Cross-sector Knowledge Transfer

North Sea Solutions for Innovation in Corrosion for Energy

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

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1. Acronyms

ACS	Anti-Corrosion Solution
AREG	Aberdeen Renewable Energy Group
CORE	Centre for Offshore Renewable Energy
CP	Cathodic Protection
EOWDC	European Offshore Wind Deployment Centre
LCoE	Levelised Cost of Electricity
MESG	Marine Energy Supply Chain Gateway
MLP	Multi-Level Perspective
NACE	National Association of Corrosion Engineers
NREAP	National Renewable Energy Action Plan
ORE	Offshore Renewable Energy
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturers
OPEX	Operating Expenditure
SE	Scottish Enterprise
SHM	Structural Health Monitoring
SME	Small to Medium size Enterprise
TEC	Tidal Energy Converter
WEC	Wave Energy converter
WES	Wave Energy Scotland
WP	Work Package

2. Executive Summary

Knowledge sharing and collaboration have been identified as important factors in the development of the offshore renewable energy (ORE) sector. Therefore, for the supply chain development of anti-corrosion solutions (ACSs) in the ORE sector, sharing and applying expertise of other sectors is seen as of importance to the market development.

There have been examples of companies transferring their knowledge to ORE projects. This occurs in a wide range of topics from manufacturing of steel structures to project management. In the case of corrosion protection in the offshore environment, best practise of corrosion control; a framework for corrosion management; and the application of standards have been identified as general corrosion mitigation processes in other industries to be useful for application in the ORE sector.

This report also indicates some examples of instruments that can encourage cross-sector knowledge transfer. These include diversification initiatives, for example through organisation networks; communication and dissemination, through webinars, workshops, conferences, LinkedIn etc.; and collaborations and consortia, such as NeSSIE.

For technologies to develop and achieve their market potential, a supportive environment needs to be established. The conditions to create such an environment are discussed in this report. To encourage knowledge transfer, NeSSIE has identified three stages based on this study and previous NeSSIE research, where NeSSIE can play a role. Firstly, creating awareness of the challenges and areas for improvement, indicating the market potential; within NeSSIE, it is important to ensure awareness of the corrosion issues and challenges of the existing ACSs. Secondly, connecting different partners. Thirdly, collaborating is essential, where expertise of different companies/organisations/regions is exchanged and applied to promote a developing market. The NeSSIE demonstration projects are good opportunities to demonstrate this.

3. Introduction

The aim of the NeSSIE project is to identify and support the development of offshore renewable energy (ORE) demonstration projects related to corrosion issues. This is done to accelerate the deployment and cost reduction of ORE. By supporting the development of ORE in the North Sea Basin, NeSSIE will support the economy in this region. A recent study by ORE Catapult showed the potential benefits in terms of the gross value added, job opportunities and carbon emission reductions of tidal and wave energy deployment in the UK [1].

Going specifically into the corrosion aspect, the NeSSIE report on the economic assessment [2] indicates a supply chain opportunity of €82bn by 2050 across Europe for the wave, tidal and offshore wind sectors. To be able to fulfil these predictions, wave, tidal and floating offshore wind energy need to mature from their current early development stage to commercial status.

Earlier studies, such as the European Technology and Innovation Platform on Ocean Energy (ETIP Ocean) [3] and in the 'Study on Lessons for Ocean Energy Development' by the Joint Research Centre (JRC) [4], identified knowledge sharing and collaboration as key points to move ORE towards commercialisation. The development of the ORE sector will benefit by building on existing experience and through taking up best practice of mature offshore sectors. Similarly, it is important to share knowledge on unsuccessful procedures, to ensure mistakes are not repeated, which would slow down the development of ORE. Building on experience within the ORE sector, from previous (demonstration) projects, is also of importance to continue to improve and develop the market.

Within the EU, there is already an established core of advanced manufacturing companies producing equipment and complete systems for the consolidated markets (oil and gas, maritime). These suppliers form a broad network of highly experienced manufacturers providing high-specification components, materials and specialist manufacturing services.

Therefore, innovation and investment from these value chains is likely to spill-over into a variety of related emerging sectors: offshore wind and ocean (wave and tidal) energy, where strong networking will enable them to benefit from related innovations and common interest technologies and know-how.

NeSSIE will boost a flow of best practices and technologies in the anti-corrosion solutions (ACSs) field coming from the more mature value chains to small to medium size enterprises (SMEs) in emerging sectors. Clustering processes and open innovation approaches for the development of new technological solutions are required to maintain or improve the competitiveness of the European manufacturing sector within this global market of ACSs.

This deliverable will build upon previous research done for NeSSIE, such as the report on the Business and Innovation Needs (D2.3) and the Roadmap for Anti-Corrosion Solutions (D3.4). This report will provide a background on the potential knowledge transfer from mature sectors to the emerging ORE sector in Section 4. A knowledge transfer strategy will follow in Section 5 to increase the transfer of knowledge across sectors and along the value chain, to encourage the development of the ORE sector. This will form part of the dissemination strategy outlined in Work Package 6. The report finishes with conclusions and recommendations regarding the cross-sector knowledge transfer.

4. Knowledge transfer

In the Ocean Energy Systems discussion paper on the future of the Ocean Economy [5], potential technology transfer from different sectors is highlighted, being the utility, mining, aerospace, shipbuilding, transport & operations, robotics, new materials, supply chain & manufacturing, third party verification & certification, oil & gas, and defence. A study by JRC in 2014 [6] indicated significant synergies between offshore wind and wave and tidal energy, about 40% of the overall cost components have great similarity. The components with the highest synergy share are operation and maintenance (O&M), electrical components and project development (Figure 1).

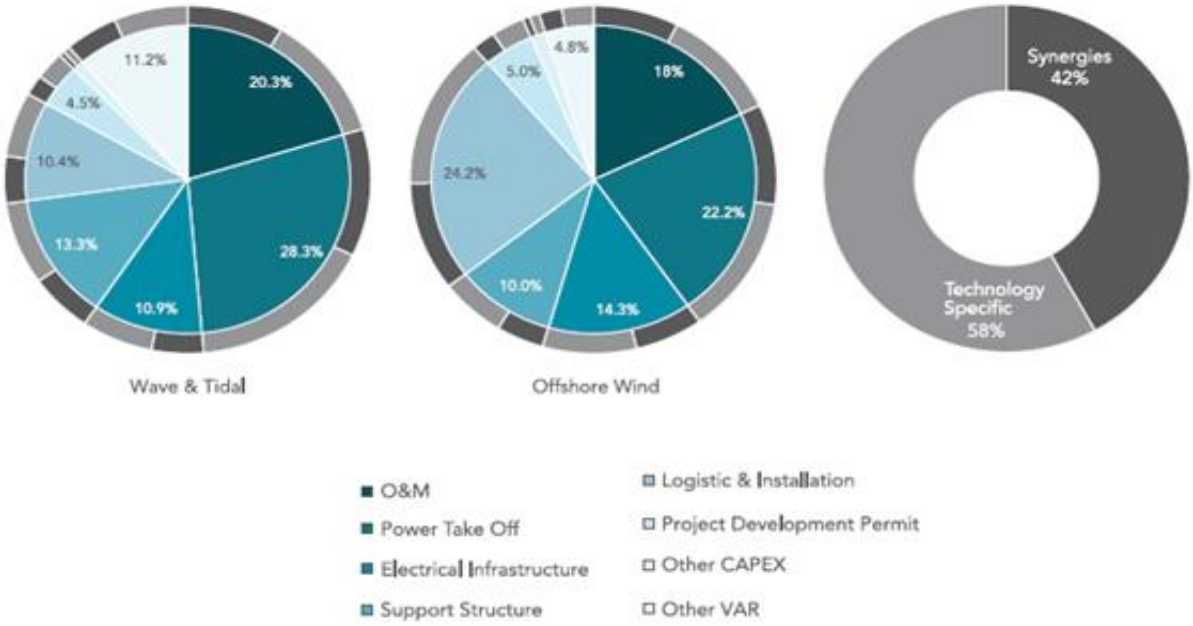

Figure 1 – Synergies between wave and tidal energy and offshore wind [6]

A study by Scottish Enterprise [7] investigated the opportunity for companies in the oil and gas sector to branch out to offshore wind energy. An 'opportunity mapping' exercise was performed by scoring all identified diversification opportunities according to a list of criteria, such as the size of the opportunity and existing synergies between the offshore wind and the oil and gas sector. This lead to the identification of nine areas with the greatest diversification potential. These are as follows: project management, array cables, substation structures, turbine foundations, secondary steelworks, cable installation, installation equipment, installation support services, and maintenance and inspection services.

NeSSIE and its demonstration projects will make use of the extensive knowledge in the Europe. The supply chain will build on this to promote the growth of the maritime supply chain. Some examples of companies that have transferred their technology and knowledge from one industry to the ORE sector can be found in Table 1.

Company	Description	Industries	Knowledge transfer topic
24SEA	24SEA specialises in structural health monitoring (SHM) and remote monitoring of offshore structures. They started from technology (sensors, data transfer, data processing, finite element method (FEM)) being used in aviation for SHM and adapted this for use on offshore wind structures [8].	Aerospace	Services
Balmoral Offshore Engineering	Balmoral Offshore Engineering is a composite and polymer developer focussed on specific segment development (i.e. design, toolmaking, manufacturing and testing) for offshore implementation in the oil and gas sector [9]. Together with WaveVenture and Corpower Ocean, Balmoral was involved with a Wave Energy Scotland (WES) funded project on innovative materials and manufacturing processes for wave energy devices [10]. In this project, Balmoral used their expertise for material feasibility studies, specifically composites, and to evaluate manufacturing.	Oil and gas	Materials/ Fabrication/ Manufacturing
Cescor Srl	Cescor SRl provides cathodic protection (CP) and inspection services. They have applied their CP design approach and their calculations deriving from 20 years Oil&Gas experience to OWF structure; FEM modelling experience previously applied to Oil&Gas applications has been applied to OWF structures [11].	Oil and gas	Cathodic Protection; Services
CG Power	Before the emergence of offshore wind, CG Power manufactured transformers for onshore high voltage substations. Starting from that technical knowhow, they now also manufacture transformers for offshore high voltage substations [12]. This required, amongst other elements, developing knowledge on how to deal with the highly corrosive offshore environment.	Electrical	Transformer
DEME Group	DEME, originally a dredging company, have applied their extensive knowledge and experience with largescale maritime operations into offshore wind installation [13].	Dredging	Maritime operations
Elsyca	Elsyca specialises in modelling of corrosion processes and cathodic protection [14]. They started by working in both the O&G and defence sectors (corrosion of pipelines, offshore platforms, fighter jets on aircraft carriers). They now apply their knowledge of corrosion processes and cathodic protection to offshore wind and model the corrosion and protection of inter alia, offshore wind foundations.	Oil and gas; Defence; Electrochemical	Cathodic Protection; Services
Green Marine	Green Marine, providing vessels for the installation, operation and maintenance of marine energy devices, has taken experience frmom working in the fishing industry into the emerging marine renewables industry. Green Marine identified the opportunity to provide vessels for marine renewable deployments, therefore displacing the need of expensive oil and gas vessels [15].	Fishing	Services
Navantia	Navantia is a Spanish company, specialised in military shipbuilding with experience in oil and gas. They have applied their experience to the wind energy sector, where they have built different types of jackets, substations and floating wind platforms [16].	Defence	Manufacturing
Smulders	Smulders is a Belgian steel construction company, active in the oil and gas sector, civil and industry, and offshore wind. With offshore experience since 1966, they now provide secondary steel structures and substations for offshore wind projects [17].	Oil and gas; Civil and industry	Materials/ Fabrication/ Manufacturing
Space Application Services	Space Application Services develp technological solutions for docking of space crafts to the ISS. Space craft are often unmanned. To facilitate the docking maneuvers for the pilot, a combination of augmented reality solutions, cameras and an exoskeleton are used. The latter can return tactile information to the pilot such as resistance encountered, vibrations, etc.. The same technology can be used to control ROV's in subsea	Aerospace	Services

	operations, where the pilot also operates vehicles from a distance. The transfer of this knowledge to offshore applications is currently being investigated [18].		
Parkwind	Parkwind is a Belgian windfarm developer, started by Colruyt group (grocery stores) [19]. It has experience in managing large scale operations and financing.	Grocery stores and supermakets	Management
Windar Renovables	Windar Renovables is a Spanish company, part of the Daniel Alonso Group, with experience in manufacturing tubular steel structures, designing and manufacturing pressure equipment and large metal structures for petrochemical, energy and naval industries. They have transferrred their knowledge and expertise to the offshore wind market, manufacturing piles and foundations [20].	Petrochemical; Oil and Gas; Naval	Manufacturing

Table 1 – Non-exhaustive list with examples of companies that have transferred their knowledge and/or technology from one sector to the ORE sector.

The next sections discusses some identified examples of best practice of corrosion protection as well as identified opportunities to encourage knowledge and technology transfer between sectors.

4.1. *Best practice*

As mentioned, it is important to implement best practice from the established offshore sectors in the emerging ORE industry. Building on existing corrosion expertise can reduce unnecessary cost to ORE and simultaneously create new market opportunities for ACS providers, encouraging both the ORE sector and ACS providers.

4.1.1. Corrosion Control

A report on guidance for corrosion management divided corrosion control into four sections, namely material design; protective coating, inhibition and cathodic protection; corrosion inspection and monitoring; and corrosion assessment [21] (see Figure 2). Within corrosion control, all these four units need to be taken into the process. From the material selection, protection of the structure with coatings and CP through to the inspection and assessment of the state of the structure. The next section goes deeper into the overall process of tackling corrosion issues with a corrosion management framework.

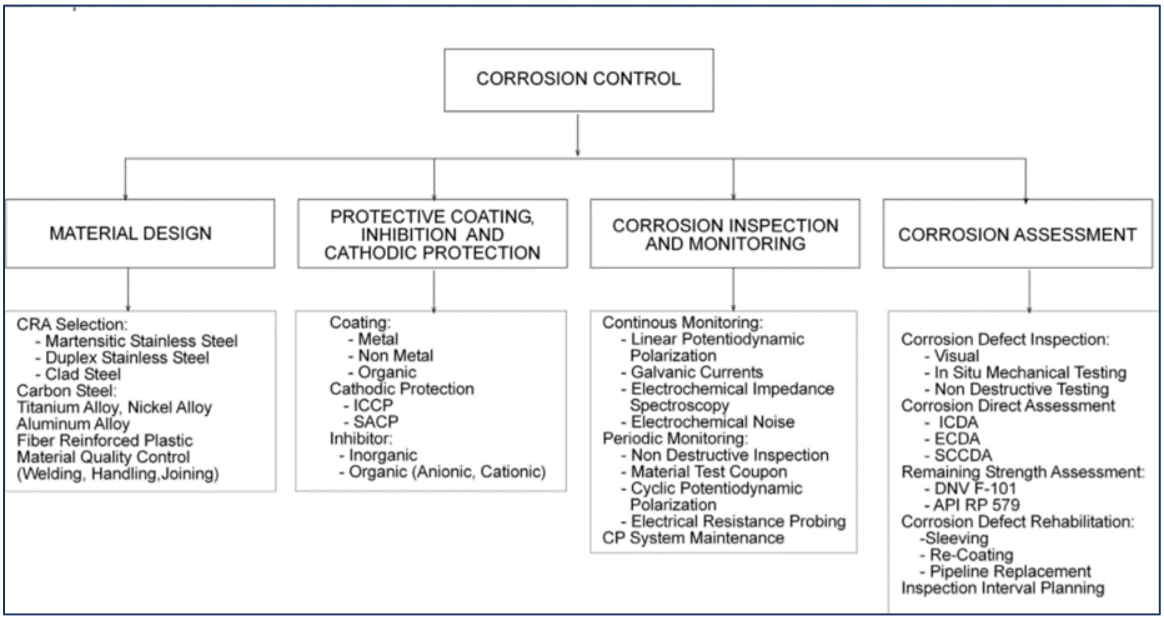

Figure 2 - Oil and Gas example of a basic corrosion control [21]

4.1.2. Health & Safety Corrosion Issues Framework

The Health and Safety Executive has provided an exemplary framework based on industry best practise in corrosion management in the oil and gas sector [22], see Figure 3. The effects of corrosion on Health and Safety within the offshore oil and gas sector are of great importance as people are present on the offshore structures. Even though the presence of people on the ORE structures will most probably be less frequent or even non-existent, Health and Safety is still of great importance and therefore functions as a good example for the ORE sector. The framework can be divided in the following stages:

- Policies and objectives;
- Organisational structure and responsibilities;
- Planning, procedures and implementation;
- Measure system performance;
- Review system performance;

The first two stages indicate that integration of corrosion issues at a high level is required to ensure implementation throughout the complete project. The planning, procedures and implementation stage includes corrosion risk assessment, mitigation and monitoring, and maintenance.

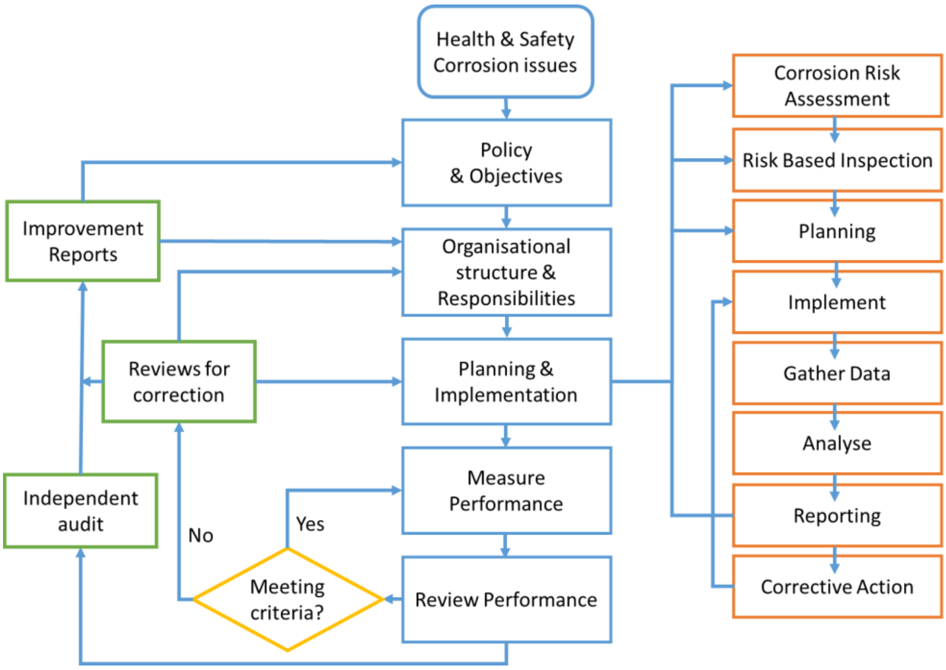

Figure 3 – Corrosion management framework based on oil and gas industry best practice based on [22]

Within the planning, procedures and implementation stage, some points of best practise that are of great interest to the ORE sector are as follows:

- Corrosion mitigation should be included in the development of a project at an early concept design stage. Additionally, inspection, monitoring and maintenance should also be taken into account at this early stage.
- Risk assessment should be a 'live' process: validating the assessment based on real life conditions showed to minimise high risks.
- Monitoring of corrosion is classified under proactive or reactive measures. The former gathers data (either during employment or retrospectively) and results in failure preventive measures, whereas the latter are measures after corrosion has been identified.

- Simple corrosion checks can also be included in regular maintenance procedures, here a connection is made to training programmes to improve the awareness and knowledge of maintenance crew.
- Keeping a record on any observed corrosion is recommended for future corrosion control purposes. It is important that the data transfer between the different stakeholders, such as 'contractor-to-operator', is ensured [22].

A report based on experience in the maritime sector, where corrosion and biofouling of vessels is a well-known challenge, is very much in line with the Health and Safety framework [23]. It also recommends taking corrosion into account from the concept stage, going through design, construction and continues within deployment. The following considerations are mentioned: stress and strain; geometry and crevices; preparation and application; influence of environmental factors; material suitability; awareness and training; corrosion management strategies. The report also indicates the necessity to employ a specific corrosion protection system that is compatible for the specific conditions and to assure quality from preparing the surface and inspection [23].

4.1.3.Standards and Certification

The established offshore sectors depend highly on the anti-corrosion standards. The procedures of mitigation, monitoring and maintenance of corrosion protection systems are well established. These standards provide the guidelines and make it possible for all the parties involved to compare the procedures and products. The standards for ORE are based on the standards in the mature sectors, such as oil and gas, electrical components, etc..

More detailed information on the standards and certification can be found in the NeSSIE State of the Art Study [24], the report on the non-technical challenges [25] and in the NeSSIE Roadmap [26].

4.2. *Knowledge transfer instruments*

This section discusses different instruments through which transfer of technology and knowledge can be encouraged.

4.2.1. Diversification initiatives

The Scottish Enterprise study [7] indicated the win-win situation of diversification; applying best practice in order to reduce the cost of offshore wind and simultaneously indicate the opportunities of market expansion for oil and gas companies.

Reasons for companies that have established a sizeable share in the market to diversify can be found based on external pressures (i.e., regulations), and internal choices with the identification of 'windows of opportunity' of value in the innovation. Further to this, it was identified that companies might seek focus on emerging technologies to 'position for the future', to 'sustain firm growth and survival in the long-term' [27].

To investigate and ensure industrial growth of the existing maritime sectors, different initiatives have been set up to encourage diversification towards the emerging ORE sectors. Some examples can be found in Table 2.

Title	Type	Company/Consortium
AREG [28]	Network company	130 member companies
Blue Cluster [29]	Network	Belgian cluster organisation to promote economic activities linked to the sea
CORE [30]	Network	English Government (The Crown Estate; UK Trade & Investment Hub)
Innovative Business Network (IBN) Offshore Energy [31]	Network	Cluster of companies active in the osshore energy sector in Belgium
MESCG [32]	Value chain database	ORE Catapult (partners: Marine Energy Wales; RenewableUK; RegenSW; Invest Northern Island, Scottish Enterprise, Highlands & Islands Enterprise)
NSRI Matchmaker [33]	Database/ Tool	Database of companies active in subsea sector

Table 2 – Non-exhaustive list with examples of diversification initiatives

The Aberdeen Renewable Energy Group (AREG) is a centre promoting the 'transfer of technology, skills and engineering expertise' to renewable energy. An example of a project they have supported is the European Offshore Wind Deployment Centre (EOWDC).

The UK Government has identified six Centres for Offshore Renewable Engineering (CORE) in England where there is great potential for offshore wind development based on skilled and trained personnel, testing facilities and manufacturing supply chain [30]. These locations, of which five located in the North Sea basin: 'North Eastern', 'Tees Valley', 'Humber', 'Great Yarmouth & Lowestoft' and 'South East', have extensive knowledge in different areas from composites to operation and maintenance.

The Marine Energy Supply Chain Gateway (MESCG) is a database with companies active in marine energy, set up by six partners and led by ORE Catapult. The database is divided in three main categories (technology development, project deployment and technology manufacture and integration) and multiple subcategories. Most of the companies in this database are also active in other sectors, diversifying in marine energy.

The National Subsea Research Initiative (NSRI) [34] was set up to share knowledge and experience of companies active in the subsea sector to support the industry in these sectors (i.e. oil and gas, defence, offshore wind energy, wave and tidal energy, subsea mining, and ocean science).

4.2.2.Communication and Dissemination

Creating awareness of corrosion issues and potential solutions can be created through different communication and dissemination channels.

Workshops

Physical workshops work well for knowledge transfer when participants are engaged, willing to participate and share, and when the workshop format is conducive to collaboration. A recent example of a successful workshop was the NSRI Mastermining event in Aberdeen in May 2018. Ninety representatives from the marine energy, maritime and oil and gas sectors were in attendance, a large proportion of which came from the oil and gas sector. This demonstrates the interest of the oil and gas sector in diversifying into marine renewable energy. The workshop took the format of round table discussions, of which corrosion was one of the topics. The discussion took place between representatives from the various sectors and highlighted the cross-sector knowledge transfer opportunities for the marine sector from the lessons learnt in other sectors. These included:

- The need to include anti-corrosion solutions at an early stage of both design and financial modelling;
- The large range of experience levels encountered with developers – some leaving little to no budget for anti-corrosion solutions, some devices overprotected, some underprotected;
- The previous experience of the high impact that geographic location has on the rate of corrosion. A participant discussed the higher corrosion rate experienced in Australia due to the warmer more oxygenated water and increased amount of marine life.

The discussion at this event also featured suggestions for further cross-sector knowledge transfer in anti-corrosion solutions, including:

- Experience from the defence sector with coatings on submarines and electrifying the outside of submarines to reduce biofouling;
- The use of the rigorous safety standards from the oil and gas sector could be very useful to the developing marine energy sector;
- The opportunities for cross-sector knowledge transfer will depend heavily on device design.

Webinars

Webinars give an opportunity for experts to discuss a topic in more detail. They can reach a widespread audience at different locations, as they are online and can be recorded to be viewed at any time. An example of a webinar series are the webinars on the technical, financial and environmental challenges in ocean energy organized by the European Technology and Innovation Platform for Ocean Energy (ETIP Ocean), funded by the European Commission [35].

Conferences

Conferences bring together different stakeholders to discuss the activities and results in a specific field or topic. These events can have a focus on academic and/or industry activities. The potential to network and connect with experts is significant. Conferences where different industries come together are seen good opportunities to share knowledge, with actors providing different viewpoints. NeSSIE Roadmap presentations were given at the International Conference on Ocean Energy (ICOE 2018) in Cherbourgh, France, in June 2018 [36]and at the National Association of Corrosion Engineers (NACE) International conference, on corrosion management, in Genoa in May 2018 [37]. The presentations and presence at these conferences lwere excellent opportunities to present the work done in the NeSSIE project, to receive feedback and to encourage potential demonstration projects and solutions providers to come forward.

Training programmes

Training programmes, such as EN15257: Cathodic Protection: Competence levels and certification of CP personnel [38] and NACE courses [39], are useful tools to increase the awareness and knowledge of corrosion issues. These education tools also provide an opportunity to learn and compare the experience of people working in other sectors.

Others

Other opportunities to distribute information on specific topics that reach a wide range of organizations are trade magazines and scientific journals; personal connections from general networking, leading to bi-lateral one-on-one contacts; and social networks, like LinkedIn. In addition, the networks, clusters and databases as mentioned in the previous section on diversification initiatives, are examples of communication hubs.

4.2.3. Collaborations and Consortia

Collaboration between different companies and research centres can accelerate technology development through combining expertise and lessons learnt. In addition, collaborations can reduce the risks in project development. This can promote market development in different regions in Europe.

NeSSIE, a project with eight project partners throughout Europe, is an example of such a collaboration project. Knowledge and networks of the different NeSSIE partners are used to identify and support three ORE demonstration projects related to corrosion issues.
Some other examples of collaborations and consortia related to corrosion issues in the ORE sector are given in Table 3.

Project	Consortium	Description
BioFREE [40]	Heriot-Watt Universit; EMEC	Multi-disciplinary study where biological, engineering and hydronamic expertise is combined to gather data on biofouling for use in the ORE sector.
CROWN; CROWN2 [41]	ORE Catapult; TWI; LIC Engineering	Investigating thermallly sprayed aluminium (TSA) to protect offshore foundations against corrosion.
HarshLab [42]	Basque Energy Cluster; Matz-Erreka, S.Coop; Credeblug; Ditrel Industrial S.L.; Glual Hydrolics; Hine Renovables; Navacel; NEM solutions; Sasyma Coatings; Tubacex; Grupo Vicinay; Foro Maritimo Vasco	European funded floating platform to test/validate technologies for energy in offshore conditions, with a focus on three challenges: 'materials and solutions to protect against corrosion and foulding; operations and maintenance; and competitive production costs'.
MaDurOs [43]	SIM; Allard Europe; DEME; Jan de Nul Group; ArcelorMittal; VU Brussel; KU Leuven; Metalogic; Syca; Zensor; Universiteit Gent; G&G International; Smulders; OWI Lab; Bekaert; Vincotte; IBS	'Material Durability for Offshore': a Belgian network to develop vertical Strategic Initiative Materials (SIM).
Oceanic [44]	AZTERLAN-IK4; GAIKER-IK-4; REPOL; WavEC: CorPower; Skandivavisk Ytförädling; Recubrimientos-Mikra	OCEANERA-NET funded project to get an anticorrosion and antifouling protection with a lifetime of more than 10 years, additionally, monitoring and mapping of fouling is gathered [45]

Table 3 – Non-exhaustive list with collaboration projects related to corrosion issues and the ORE sector.

5. Cross-sector knowledge transfer strategy

In the NeSSIE Roadmap [25], market observations were identified based on the current ORE landscape in the report with the non-technical challenges for the development of ORE projects. These observations indicated that NeSSIE can 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 different sectors is critical to encourage diversification, to create awareness of the existing ACSs in the developing ORE sectors and to support the development of ACSs in the emerging market.

Following these observations, recommendations were made to ensure targeted knowledge transfer and to create awareness of corrosion issues to be taken into account at an early design stage [26].

Among other things, the identification and support to demonstration projects within the NeSSIE project can support these observations. Projects can be seen as ‘time-limited niches’, to investigate the potential of the company’s knowledge in another market [46]. The development of demonstration projects as part of NeSSIE is such an example, where companies can investigate the potential to diversify into and collaborate with the ORE sector. Projects with different partners bringing their knowledge together is a well-applied course of business.

An important point coming forward from interviews with diversified oil and gas companies, in a study by Steen and Hansen [46], is that the experience in leading and carrying out projects of these companies in the established sector is essential for the success of a demonstration project. Considering installation and operation (and maintenance) should be key engineering and design aspects, i.e. integrated project and operational planning. This experience is present in the oil and gas sector and can be useful for ORE project development.

The Steen and Hansen study also points out that ‘academics should scout for both enabling and constraining factors involved in transferring knowledge’ [46]. It is also indicated that just the knowledge in a mature sector is not per definition a suitable base for a related sector. This supports the NeSSIE recommendation of targeted knowledge transfer. With the identified ACS challenges and the industry needs, NeSSIE provides a base for targeted knowledge transfer. These challenges are areas where there is a need for improvement, which can be sought in the knowledge and expertise of established sectors and its project developers and solution providers. Bearing in mind that a direct transfer may not always be possible, i.e. the core elements of the knowledge and expertise available from established sectors may be used, but require adaptation to the techno-economic circumstances in the ‘new’ sector.

In addition, this report provides a strategy to encourage the cross-sector knowledge transfer through the creation of a supportive environment. This is discussed in the following sections.

5.1. *Conditions for transfer and development*

In technology development, to move from a novel to established market, i.e. ‘creating a path’, there needs to be a supportive environment.

According to MacKinnon et al. [47], this path creation depends on regional assets, key actors, mechanisms of path creation, and multi-scalar institutional environments and policy initiatives. Strategic coupling between the regional assets and the mechanisms of path creation is the process that can provide the growth of an industry.

In their study, MacKinnon et al. define regional assets consisting of five components, namely natural, infrastructural and material, industrial, human and institutional assets [47]. These assets form the base for path creation in regions if they are 'identified, harnessed and valorised by economic actors and institutions'. This should be done by development activities and initiatives.

The mechanisms of path creation are mentioned as new technology exploitation; connections/collaborations of different organisations to increase variety and innovation; transplantation (i.e. import and diffusion of new technologies); diversification; and upgrading of regional industry. Supporting these mechanisms can encourage the take-off of a novel technology. The previously mentioned study by Hansen and Steen [46] highlights that for a successful novel industry to develop, three requirements are essential in the knowledge spill-over between different sectors, namely adaption, application and collaboration. This is therefore included as essential for the mechanisms for path creation.

Activities and initiatives where the identified regional assets are combined with mechanisms of path creation can unlock the growth of a technology; harnessing and valorising the regional assets. The NeSSIE project is an example of an initiative where strategic coupling will foster path creation, specifically the path of ACSs and novel materials in the ORE sector. The regional assets have been identified in the 'Non-technical challenges in developing ORE projects' report [25] and the NeSSIE Roadmap [26], where the current landscape in terms of market, finance, infrastructure and regulations was identified. NeSSIE's aim to identify and support three demonstration projects based on existing anti-corrosion solution challenges and experience in the different European regions from different sectors, encourages multiple of the mentioned mechanisms of path creation. The demonstration projects will function as 'time-limited niche activities' in which ACSs should be adapted and applied, through collaborations.

In their study on the involvement of the oil and gas sector in offshore wind development, Hansen and Steen [48] describe the interaction between the established regime and emerging technologies, or so-called niche activities, based on the multi-level perspective (MLP). The MLP provides an explanation of socio-technical transitions based on the interaction between three different levels, namely niche, regime and landscape, where transitions are the change between one regime to another [49].
In this theory, both the technological innovation and the social factors are taken into account in the development of an innovative technology (niche level) towards the established sector (regime and eventually landscape level). The attitude of the actors is important, referring to established companies or organisations that actively move between the regime and niche level whilst exchanging knowledge, resources and routines based on their expectations, ideas and assessments of (novel) technologies (Figure 4) [48]. It is mentioned that visions can become reality when they gain support from actors, as they will act upon them. The visions that see this fulfilling development are considered as strong when they are collective, credible and specific, and often coupled to societal problems that the established regime cannot resolve.

The identification of the existing ACS challenges and industry needs within NeSSIE and its validation by industry through interviews and workshops provides the collective and credible message on the issues to tackle. The specific challenges and solutions will be presented in the form of the demonstration projects.

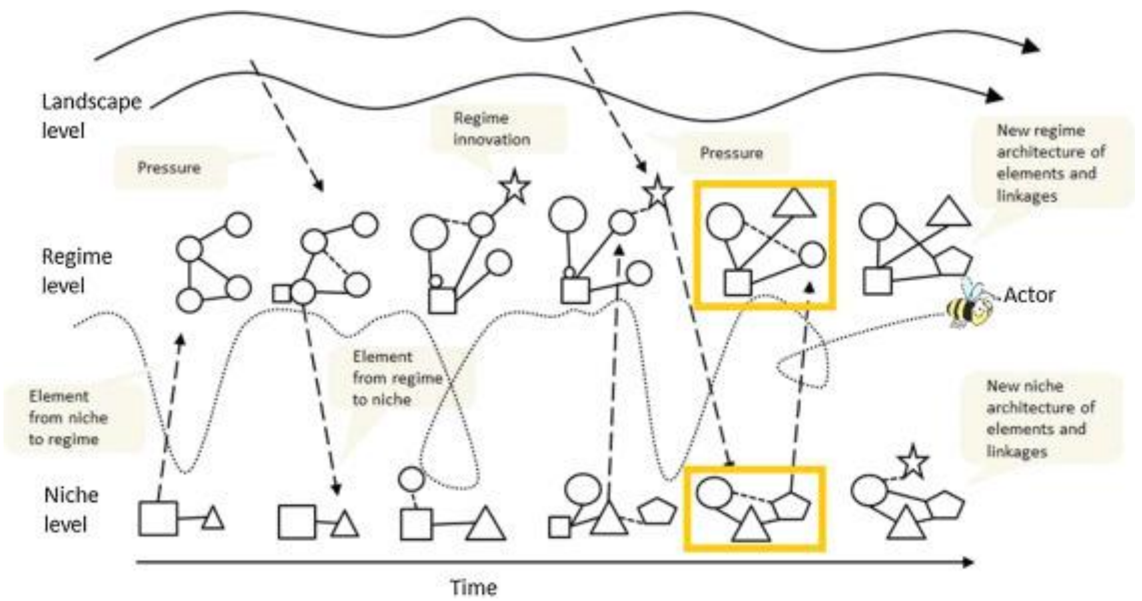

Figure 4 – Representation of the multi-level perspective, the actor is portrayed as a bee: cross pollinating between the niche and regime level [48]

The investment of established offshore companies can support innovations from niche to full market. Steen and Weaver [27] recommend focusing on specialised suppliers to understand the development trajectories and diffusion of niche technologies through adjacent sectors. In addition, it is pointed out that with investments of energy producers in developing technologies, suppliers may follow and strengthen the development with knowledge and resources. Encouragement of engagement is recommended through policy support.

Figure 5 indicates the different aspects and relations to achieve an environment in which the ACSs and ORE can move forward based on the previous studies [46] [47] [48]. Policy initiatives should encourage the complete environment, which includes supporting incumbent's engagement in novel technologies, supporting novel ACSs with their technology development, and supporting the strength of regional assets with training programmes. The novel or niche technologies, in this case ACSs applied to ORE, should be collective, credible and specific for key actors to support their development. Simultaneously, for these technologies to be able to seize their potential to grow, regional assets need to be identified, harnessed and valorised, as mentioned with support from policy initiatives such as training programmes and testing centres. In addition to the regional assets, mechanisms for path creation, such as diversification and transplantation, need to be encouraged. Where knowledge spill-over between sectors is achieved when knowledge and technologies are adapted, applied and through collaboration. The NeSSIE project fulfils different roles in achieving the required conditions as mentioned in the above paragraph, from identification of the regional assets and the ACS challenges to the facilitation of knowledge spill-over through the demonstration projects.

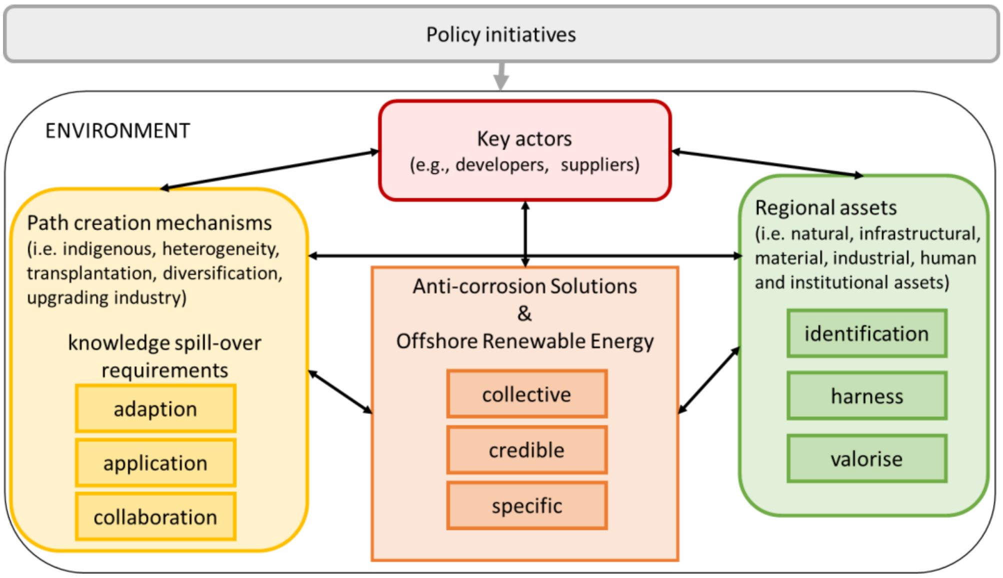

Figure 5 – Ensuring a supportive environment for NeSSIE's novel industry development based on knowledge transfer from established sectors, based on literature study [46] [47] [48].

In this chapter, the knowledge transfer strategy of the NeSSIE project is discussed to encourage the development of ACSs and novel materials applied in the ORE sector.

5.2. *Challenges*

Until recently, the oil and gas sector has not been driven to reduce the cost of installation procedures and the equipment, such as vessels, due to the high returns. For marine renewable energy, where the need for cost reductions is of great importance for the future development of the sector, reductions in cost through innovation is important. Thus, experience from the existing sectors is necessary, whilst innovating the bespoke equipment to reduce the installation costs.

The study by Steen and Hansen [46], on the knowledge spill-over between different sectors, also points out the barrier of ORE projects having a high financial risk. To reduce the risk of a project, proven technologies are chosen, with the example given of subsea cables, whereas novel solutions to achieve cost reductions are important for the ORE sector development. This confirms the 'novel product' challenge identified in the NeSSIE Roadmap.

5.3. *Knowledge Transfer Strategy*

Based on the research in the previous sections (Figure 5), the work done by NeSSIE and NeSSIE's aim to identify three demonstration projects, the recommendations can be made. These recommendations form a starting ground to achieve a supportive and suitable environment where the knowledge and experience of the established sectors can be applied to the application of ACSs and novel materials in the emerging ORE sector:

- Ensure awareness: through webinars, conferences, etc.;
  Awareness of corrosion issues was a recommendation in the NeSSIE roadmap, a result from the interviews and feedback. In their report, the Health and Safety Executive also mentions corrosion awareness as a successful method to improve the overall corrosion performance [22]. Training programmes can increase the observation of corrosion related issues at an early stage as well as

the understanding of inspection, monitoring and mitigation measures.

- Connect: through tools, events, workshops, etc.;
  By connecting developers, suppliers and other stakeholders at different levels of maturity, the exchange of knowledge and experience can provide a boost to the market where novel ideas can grow and established technologies innovate, as described in the multi-level perspective in Section 5.1. This can be done through tools such as those discussed in Section 4.2 including diversification initiatives, and communication and dissemination activities in the form of conferences and workshops.
- Collaborate: through consortia (across Europe), associations (within industry) and clusters (regionally) [4]
  Finally, collaborations are promoted. For example, working together with Original Equipment Manufacturers (OEMs) to design products with their experience to adapt the design to the site characteristics. Evidently, for NeSSIE this occurs in the consortia of the demonstration projects, where the knowledge of different partners is applied.

6. Conclusions

In conclusion, the NeSSIE project advocates the need for awareness of the ACS challenges within the ORE sector. These areas have a great potential for collaborations between the emerging ORE and established offshore industry. The ORE sector can take up the knowledge from the established offshore sectors, from the application of technologies to experience in corrosion and project management. Simultaneously, it is important to point out the potential of a new market for the companies that are active in the established sectors. Additionally, there is the potential of novel technologies to be implemented or transplanted in the established industry. The mentioned ACS challenges have been identified in the Roadmap. This provides an overview of the areas seeking improvement, and therefore collective message of potential market exploration for the established market.

Events and tools, such as workshops, webinars, and conferences, can be a platform to encourage awareness and to connect different actors within one and from different sectors. NeSSIE, and other similar projects, can play an important role as a development facilitator, through the identification of the challenges, needs and opportunities, and by providing a platform to establish collaborative projects.

For a technology to grow and seize its market potential, the right environment needs to be established. This environment is based on many variables and their interaction, from key actor engagement to regional asset identification and development. Policy initiatives play an important role here in encouraging the activities to establish a supportive environment.

Through the process of NeSSIE of identifying the specific demonstration projects, collaborations are set up (within Europe) in which potential solutions are adapted and applied to harness and valorise the ACSs and ORE developers; growing the industry and supporting the supply chains.

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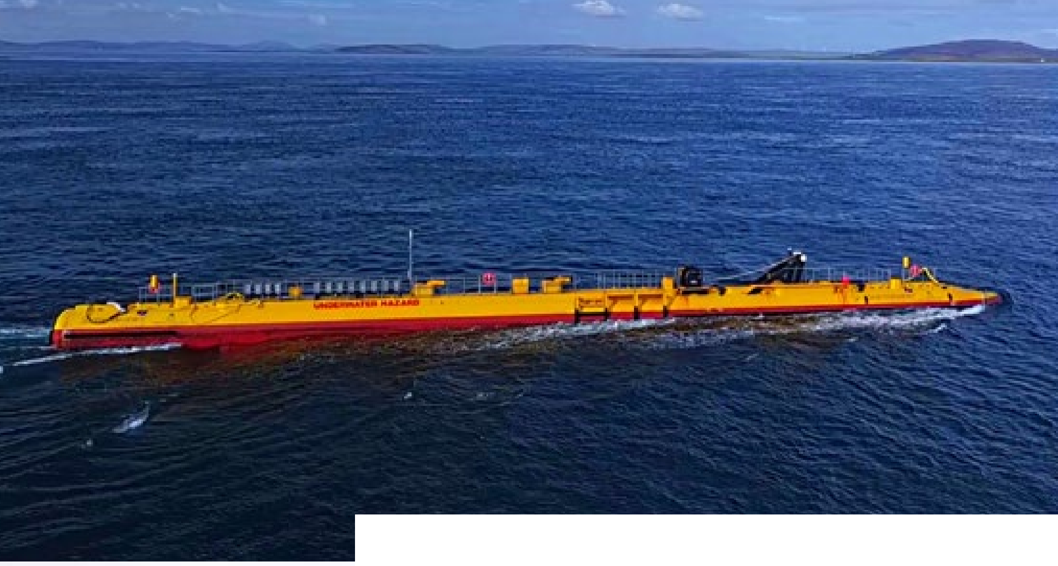

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