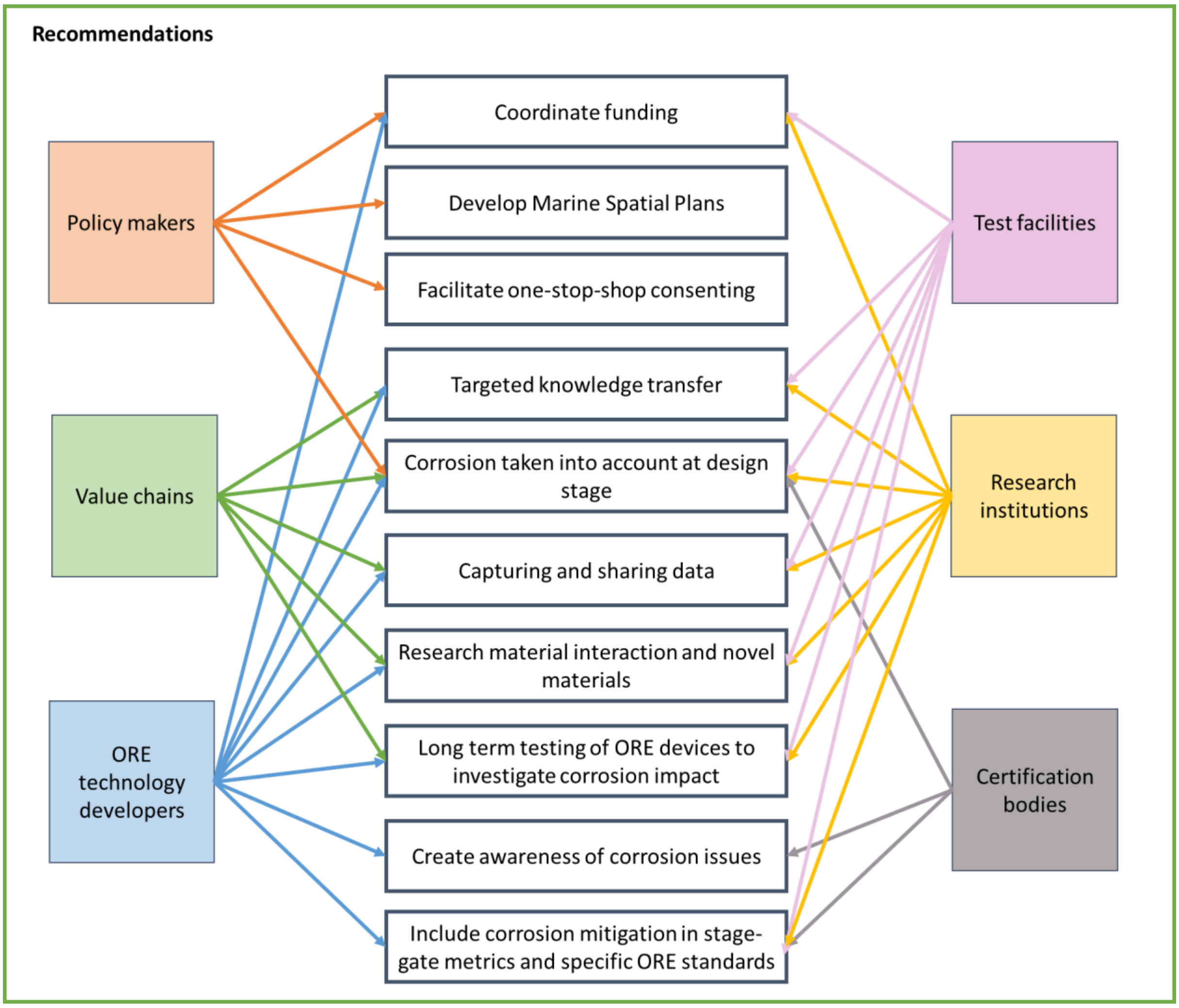



*Figure 18 – Stakeholder recommendations*

# 6 Conclusions

The NeSSIE project aims to deliver high-value manufacturing opportunities to the North Sea basin and wider EU supply chain of Anti-Corrosion Solutions (ACSs), aiding the Offshore Renewable Energy (ORE) sector goal to reduce cost of ocean energy. This roadmap is built on the research undertaken within the preliminary stages of the NeSSIE project, outlining the observations of the current landscape of applying ACS in the ORE sector with regards to the technology, market, finance, infrastructure and regulation already in place. From this existing landscape, key challenges have been identified which could have a decelerating impact on the commercialisation of ACS within the ORE sector. These challenges are 'Preparation and application of coatings', 'Maintenance difficulties and coating repairs', 'Inspection', 'Quality control', 'Novel product risk', 'Cathodic Protection challenges', 'Design' and 'Experience and unknowns'.

A prioritisation process in terms of the 'Sector needs' and the 'NeSSIE project aims' identified the key challenges to focus within NeSSIE. The results of the NeSSIE prioritisation of the identified ACS challenges reflect the existing issues with corrosion, namely with the problems of the established ACS procedures, which are mainly related to the protective coatings. Potential solutions to the identified challenges will most likely address multiple of these key challenges.

Based on the current landscape and the identified challenges, a set of recommendations to various key stakeholders has been produced. The potential impact of the NeSSIE project on the current landscape of ACS technology, market, finance, infrastructure and regulation is also discussed. These recommendations are a key output of this work.

A key conclusion to draw would be that due to the relatively new ORE sector; there is still a great deal of scope for innovation and cross-sector knowledge sharing of ACSs between the established and ORE sectors. The wave and tidal sectors in particular present many new challenges as these devices will not experience corrosion in the same way as existing offshore structures. This is due to the submerged moving parts specific to these technologies and the aerated environment of the splash zone and tidal stream. It is of key importance that corrosion issues is taken into account at an early design stage. As ORE technologies are still very much in the early stages of development, little is known about the long-term impacts of the ocean environment on the corrosion rates. The transfer of knowledge and lessons learned from sectors with experience in ACSs such as oil and gas, maritime, fishing, defence and aeronautics could greatly assist with the reduction of costs in the path to commercialisation of ORE technologies. In addition to building on existing knowledge and experience, novel solutions to tackle corrosion issues should be investigated to embrace the differences and therefore assist the ORE sector in their path towards commercialisation.

Through generating corrosion issue awareness, providing connections between different sectors, and assisting in the development of demonstration projects, NeSSIE will encourage the development of ORE with the application of ACS and novel materials to tackle corrosion to reduce the cost of energy and move towards commercialisation.

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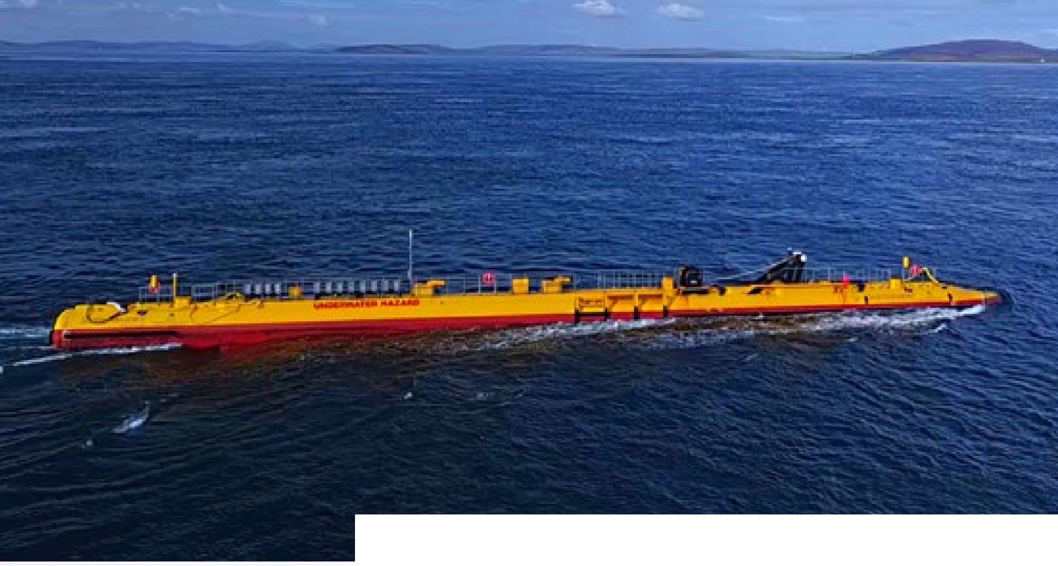
# 8 Appendix

| Assessment Criterion | Importance (1-10) |
|---|---|
| Sector urgency | 9 |
| Impact on cost reduction CAPEX | 8 |
| Impact on cost reduction OPEX | 10 |
| Imact (technical) risk reduction | 8 |
| Impact demonstration project on the sector development | 8 |
| Ambition and innovation content | 6 |
| Future market deployment | 8 |
| Sustainability; value to economy, environment, social factors | 5 |
| Cross-sector transferability | 5 |



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