Environmental Baseline Study for the Development of Renewable Energy Sources, Energy Storages and a Meshed Electricity Grid in the Irish and North Seas

WP3 Final Baseline Environmental Report

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ABSTRACT

The development of an offshore renewable energy system, including grid infrastructure, in the Irish and North Seas represents a significant opportunity towards meeting the European Union's energy goals. To ensure that environmental concerns and impacts are appropriately considered at an early stage in the development of such an offshore energy and grid system, the European Commission has appointed a multi-disciplinary team to prepare an environmental baseline study based on a regional concept. This **Baseline Environmental Study** has been named BEAGINS which stands for **B**aseline **E**nvironmental **A**ssessment for the **G**rid in the **I**rish and **N**orth **S**eas. The six target Member States for this study include: Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom.

The initial output of the study included the preparation of a **Regional Concept Report** with the objective of developing a detailed plan of the combined energy and grid infrastructure in the Irish and North Seas. Three capacity scenarios have been developed with associated radial and grid infrastructure options. A **Baseline Environmental Report** was then prepared comprising a comprehensive **Impact Dictionary**, a **Data Catalogue** and an **Environmental Baseline**. The environmental baseline examines the relevant significant issues of the current state of the environment in relation to biodiversity, flora and fauna; population and human health; soils, geology and sediment; water; air quality and climatic factors; materials assets; cultural heritage; and landscape and seascape. Stakeholder consultation with the Member States was undertaken throughout the development of the study and key issues identified where considered in the development of the Baseline Environmental Report.

Six **Recommendations** were identified from the baseline study to set building blocks toward creating a backdrop where coordination is facilitated across Member States. They include suggestions relating to development of an appropriate planning framework; coordinated infrastructure roll-out; development of an appropriate management framework; data management and storage; development of best practice guidance; and monitoring and data requirements. The recommendations reflect progress towards an integrated meshed grid scenario, in line with the impact assessment findings.

1 EXECUTIVE SUMMARY

1.1 Introduction

The development of an offshore renewable energy system in the Irish and North Seas represents a significant opportunity towards meeting the European Union's (EU) energy, environmental, growth and employment objectives. The region has a vast renewable energy potential that could provide a significant share of Europe's power supply by 2030 and beyond. Furthermore, such a regional energy system could also contribute to the further integration and flexibility of the electricity market in northwest Europe, which is an important step towards a single European electricity market and improved energy security within the EU. To ensure that environmental concerns and impacts are appropriately considered in the development of such an offshore energy system, the European Commission has appointed a multi-disciplinary team to prepare an environmental study. This baseline study has been named BEAGINS which stands for **B**aseline **E**nvironmental **A**ssessment for the **G**rid in the **I**rish and **N**orth **S**eas.

This Baseline Environmental Report, prepared as part of the study, sets out the effects (both positive and negative) of future energy and grid scenarios up to 2030. The future energy and grid scenarios have been developed as a complementary part of the study in the form of a Regional Concept Report.[1] The study area for BEAGINS has been developed with reference to work carried out for the Regional Concept Report, and includes the territorial waters of Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom (UK). An outline of the broad study area for the Baseline Environmental Study is presented in **Figure 1-1**.

1.2 Purpose of the Baseline Environmental Study

This Baseline Environmental Study and associated report is intended to inform any future plans for renewable energy generation, energy storage, grid cables and associated equipment in the Irish and North Seas. It will be available as a resource for the relevant Member States and stakeholders to inform environmental assessments, such as Strategic Environmental Assessment (SEA), Appropriate Assessment (AA) and Environmental Impact Assessment (EIA), as appropriate. This Baseline Environmental Study is a tool to assist in the realization of EU-wide and national renewable energy targets by providing a source of data on baseline, impacts and mitigation which can be applied across and within the various Member States within the study area. It will also provide a forum for identification of data gaps and coordination of solutions between Member States.

1 Ecofys (2017) Regional Concept Report.

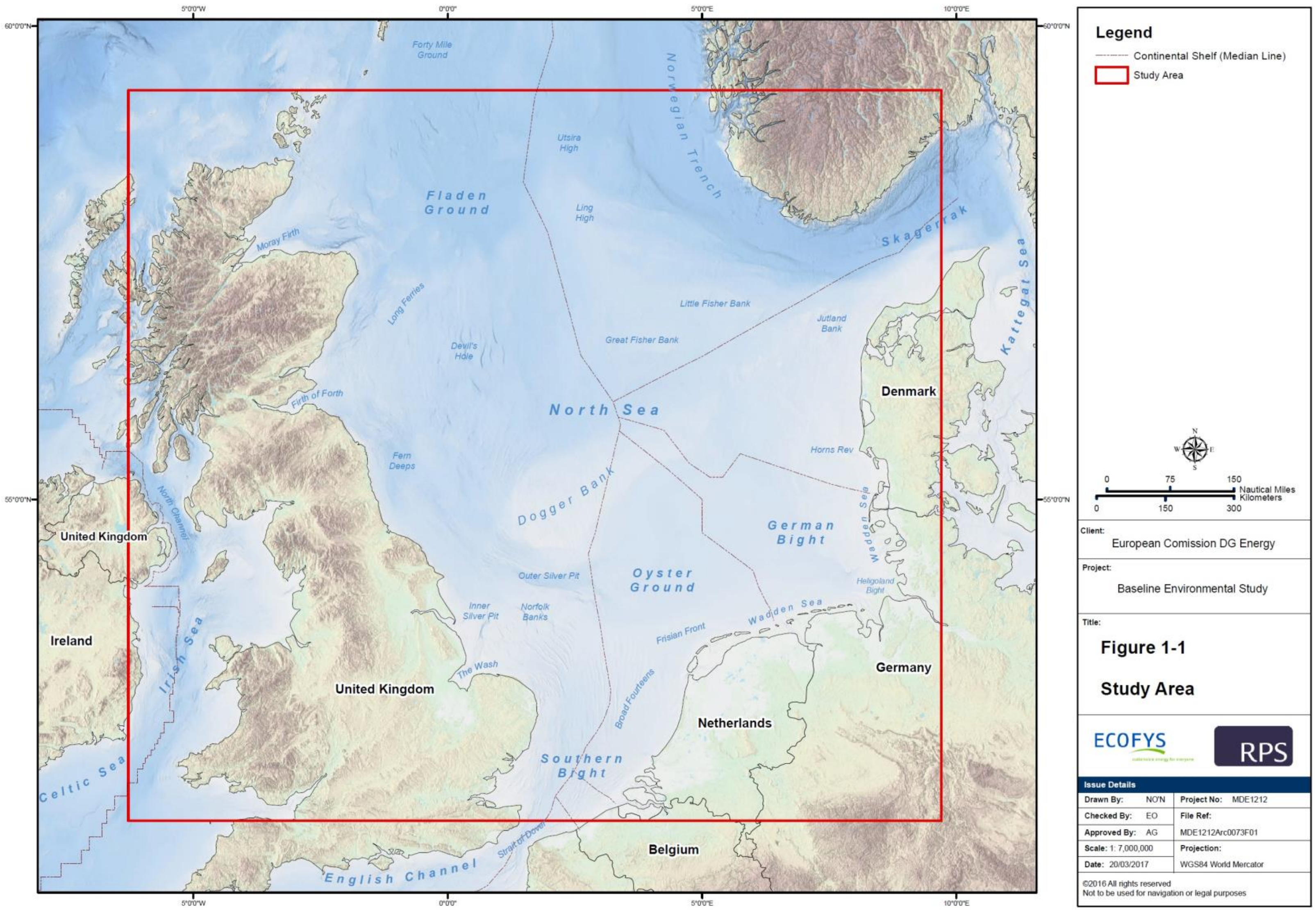

Figure 1-1 - Study Area

1.3 Baseline Environmental Study – Key Outputs

The Baseline Environmental Study involved a number of phases including the development of a: Scoping Report; Regional Concept Report; Impact Dictionary; Data Catalogue; and Environmental Baseline. As part of the development of these elements various consultation opportunities were undertaken, as outlined in **Figure 1-2**. The feedback received has informed the overall development of this Baseline Environmental Report.

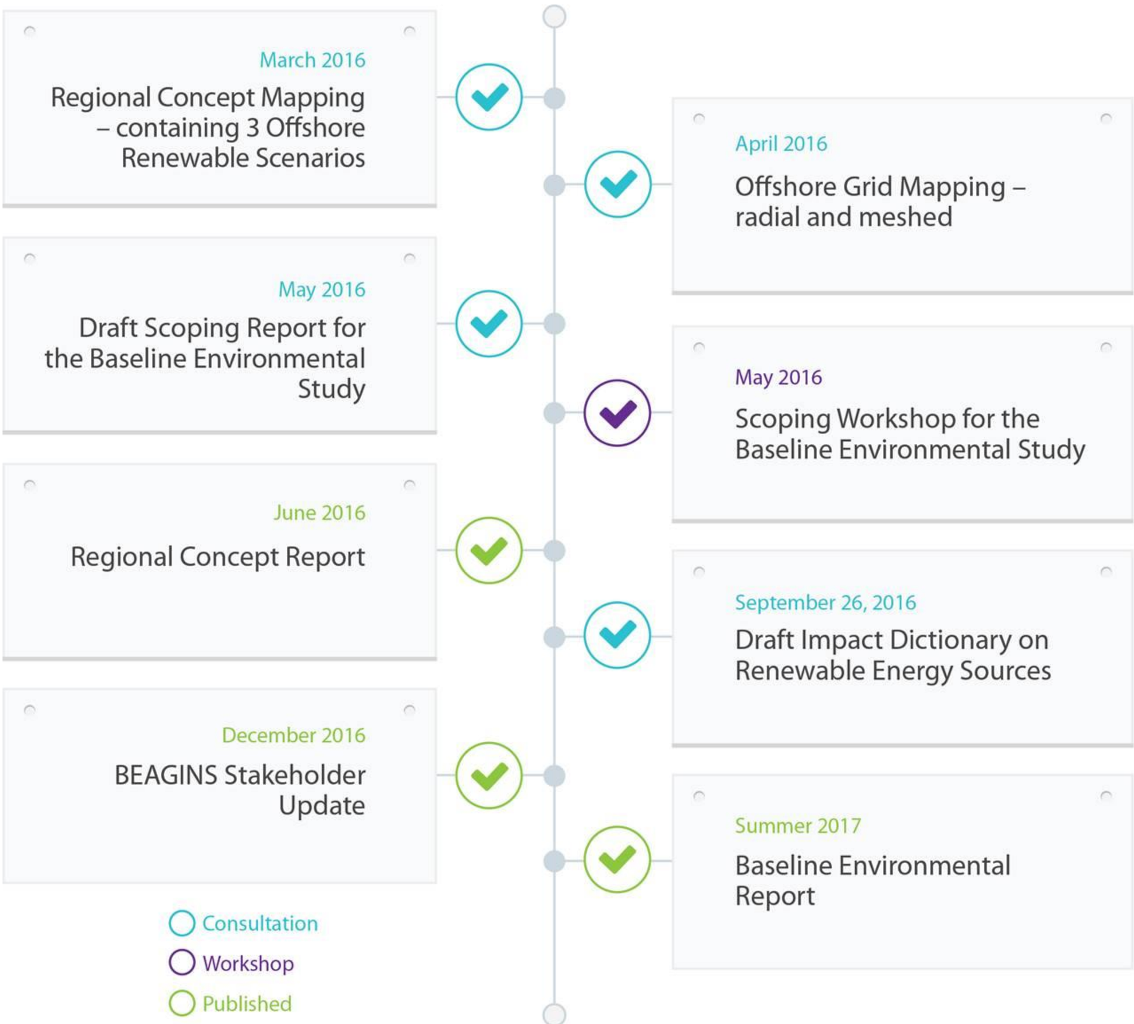

Figure 1-2 - Overview of Consultation Timeline

Scoping Report

In early 2016 (April and May) the capacity scenarios and the topology for the grid connection, including its interconnectors, for the Regional Concept were consulted with stakeholders. The stakeholders consulted included Transmission System Operators (TSO's) and representatives of the Member States. The overall feedback was positive and agreed with the proposed purpose being that the locations of the renewable energy sources (RES) for 2030 are intended only to provide a reasonable distribution achieving the capacities per scenario, and are not a reflection of any government policies or plans, which are subject to change.

In May 2016 a draft Scoping Report on the Baseline Environmental Study was published on the project website [www.beagins.eu]. This provided an overview and description of a number of features relating to the development of an energy system in the Irish and North Seas including:

- The institutional and legislative framework;
- The scope, objectives and conclusions of the existing national SEA studies relating to maritime spatial planning at national level;
- Key stakeholders;
- Key environmental aspects to be addressed in the Baseline Environmental Study and a description of the scope of the environmental baseline to be prepared; and
- Recommendations on specific impact identification and evaluation methodologies to be used.

As part of this Scoping Stage, each of the Member States were contacted and asked to contribute with reference to the draft scoping report. The Scoping Report was then used to inform the overall development of this Baseline Environmental Study.

The Regional Concept Report

As part of the Baseline Environmental Study a Regional Concept Report has been prepared and this has also been subject to stakeholder consultation. It provides details on the renewable energy system across the six target countries, in the Irish and North Seas.

The objective of the Regional Concept Report is to develop a detailed plan of the combined energy infrastructure in the Irish and North Seas. The approach taken is consistent with current targets related to renewable energy and current network developments in the region. The level of detail is at single power plant resolution (e.g. offshore wind farms or wave power plants) and to a high level of detail for the grid infrastructure (e.g. number of cables in each corridor, technology specifications and ancillary equipment).

The Regional Concept Report does not intend to present a fully realistic projection of the system development roll-out. Rather, the study aims to show the impact of policy choices on system development by analysing the two extremes in offshore development: a fully radial and a fully meshed system. By focusing on two more extreme concepts the whole range of intermediate concepts is covered also. This is a common approach in long-term planning processes, which is also used by grid operators when making their long term projections on energy mix scenarios.

The Regional Concept Report varies on two aspects:

- The offshore generation capacity in place by 2030: ranging from business as usual to highly ambitious; and
- The grid design: ranging from no coordination (radial grid) to full coordination of wind farm connections and country interconnectors (meshed grid).

Some countries already coordinate their connections from offshore windfarms to shore through offshore (platforms/ hubs), e.g. Germany and the Netherlands. In the BEAGINS topologies all existing and decided hubs in Germany[2] and the Netherlands were included. Given that any grid development has its uncertainties, future projects for hubs, even those currently labelled as under consideration or in planning, have not been taken into consideration in the Regional Concept Report.

Within the Regional Concept Report three scenarios for the installed capacity of offshore renewables for the target year 2030 are considered. The adopted scenarios are based on adapted reference scenarios for the European offshore RES which are generally accepted by key stakeholders. For consistency, the scenarios, in general maintain similar capacity levels as in the 2014 EC Study of the Benefits of Meshed Offshore Grid.[3] The scenarios are as follows:

1. *High Renewables:* This scenario refers to a high level of offshore renewables deployment, combining multiple sources. The offshore wind capacity development (2015) is based on the European Wind Energy Association (EWEA)[4] 'High' wind energy scenario for 2030.[5] The wave and tidal capacity is based on the European Commission (EC) Energy Roadmap 2050 'High Renewable Energy Source' scenario[6] combined with the country-specific offshore energy roadmaps of Ocean Energy Services (OES) and an IEA Technology Initiative.[7]
2. *PRIMES Reference:* This scenario is similar to NSCOGI scenario, but presents a stronger deployment of offshore wind energy development.[8]
3. *NSCOGI:* This reference scenario was developed in 2011 by The North Seas Countries' Offshore Grid Initiative (NSCOGI)[9] in collaboration with the TSOs, governments and regulators. In this scenario, the year 2020 is based on ENTSO-E EU2020 scenario, following the national RES targets defined. The 2030 scenario is based on the PRIMES model, and was adjusted to take into account the views of national authorities.[10]

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2 http://amscap.eu/amscapwebsite/wp-content/uploads/2016/12/German-offshore-wind-development-2015.pdf

3 Cole, S., Martinot, P., Rapoport, S., Papaefthymiou, G. and Gori, V. (July 2014) 'Study of the Benefits of a Meshed Offshore Grid in Northern Seas Region'. Retrieved: https://ec.europa.eu/energy/sites/ener/files/documents/2014_nsog_report.pdf

4 EWEA is now known as WindEurope. The scenario however is named the EWEA scenario and therefore we will remain referring to EWEA.

5 EWEA (August 2015) 'Wind Energy Scenarios 2030'. Retrieved: http://www.ewea.org/fileadmin/files/library/publications/reports/EWEA-Wind-energy-scenarios-2030.pdf

6 EC (2011) 'Impact Assessment – Energy Roadmap 2050 – Annex 1 Scenarios – Assumptions and Results'. Retrieved: https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1565_part2_0.pdf

7 Ocean Energy Systems: Annual Reports. Retrieved: https://www.ocean-energy-systems.org/library/countries-roadmaps/

8 EU Energy, Transport and GHG Emissions Trends to 2050 Reference Scenario 2013. Retrieved: http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf

9 North Seas Countries' Offshore Grid Initiative. Retrieved: http://www.benelux.int/NSCOGI/

10 PRIMES results were refined based on recent developments. During the stakeholder consultation process these were checked and approved.

Impact Dictionary

In order to inform the full scope of the Baseline Environmental Study, it was considered necessary to identify the range and type of impacts that could arise as a result of the development of an offshore energy system. Therefore, an Impact Dictionary was developed, designed to be a searchable digital document that can be accessed by the majority of users.

The key sensitivities and impacts are arranged in an Excel file and reflect the broad topics which are generally included in SEA, and also follow the outline of the Environmental Baseline which is discussed further below in **Section 1.3: Environmental Baseline**. It is intended that the Impact Dictionary should be utilised in conjunction with the Environmental Baseline and Data Catalogue (discussed below in **Section 1.3: Data Catalogue**) to inform developers and regulators whenever new plans and projects require environmental assessment (SEA or EIA) or assessment of Natura 2000 sites (AA). This will allow for environmental considerations to be incorporated into plans and projects early in the policy, design or planning processes.

It will help flag key relevant impacts and environmental receptors for consideration at an early stage, or help to focus on the issue areas of particular relevance for an area.

Data Catalogue

Alongside the development of an Impact Dictionary it was considered necessary to compile a robust geographic information system (GIS) database. GIS has been used as an integral part of this Baseline Environmental Study to ensure that all relevant datasets to the energy system are sourced and collated. ESRI ArcGIS, being a widely used GIS system, was utilised as the main GIS software for the data storage. The approach taken to collate the spatial datasets involved key data holders, data clearinghouses, relevant studies/ projects and relevant departments in both the European and target Member States.

In order to identify the range and type of spatial datasets that could be utilised in decision support for energy system development and to facilitate user-friendly access, a Data Catalogue was compiled. The structure of the Data Catalogue is arranged as per the headings typically included in an SEA, in order to best facilitate Member States. The Data Catalogue holds information on the data format, data owner, links to full metadata and disclaimer and licence status. The Data Catalogue will give users the ability to: search for and view metadata; download data; request data from the original source; and link data to the impacts. It is intended that the Data Catalogue will be available to users through an online web portal. Discussions are currently ongoing within DG Energy as to the most suitable web host (e.g. the European Atlas of the Seas).

Environmental Baseline

The information collated through the Data Catalogue was utilised to inform the Environmental Baseline and has also facilitated the generation of a suite of static maps. Given the volume of information collated for the Environmental Baseline and to facilitate readability a summary is provided in **Chapter 5**, with the full baseline presented in **Appendix D**.

The Environmental Baseline examines the relevant significant issues of the current state of the environment in relation to: biodiversity, flora and fauna; population and human health; soils, geology and sediment; water; air quality and climatic factors; materials assets; cultural heritage and landscape and seascape, as well as the interrelationships between these factors. This baseline has been compiled using available datasets and data sources some of which were identified during the scoping phase.

1.4 Alternatives

Strategic Alternatives were considered in the context of the Regional Concept Report. The alternatives considered are referenced to the overarching objectives of the study i.e. to provide a concept for an integrated offshore electricity transmission network across multiple jurisdictions.

Each of the three capacity scenarios discussed in **Section 1.3: the Regional Concept Report** will have to develop grid configurations to ensure optimal connection to RES. There are two principle types of grid connection configurations for offshore renewable energy, namely radial and meshed, and there are levels of coordination between these two extremes at national and international level. The focus of alternatives has therefore been at the grid alternative, specifically radial and meshed alternatives.

The development of an offshore energy system in the North Sea will present a significant opportunity towards meeting the EU's energy objectives and corresponding positively impact on future growth, employment and the environment. Considering the radial versus meshed grid solutions in this case, the radial presents the greater potential for impact on the environment. Ultimately this is down to the greater lengths of cable which would need to be installed in creating individual connections from wind farms, with a greater number of landfall points and with little to no integration with existing grid structures. The meshed grid may require a more localised concentration of associated infrastructure (e.g. hubs, connectors) however the meshed grid takes advantage of the ability to tee-in to existing grid options or presents an opportunity to group renewable source connections with the need for less cabling. This has knock-on positive impacts in terms of reduced environmental footprint and disruption or exclusion to other maritime users.

Broadly speaking the preferred alternative is towards the meshed configuration as it offers the greatest potential to avoid or reduce environmental conflict. This is however subject to sensitive routing and siting of infrastructure, regardless of the final configuration chosen at local level.

1.5 Environmental Assessment

The purpose of the Impact Assessment is to evaluate, as far as possible, the likely significant effects on the environment of implementing the concepts envisaged within the Regional Concept Report. As noted previously in **Section 1.3**, the Regional Concept Report outlines three capacity scenarios. These are:

1. A high ambition renewables scenario (High Renewables);
2. A moderate ambition scenario similar to NSCOGI but with more wind energy deployment (PRIMES Reference); and
3. A moderate ambition scenario (North Seas Countries' Offshore Grid Initiative or NSCOGI).

The High Renewables Scenario refers to a high level of offshore renewable energy deployment, combining multiple energy sources, and is considered for the purpose of this Baseline Environmental Study to represent the highest intensity deployment. **Figure 1-3** presents the High Renewables Scenario using a meshed grid system which broadly reflects the preferred grid solution alternative discussed in **Section 1.4**. As such, it is considered the most appropriate scenario to explore in terms of opportunities and constraints as both PRIMES and NSCOGI represent reduced levels of capacity in comparison and could reasonably be considered to have also been addressed as a result.

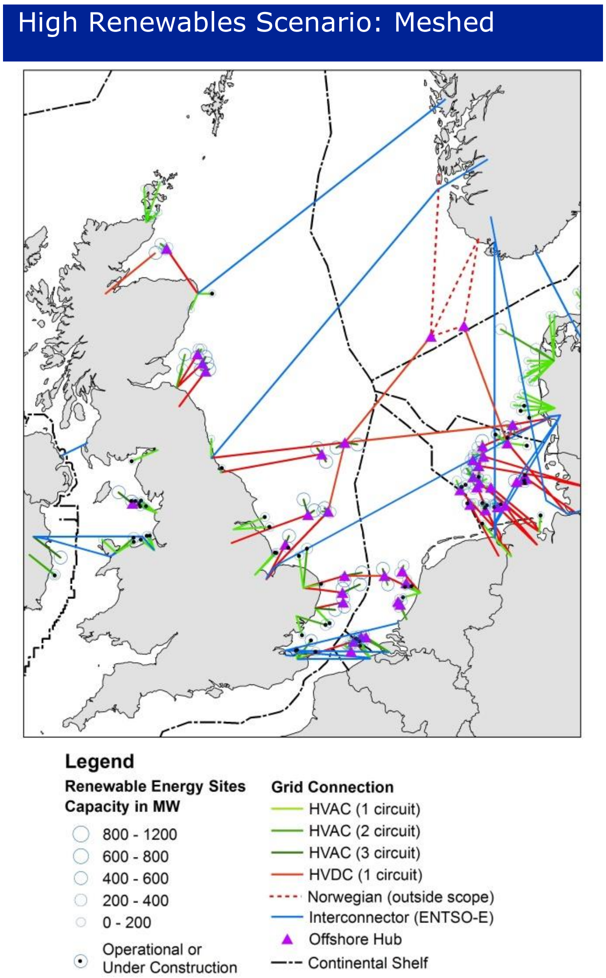

Figure 1-3 - High Renewables Scenario under a Meshed Grid Solution

The delivery of the High Renewables Scenario would see the deployment of up to 76.6 GW of renewable energy in the Irish and North Seas. The vast majority of this would be in the form of wind energy although there are also concentrations of wave and tidal energy anticipated off the northwest coast of Scotland and along the Danish coast.

There are obvious benefits to the delivery of the High Renewables Scenario, not least the reduced reliance on fossil fuels and improved air quality. However there is no doubt that a high level of offshore renewables deployment, combining multiple sources, as envisaged under the High Renewables Scenario has the potential to both positively and negatively impact on the wider environment across a range of receptors. Much of the impact from the offshore elements relate to biodiversity through direct conflict (e.g. collisions, loss of habitat, smothering etc.) or indirect impacts (increased effort required for feeding, avoidance behaviour etc.).

Closer to shore, the biodiversity impacts are compounded by impacts to people as they occupy the inshore and coastal areas to a much greater extent be it as resident or visitors.

The impact assessment has identified as far as possible the key issues of concern, and where appropriate has included mitigation measures, as outlined in **Table 1.1**. It should be noted that the Regional Concept is inherently flexible in nature and much of the potential impact associated with the meshed grid can be mitigated by sensitive siting and routing along with a better understanding of the complexities of the receiving environment.

Table 1.1 - Key Issues and Proposed Mitigation Measures

Key Issues	Mitigation Measures
Biodiversity, Flora and Fauna	
• Sensitive siting and routing of energy generators and cable routing is required to minimise impacts on protected habitats. • The nature of protected areas and designations must be fully understood relative to the infrastructural element as not all aspects will pose risk for all protected habitats or species. • Considerable uncertainty remains in terms of potential for impacts as a result of wave and tidal devices. • Evasion or avoidance responses may be more prevalent than collision for mammals. • There is a lack of information on displacement effects as a result of impulsive sound and the associated impact at the population level. • There are large gaps in understanding of the response to EMF.	• Apply industry standard siting and routing guidelines. • Long-term studies into the effect of wave and tidal devices required. • More detailed telemetry data needed to provide information on evasion / avoidance responses. • More detailed studies on mammal hearing thresholds and hearing recovery rates needed. • Research and field studies needed on dose-response assessments for invertebrates, fish and commercially-sensitive species and exposure assessments for baleen whales where there is spatial overlap with RES and the occurrence of these taxa. • Targeted research needed into the effects and significance of EMF (e.g. dose-response and exposure assessments for various species).
Population and Human Health	
• Offset of carbon through use of renewable energy and contribution to reduced greenhouse gas emissions. • Conflict with existing users of the sea (e.g. fishing, recreational boating) and potential exclusion from recreational areas. • Collision risk with other ships or RES. • Health concerns regarding EMF and proximity to overhead lines.	• Collation of recreation and amenity datasets needed at Member State level in order to better quantify the impacts to recreation and amenity users. • Develop good siting and routing guidelines for avoidance of built-up areas (e.g. undergrounding, minimum distances, cable shielding etc.).
Soils, Geology and Sediment	
• Permanent alteration of the seafloor. • Potential for loss of or sealing of soils. • Localised scouring around foundations, also affecting sediment transport. • Effects from wave and tidal devices less well understood.	• Undertaking of appropriate bathymetric, geophysical and oceanographic surveys • Good siting principles to avoid sensitive benthic habitats, polluted sites, dredge spoil, munitions dumps or dangerous shipwrecks. • Project level requires detailed seabed modelling of seabed, sediment processes and local bathymetry.
Water	
• The impacts to water quality as a result of renewable energy development are not fully understood. Lack of quantified studies and monitoring data on	• Compliance with MARPOL and follow industry best practice guidance for working over water. • Use of appropriate ship management systems including

Key Issues	Mitigation Measures
water quality, in particular quantification of long-term impacts. • Potential for accidental losses of contaminants (from ships and RES/ grid). • Legacy contaminated sites and potential for disturbance.	Health and Safety Plans and reduce the effects of contamination or incidents occurring through for instance implementation of Shipboard Oil Pollution Emergency Plan (SOPEP). • Long-term studies into the effects of wave and tidal devices on hydrography.
Air Quality and Climate	
• Localised impacts to air quality with an associated carbon footprint associated with the manufacturing, transport and installation of RES and grid.	• Aim to ensure that the carbon footprint associated with RES and grid development is 'carbon neutral' and preferably 'carbon positive'.
Material Assets	
• Potential for exclusion from opportunity or resource areas.	• The presence of RES and/or grid may not necessarily preclude usage of an area, and will depend on best practice in different jurisdictions, the extent of safety/ exclusion zones and what types of activity are permitted in certain circumstances etc.
Cultural Heritage	
• Impacts on cultural heritage features which have yet to be discovered. • The positional accuracy of subsea heritage can vary depending on the survey date (e.g. older GPS coordinates are less reliable).	• Avoid known heritage features by a suitable distance. • Allow sufficient time to resolve conflicts with cultural heritage, either through avoidance or proper investigation and recording of features for the historical record. • Report new heritage features as discovered during RES and grid development.
Landscape	
• None/ limited impact to landscape if wind farms are situated beyond the visible horizon. • The visual impact from turbine nacelle lighting or other safety/navigational features are uncertain.	• Avoid highly sensitive landscape and seascape designations in the first instance. • Apply sensitive siting principles such that infrastructure does not fragment the landscape, fills a bay/ lough/ narrow, or otherwise provides an unreasonable obstruction to views.

1.6 Recommendations

During the development of this Baseline Environmental Study a number of key issues were identified by the study team, in addition to stakeholder consultation. These issues relate to both practical implementation of the regional concept, such as coordination and governance, and strategic considerations of a regional scale such as overall data management, guidelines etc. A number of recommendations have been provided that reflect an integrated meshed grid scenario and includes:

- Planning Framework;
- Coordinated Infrastructure Roll-out;
- Management Framework to Minimise Environmental Impacts;
- Data Management and Storage;
- Best Practice Guidance; and
- Monitoring and Data Requirements.

Under the Planning Framework it is recommended that phased Regional Implementation Plans be developed, which have regard to a Regional Concept and the findings of this Baseline Environmental Study. The plans will outline policies and objectives for the implementation of offshore RES, grid cabling and associated equipment including hubs.

To adequately support the existing coordination initiatives, both EU and Member State regulatory approaches must encourage opportunities for synergies in connecting renewable energy infrastructure and grid infrastructure. Given that the full capacity of a hub may not be realised for many years and inhibits higher costs and risks, private developers will not take the initiative for such significant investment and continue to try to deliver individual radial solutions. Consideration should therefore be given to support or possibly mandate a developer (TSO or based on competitive bids) to put in place key hub points up front so that any investor would only be required to invest in the connection to the hub. Such a hub approach is already implemented in the Netherlands, Germany and Belgium, though still from a national perspective with the hubs being directly connected to shore. No hubs are planned yet based on Regional Planning with wind farms for different countries tying in, nor are these hubs planned from the perspective of linking to interconnectors where it would lower societal costs. A regional view could find the appropriate phased solutions of hubs and key strategic hubs could be developed within the first phase of one of the Regional Implementation Plans.

It is recognised in the planning framework recommendation, that formal SEA under Directive 2001/42/EC should be considered for multi-phased roll out of Regional Implementation Plans. It is recommended that following SEA, an Environmental Management System (EMS) type approach should be considered for projects arising from the plans. An EMS will facilitate the development of processes and practices which allow the coordinating Member States to reduce environmental impacts. Key elements of such an EMS would be to develop agreed templates for Environmental Management Plans, Environmental Impact Assessments, Monitoring and Mitigation Plans and Stakeholder Engagement Plans which identify the agreed acceptable standards (note this should not necessarily be a minimum acceptable standard but rather an agreed acceptable standard for participating Member States). It is acknowledged and accepted that Member States may have specific local requirements reflecting their specific environmental sensitivities and these can and should be accommodated beyond any agreed standard template.

To address the data management issues in the short to medium term, before the potential frameworks such as Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD) are fully in place, the BEAGINS study has developed a searchable Data Catalogue which identifies both the scope and source of spatial datasets under defined environmental topic headings. The intention is that this tool will assist Member States in the planning and rollout of coordinated RES and grid as they move through planning. In order to maximise the access to this tool and make it as user-friendly as possible, it is intended that this Data Catalogue will be made available through an online web portal. Discussions are currently ongoing with a number of host sites. Alongside the future maintenance of the Data Catalogue, it is anticipated that new data will become available over time and this should be added as appropriate by each Member State representative. To be of most use and to integrate with the existing data, all new data should align with specific criteria that have been outlined in the recommendation.

Best practice guidance is also recommended in order to establish coordinated approaches to undertaking surveys/data gathering exercises, agreed limit values to inform marine environmental assessments and siting guidance for landfall points. It is recommended that a cross-jurisdictional group (such as the existing North Sea Support Group on Maritime Spatial Planning or newly established group if necessary) be identified to develop in the first instance, an overarching methodology for marine assessments and marine monitoring. The group should also oversee long-term monitoring and coordinate the dissemination of relevant information to the target Member States.

Lastly in relation to Monitoring and Data Requirements, a structure is required across the Member States to facilitate the storage, collation and public accessibility of monitoring data and to also provide advice on proposed large scale monitoring programmes. Consideration should be given to establishing a centralised data centre for offshore energy projects. As a minimum, those receiving EU funding or support should be required to submit monitoring data and monitoring programmes for general access. In addition, it has also been recommended that a programme of evidence base studies is funded and developed to specifically address uncertainties in relation to the delivery of an offshore energy system. A prioritisation of key data gaps to be addressed as part of the proposed evidence base studies has also been outlined, such as studies into the effects of multiple sources of electromagnetic fields (EMF) on marine organisms from the deployment of grid cables.

2 INTRODUCTION

2.1 Background to BEAGINS

The development of an offshore renewable energy system in the Irish and North Seas represents a significant opportunity towards meeting the European Union's (EU) energy, environmental, growth and employment objectives. The region has a vast renewable energy potential that could provide a significant share of Europe's power supply by 2030 and beyond. Furthermore, such a regional energy system could also contribute to the further integration and flexibility of the electricity market in northwest Europe, which is an important step towards a single European electricity market and improved energy security within the EU. To ensure that environmental concerns and impacts are appropriately considered in the development of such an offshore energy system, the European Commission has appointed a multi-disciplinary team to prepare an environmental study. This baseline study has been named BEAGINS which stands for **B**aseline **E**nvironmental **A**ssessment for the **G**rid in the **I**rish and **N**orth **S**eas.

This Baseline Environmental Report, prepared as part of the study, sets out the effects (both positive and negative) of future energy and grid scenarios up to 2030. The future energy and grid scenarios have been developed as a complementary part of the study in the form of a Regional Concept Report.[11] Details of the Regional Concept Report are outlined further in **Chapter 3** of this report. The Regional Concept Report shows the two extremes in offshore development: a fully radial and a fully meshed system. By focusing on two more extreme concepts the whole range of intermediate concepts is covered as well. The study area for BEAGINS has been developed with reference to work carried out for the Regional Concept Report, and includes the territorial waters of Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom (UK).

It is intended that this Baseline Environmental Study and associated report may be used to inform future plans for renewable energy generation, energy storage, grid cables and associated equipment in the Irish and North Seas. It will be available as a resource for the relevant Member States and stakeholders to inform environmental assessments, such as Strategic Environmental Assessment (SEA), Appropriate Assessment (AA) and Environmental Impact Assessment (EIA), as appropriate. This will allow for commonly agreed environmental baselines to be incorporated into the assessment of plans, programmes and projects early in the policy, design or planning processes.

2.2 Study Area

The study area for this Baseline Environmental Study includes the territorial waters of Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom. It reflects the possible objectives in terms of renewable energy development in the Irish and North Seas, the infrastructure plans contained in the Ten-Years Network Development Plan of ENTSO-E and the list of Projects of Common Interest adopted under the Guidelines for the Trans-European Energy Network. The study area has also been developed with reference to work carried out for the Regional Concept Report. An outline of the broad study area for the Baseline Environmental Study is presented in

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11 Ecofys (2017) Regional Concept Report.

2.3 Objectives of the Study

Prior to the EU SEA Directive 2001/42/EC on the Assessment of the Effects of Certain Plans and Programmes on the Environment, there was no formalised way of ensuring that the environment was taken into account at the plan making stage. There simply was an expectation that environmental impacts could be assessed and mitigated at the project level through EIA. The SEA Directive fundamentally changed this and aims to ensure that environmental considerations are integrated into plans prior to their adoption. It emphasises the importance of considering the environment early in the process before projects are conceived and provides an opportunity to further integrate with other pieces of environmental legislation e.g. the Water Framework Directive and Habitats Directive. The provisions of the SEA Directive apply to plans and programmes which are subject to preparation and/ or adoption by an authority at national, regional or local level or which are prepared by an authority for adoption through a legislative procedure. An SEA is mandatory for plans and programmes which are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste or water management, telecommunications, tourism, town and country planning or land use and which set the framework for future development consent of projects listed in the EIA Directive 2014/52/EU[12] or which have been determined to require an assessment under Article 6 or 7 of the Habitats Directive 92/43/EEC.[13]

It is acknowledged that the capacity scenarios and grid infrastructure contained within the Regional Concept Report, discussed in **Chapter 3**, are not applicable to the provisions of the SEA Directive. However, it is acknowledged that there must be a strong commitment from the outset of this type of EU regional planning to ensure that Member States can employ the highest degree of environmental protection through the provision of sound environmental protection measures and policies from plan inception through to project realization. With this in mind, DG Energy have identified the baseline study as a tool to assist Member States in realization of EU-wide and national renewable energy targets by providing:

- A source of data on baseline, impacts and mitigation which can be applied across and within jurisdictions.
- A forum for identification of data gaps and coordination of responses between Member States.

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12 Directive 2014/52/EU. Retrieved: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0052&from=EN

13 Council Directive 92/43/EEC (The Habitats Directive). Retrieved: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01992L0043-20070101&from=EN

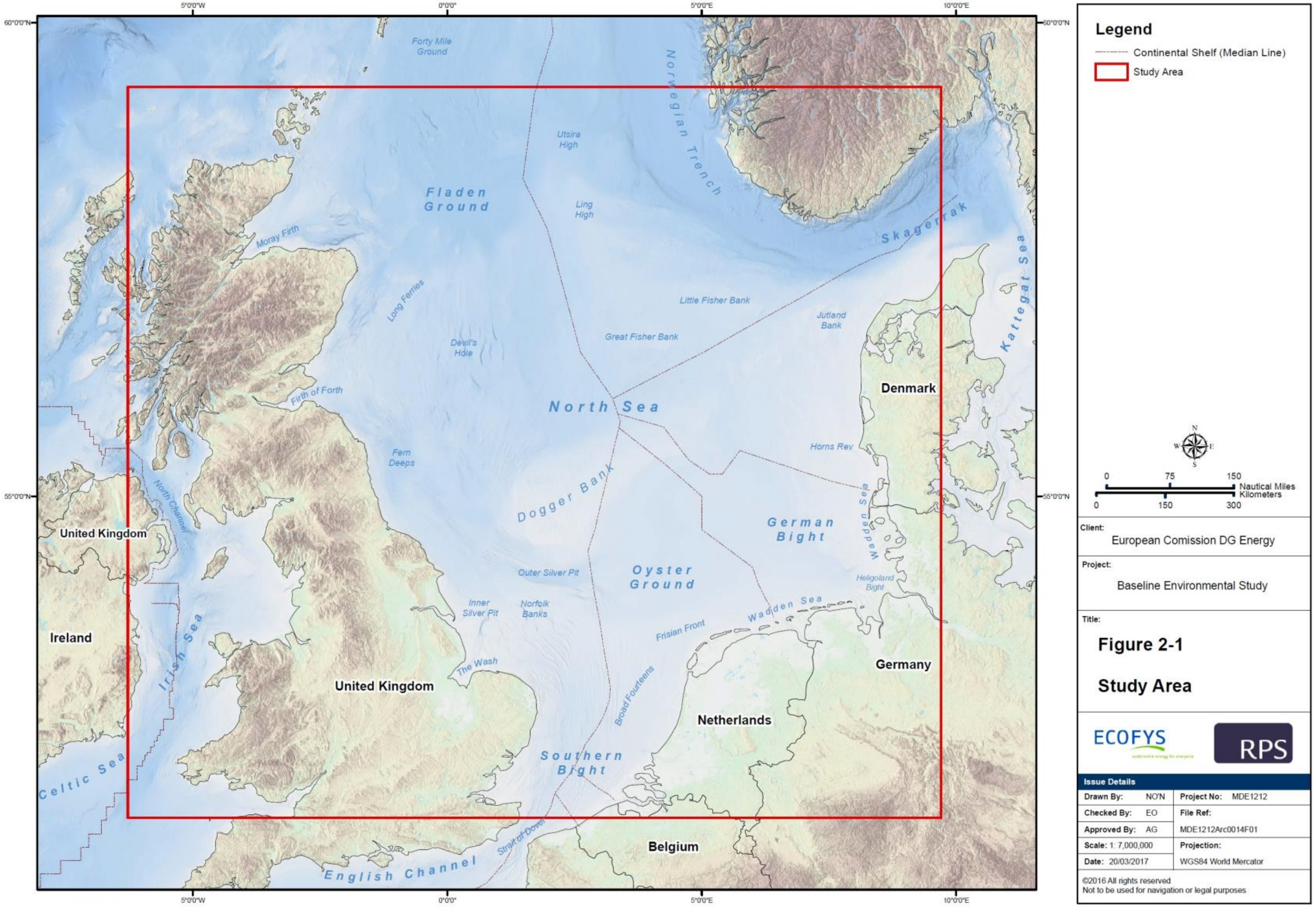

Figure 2-1 - Study Area

The key objectives of the Baseline Environmental Study are to:

- Describe, identify and assess the likely significant effects on the environment of implementing a regional concept;
- Assess reasonable alternatives to implementing the regional concept;
- Provide decision-makers, the EU and other stakeholders with relevant information (quantitative and qualitative) to assess the adequacy of environmental considerations when supporting the implementation of the regional concept; and
- Provide recommendations at strategic level on how potential negative effects can be minimized and how positive effects can be optimized.

In addition to the key objectives outlined for this Baseline Environmental Study it must be recognised that significant developments have occurred for offshore renewable energy since the commencement of the Study in early 2016. Since the summer of 2016 costs of building and operating future windfarms have decreased significantly and the Power Link Island cooperation agreement between TenneT TSO B.V. (Netherlands), Energinet.dk (Denmark) and TenneT TSO GmbH (Denmark) was signed at the North Seas Energy Forum held in March 2017. The cooperation agreement was signed by representatives TenneT and Energinet in order to develop a Wind Power Hub which will involve building artificial island hubs in order to facilitate the development of large scale far offshore wind farms. The intended infrastructure on the hubs will link wind farms in the North Seas region and transmit the electricity they generate to Belgium, Denmark, Germany, the Netherlands, Norway and the United Kingdom via interconnections.

2.4 European Policy Context

The EU has defined ambitious objectives for decarbonisation through the efficient use of renewable energy sources (RES), their continued development and the acknowledgement of a cost associated with carbon emissions in several sectors of the economy. Targets and objectives for RES development and energy efficiency have been defined for 2020 and negotiations are ongoing for 2030. In addition, the European Commission has also tabled scenarios where carbon dioxide (CO_2) emissions would be reduced by 80 to 95% between 1990 and 2050. In that respect, the development of an offshore grid in the Irish and North Seas represents a significant opportunity towards meeting these environmental objectives, as it would support the significant integration of offshore wind in the North-West European grid together with other forms of renewable energy generation and energy storage.

Renewable Energy

The Renewable Energy Directive 2009/28/EC, establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020, to be achieved through the attainment of individual national targets. By using more renewables to meet its energy needs, the EU will lower its dependence on imported fossil fuels and make its energy production more sustainable. To achieve this binding target of 20% final energy consumption from renewable sources by 2020, EU countries have committed to reaching their own national renewables targets (**Figure 2-2**).

For the Member States within the study area, the following respective targets apply for 2020: Belgium (13%), Denmark (30%), Germany (18%), Ireland (16%), the Netherlands (14%) and the United Kingdom (15%). The EU countries have adopted national renewable energy action plans outlining what actions they intend to take to meet their renewables targets. Renewables will continue to play a key role in helping the EU meet its energy needs beyond 2020. EU countries have already agreed on a new renewable energy target of at least 27% of final energy consumption in the EU as a whole by 2030 and focus is required towards the 2050 targets.

In tandem with the generation of renewable sources of energy, the EU Energy Efficiency Directive 2012/27/EU, establishes binding measures to help the EU reach its energy efficiency target of 20% by 2020. EU countries are required to use energy more efficiently at all stages of the energy chain through from production to final consumption.

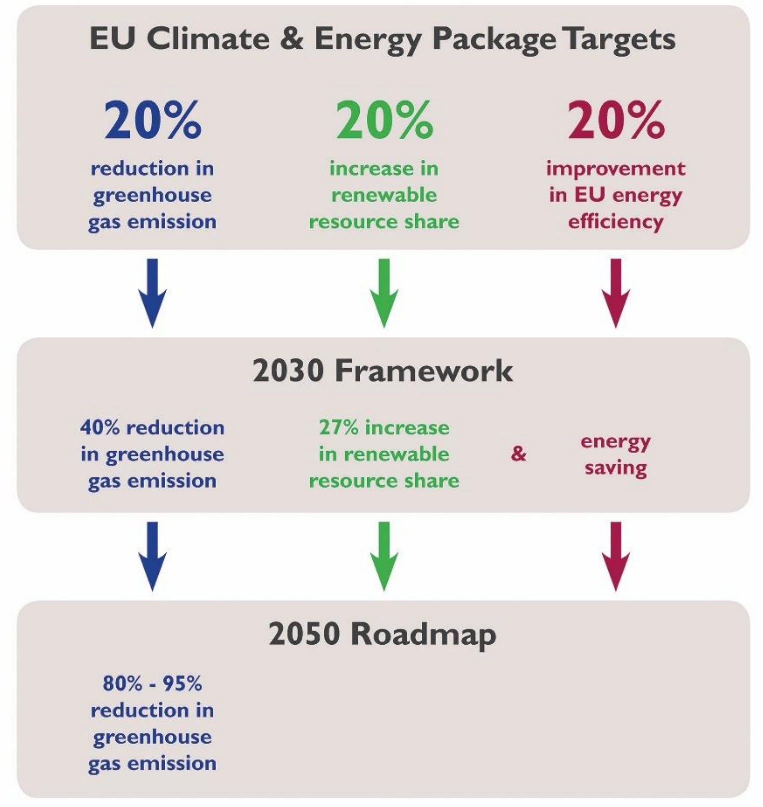

Figure 2-2 - EU Climate and Energy Package Targets

Climate Change and Decarbonisation

The United Nations Intergovernmental Panel on Climate Change (IPCC) states that there is now "unequivocal" evidence of climate change. In 2007, the EU Climate and Energy Package agreed targets referred to as the EU-20-20-20 Agreement which is described as a "*package of binding legislation to ensure the EU meets its climate and energy targets for the year 2020*." The Agreement sets three key targets; a 20% cut in EU greenhouse gas (GHG) emissions on 1990 levels; 20% of EU energy from RES and a 20% improvement in energy efficiency.

The European Commission published the 2030 EU Climate and Energy Package[14] which continues on from the base set out in the 2020 Climate and Energy Package. The 2030 framework proposes new targets and measures to make the EU's economy and energy system more competitive, secure and sustainable. It includes targets for reducing greenhouse gas emissions and increasing use of renewable energy, and proposes a new governance system and performance indicators. In 2014, the policy framework for climate and energy outlined three key targets for the year 2030:

- At least 40% cuts in GHG from 1990 levels;
- At least 27% share for the renewable energy; and
- At least 27% improvement in energy efficiency.

14 COM(2014) Commission Communication on a Policy Framework for Climate and Energy from 2020 to 2030

The agreement on the 2030 framework, specifically the EU domestic greenhouse gas reduction target of at least 40%, will form the basis of the EU's contribution to global climate change. At the Conference of the Parties in Paris (COP21), for which Belgium, Denmark, Germany, Ireland, the Netherlands, and the United Kingdom are Members, the Paris Agreement (2015) was produced. This agreement includes "*holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels*" as its overarching objective.

The longer term perspective as set out in the EC's Energy Roadmap 2050 is for moving to a low carbon economy in 2050. The ultimate goal is to cut EU-wide emissions by 80-95% of 1990 levels by 2050. Based on the premise that achieving this reduction in greenhouse gas emissions will require EU energy production to become almost carbon free, the roadmap explores the challenges of delivering on this decarbonisation objective for the energy sector, while at the same time ensuring security of supply and competitiveness.

More recently in July 2016, a communication was issued from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, titled:

'*Accelerating Europe's transition to a low-carbon economy – Communication accompanying measures under the Energy Union Framework Strategy: legislative proposal on binding annual greenhouse gas emissions reductions by Member States from 2021 to 2030, legislative proposal on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and communication on a European Strategy for low-emission mobility.'*

It concludes that "*Europe's transition to the low-carbon economy needs to accelerate*".

Energy Security

The EUs goal of decarbonisation and increased usage of renewable energy is further supported by 2014/94/EU on the Deployment of Alternative Fuels Infrastructure. The directive addresses a situation where more than 90% of the energy used in transport within Europe is derived from crude oil, most of which is imported. Through the Directive 2014/94/EU, the Commission is aiming to resolve this cycle of dependence through the introduction of binding targets on Member States for a minimum level of infrastructure for clean fuels. Electricity is one of the clean fuels specified in the directive and with the focused establishment of supporting infrastructure by Member States for electricity usage in transport there is a likely scenario that future demands for electricity will rise. This is directly applicable to the establishment of offshore renewable resources and their connection to the existing electricity grid.

The wider picture sees that the EU imports more than half of all the energy it consumes and many countries are also heavily reliant on a single supplier, including some that rely entirely on Russia for their natural gas. This dependence leaves them vulnerable to supply disruptions. In response to these concerns, the European Commission released its Energy Security Strategy[15] in May 2014. The strategy aims to ensure a stable and abundant supply of energy for European citizens and the economy.

15 COM (2014) The Communication from the Commission to the European Parliament and the Council on European Energy Security Strategy (COM/2014/0330 final)

It also addresses both short and long-term measures including:

- Increasing energy production in the EU and diversifying supplier countries and routes. This includes further deployment of renewables, sustainable production of fossil fuels, and safe nuclear where the option is chosen; and
- Completing the internal energy market and building missing infrastructure links to quickly respond to supply disruptions and re-direct energy across the EU to where it is needed.

The strategy recognises that the EU can reduce its dependency on particular suppliers and fuels by maximising its use of indigenous sources of energy including renewable energy. It concludes that the transition to a competitive, low-carbon economy will reduce the use of imported fossil fuels by moderating energy demand and exploiting renewable and other indigenous sources of energy.

European Maritime Spatial Planning

In recent years maritime spatial planning has been increasingly required to effectively and sustainably manage global, European and national marine waters. The reason for this is the ever increasing use and exploitation of the maritime space and its resources by a cross-section of stakeholders involved in a number of sectors including offshore renewable energy, cable and pipeline infrastructure, oil and gas, fishing, shipping, aquaculture and recreation, sport, leisure and tourism. Maritime spatial planning contributes to the management of these sectors and their associated activities to enable effective coordination that reduces potential conflict and helps meet environmental, economic and social objectives. Maritime spatial planning is a practical way of managing maritime resources and space in combination with environmental requirements and sector-specific policy goals.

In the Irish and North Seas, such planning is a key tool to enhance the offshore grid and advance offshore renewable energy development in the region. Indeed, considering the increasing spatial demands and growing competition between sea users, maritime spatial planning outputs (i.e. the maritime spatial plans) can provide certainty for investors and can help to reduce the costs of harnessing RES through optimal integration of generation assets infrastructure. The Littoral States of the Irish and North Seas are continuously updating their national plans where areas for the development of RES, energy storage, grid cable infrastructure and associated facilities are usually defined.

The European Commission's intention is to support the development of maritime spatial planning throughout the EU, by facilitating cooperation between Member States in the management of sea basins surrounding the EU. In July 2014, the European Council adopted legislation to establish a framework for the implementation of maritime spatial planning in EU waters (2014/89/EU) with the objective to promote the sustainable growth of maritime activities. The Maritime Spatial Planning Directive (MSPD) supports on-going implementation of sea-related policies in Member States through more efficient coordination and increased transparency. At an early stage, the MSPD can improve the articulation of, and reduce potential conflicts between, economic objectives and environmental legislation. While each EU country will be free to plan its own maritime activities, Member States are required to develop and implement coherent processes to plan human uses of maritime space, and to establish appropriate cross border cooperation among them.

The MSPD obliges all coastal Member States to establish maritime spatial plans as soon as possible and at the latest by 31st March 2021. The implementation of this directive and the establishment of maritime spatial plans will integrate maritime users and their activities as well as environmental requirements e.g. protected sites e.g. Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Marine Protected Areas (MPAs).

All of the Member States within the Baseline Environmental Study undertake some degree of maritime spatial planning and support the advancement of sectors and their policies e.g. offshore wind energy, in conjunction with other maritime activities and environmental requirements. It is acknowledged that the level of planning is neither consistent between Member States or between sectors within each Member State. A sectoral approach has been a driving force for the development of maritime spatial planning in Member States to date, however it is recognised that problems do exist with the implementation of this approach and that the MSPD is not sector-specific.

European Maritime Protection

The EU Marine Strategy Framework Directive (MSFD) 2008/56/EC has adopted an ecosystem-based approach to protect and manage the marine environment. This forms an integral component of maritime spatial planning within the EU and requires Member States to develop a strategy to achieve or maintain Good Environmental Status (GES) in their marine waters by 2020. The strategy must include a Programme of Measures that will meet targets set in order to achieve or maintain GES. GES is defined by the MSFD as: "*the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations,…*"

The development and implementation of the MSFD is a cyclical process that is repeated every six years, initially commencing in 2012 with the second period of reporting beginning 2018. This ensures that, as new and more detailed information becomes available through better scientific understanding, the results from ongoing monitoring and the implementation of measures, Member States will update their assessments and move towards achieving or maintaining GES.

The OSPAR Convention was established to protect the marine environment of the North-East Atlantic and came into force in 1998. Under this Convention contracting parties have committed to establishing a network of MPAs to protect biodiversity (called OSPAR MPAs). Significant areas of the North-East Atlantic have been designating as OSPAR MPAs, nearly 18% of the Greater North Sea (i.e. the North Sea also including the English Channel, Skagerrak and Kattegat) is currently within MPA boundaries (the highest amount in European seas). All of the Member States within the Baseline Environmental Study are contracting parties of OSPAR and as well committing to progressing and developing an ecologically coherent network of MPAs, also cooperate in terms of MSFD requirements.

There is no single definition for an MPA however they are understood to be geographically distinct zones for which conservation objectives can be set. MPAs are often established in an attempt to strike a balance between ecological constraints and economic activity, so that the seas may continue to allow for goods and services to be delivered. MPA networks are a collection of individual MPAs operating synergistically, at various spatial scales, and covering a range of protection levels, designed to meet objectives that individual MPAs cannot achieve.[16]

MPAs must be given consideration in maritime spatial planning and environmental assessment processes. Added importance is given to them through Article 13.4 of the MSFD which states that:

16 EEA Report No. 3/2015 Marine Protected Areas in Europe's Sea'. An Overview and Perspectives for the Future.

"*Programmes of measures established pursuant to this Article shall include spatial protection measures, contributing to coherent and representative networks of marine protected areas, adequately covering the diversity of the constituent ecosystems, such as special areas of conservation pursuant to the Habitats Directive, special protection areas pursuant to the Birds Directive, and marine protected areas as agreed by the Community or Member States concerned in the framework of international or regional agreements to which they are parties*".

In addition, the Water Framework Directive (WFD) 2000/60/EC establishes a framework for the protection/ enhancement of all waters (surface, ground and coastal waters). The WFD sets a goal of achieving Good Ecological Status for all EU ground and surface waters (including intertidal, transitional and coastal waters), which directly complements the goal of good environmental status (GES) under the MSFD. The WFD has subsumed the Shellfish Waters Directive 2006/111/EC, which aims to protect or improve shellfish waters in order to support shellfish life and growth. Whilst a large proportion of a RES (especially offshore wind projects) will be located in offshore waters, the cables and grid infrastructure will pass through and have a footprint in WFD waters. As well as this, projects will be connected to land and have an onshore footprint. Accordingly, the WFD is applicable to RES development and electrical grid cable infrastructure.

Environmental Conservation

There are a number of directives that form the backbone of the EU legislative context for environmental assessment of plans, programmes and projects delivering the renewable energy and grid infrastructure. The directives aim to provide a high level of protection for the environment and to contribute to the integration of environmental considerations into the preparation of plans, programmes and projects, with a view to avoiding or reducing their environmental impact.

Directive 2001/42/EC, known as the SEA Directive applies to a wide range of public plans and programmes including those related to land use and energy. The directive, which came into force in 2001, has been transposed into all of the target Member States included within the Baseline Environmental Study and all the Member States that have compiled national plans (both statutory and non-statutory) have applied this legislation. It is likely that further plans and programmes emanating from the regional concepts proposed in this study will also be required to consider environmental impacts under this directive. For those plans not mandatorily falling under this SEA legislation, screening may be required based on criteria set out in Annex II of the directive.

While SEA applies to plans and programmes, it is the Environmental Impact Assessment (EIA) Directive that applies to projects. The initial EIA Directive came into force in 1985 and underwent three amendments before being codified in 2011 (Directive 2011/92/EU). This directive was subsequently updated in 2014 by Directive 2014/52/EU and this must be transposed by all Member States by May 2017. The new directive places greater emphasis on the marine environment through the inclusion of a specific recital (12) which states that:

"*With a view to ensuring a high level of protection of the marine environment, especially species and habitats, environmental impact assessment and screening procedures for projects in the marine environment should take into account the characteristics of those projects with particular regard to the technologies used (for example seismic surveys using active sonars). For this purpose, the requirements of Directive 2013/30/EU of the European Parliament and of the Council*[17] *could also facilitate the implementation of the requirements of this directive.*

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17 Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations and amending Directive 2004/35/EC (OJ L 178, 28.6.2013, p. 66).

Similar to SEA, the objective of the EIA Directive is that before a decision is made to authorise project approval, those likely to have significant effects on the environment must undertake an assessment with regard to the potential effects".

To support the implementation of the EIA Directive, the commission has intermittently developed guidance for Member States, including guidance specifically relating to energy projects, particularly where transboundary issues will arise. This is likely to be the case for projects arising from current RES development for the Irish and North Sea.

Ecological Protection

Appropriate Assessment (AA) is required for any plan or project likely to have an adverse effect on the integrity of a European Site, designated pursuant to Directive 92/43/EEC (the Habitats Directive) or 2009/147/EC (Birds Directive). The ultimate objective is to ensure that the species and habitats reach "*favourable conservation status*". Where a plan or project will have a likely significant effect on a Natura 2000 site, an AA (required under Article 6(3) of the Habitats Directive) requires decision makers to establish *beyond reasonable scientific doubt* that adverse effects on site integrity in light of the conservation objectives of the site, will not result. It is important to note that the intention of the assessment process is not to preclude development which affects these European Sites but rather to ensure that adverse effects on the integrity of the site will not result. Where adverse effects may result but where there are no alternatives and where a project must be carried out for imperative reasons of overriding public interest (IROPI), compensation measures must be taken to ensure the overall coherence of the Natura 2000 network.

Complexities are intensified by the mobile nature of a number of bird, fish and mammal species in the wider marine environment and their life cycle which may include migratory routes, feeding areas, breeding/ spawning areas etc. Energy infrastructure plans, such as any offshore grid in the Irish and North Seas, is subject to these AA requirements, which can be usefully combined with SEA procedures, with a view to assessing potential impacts on Natura 2000 sites and identifying measures to prevent or mitigate those impacts and possible alternatives. In recognition of the possible conflicts arising from development of offshore renewables, guidance is anticipated from the EU to cover energy infrastructure and hydropower, which will complement existing guidance on wind energy and ports and harbours.

Research on Developing an Offshore Grid

Energy policy within Europe is geared towards three main objectives, i) affordable energy and competitively priced, ii) environmentally sustainable and iii) secure for everybody. The development of a grid in the Irish and North Seas linking the different littoral States will contribute to the further integration of the regional electricity market in North-West Europe, which is an important step towards the development of a single European electricity market.

The strategic importance of the grid has been pointed out previously in several key EU policy documents. The Second Strategic Energy Review (2008) identified the development of a blueprint for an Irish and North Seas' offshore grid interconnecting national electricity grids and plugging in planned offshore wind projects as one of six infrastructure priorities for the EU in the coming years. In 2010, the North Seas Countries Offshore Grid Initiative (NSCOGI) was established by a Memorandum of Understanding as a multilateral forum including governments, regulators, transmission system operators (TSOs) and the European Commission in order to offer necessary support with the implementation of the offshore grid. It is the body responsible to evaluate and facilitate coordinated development of a possible offshore grid that maximises the efficient and economic use of those renewable sources and infrastructure investments.

More recently, the new regulation on Guidelines for Trans-European Energy Infrastructure[18] designated the North Seas offshore grid as one of 12 priority corridors and areas. It defines this priority as the development of an integrated offshore electricity grid and related interconnectors in the Irish and North Seas, the English Channel, the Baltic Sea and neighbouring waters, in order to transport electricity from renewable offshore energy sources to centres of consumption and storage and to increase cross-border electricity exchange.

In addition, there have been many EU funded projects/ initiatives relating to renewable energy development and integration. The Offshore Grid Project[19] was the first in-depth analysis of how to build a cost-efficient grid in the North and Baltic Seas. As such, it is a compelling milestone in the development of a secure, interconnected European power system, able to integrate increasing amounts of renewable energy. The Offshore Grid project results are a practical blueprint for policymakers, developers and transmission grid operators, to plan and design a meshed offshore grid. The North Sea Grid[20] project, funded by the Intelligent Energy Europe (IEE) program, was the follow-up project of Offshore Grid.   THINK[21] was an FP7-financed project that advised the European Commission (DG Energy) on a diverse set of energy policy topics. A number of additional reports were produced over this period including "Offshore Grids: Towards a Least Regret EU Policy", "Study of the Benefits of a Meshed Offshore Grid in the North Seas Region"[22] and "Study on Regulatory Matters Concerning the Development of the North Sea Offshore Energy Potential."[23] Other initiatives include:

- E-Highway 2050 presents a top-down planning methodology to provide a first version of a modular and robust expansion of the Pan-European Electricity Network from 2020 to 2050;
- Baltic Integrid will provide a professional network for expertise exchange and a state-of-the-art interdisciplinary research on the optimisation of potential offshore wind energy in the Baltic Sea Region by applying the meshed grid approach;
- Best Paths aims to overcome the challenges of integrating renewable energies into Europe's energy mix;
- PROMOTioN aims to set up a regulatory framework for operation and management of meshed offshore grids governing legal, technical, and market-related aspects; and
- SEANERGY 2020 was an EU funded project – Intelligent Energy Europe programme. It was coordinated by the European Wind Energy Association. The project provided an in-depth analysis of the national and international maritime spatial planning practices, policy recommendations for developing existing and potentially new maritime spatial planning for the development of offshore renewable generation, and promoted acceptance of the results.

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18 Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009

19 Offshore Grid; Intelligent Energy Europe. Retrieved: http://www.offshoregrid.eu/

20 North Sea Grid: Offshore Electricity Grid Implementation in the North Sea. Retrieved: http://northseagrid.info/

21 Creating offshore electrical grids. Retrieved: https://www.thinkproject.com/en/projects/details/project/offshore-grid-connection-in-the-north-sea/pa/show/industry/5/country/0/

22 Study on the Benefits of a Meshed Offshore Grid in the North Seas Region. Retrieved: http://ec.europa.eu/energy/sites/ener/files/documents/2014_nsog_report.pdf

23 PwC, Tractebel Engineering, Ecofys. (2016) 'Study on the Regulatory Matters Concerning the Development of the North Sea Offshore Energy Potential'.

2.5 Approach to Baseline Environmental Study

As outlined in **Figure 2-3** a number of steps were undertaken during the development of the Baseline Environmental Report. The key steps involved; development of mapping for capacity scenarios and grid; scoping of the Baseline Environmental Report; development of the Regional Concept Report and compilation of the Baseline Environmental Report. The following sections describe the consultation process as part of the Baseline Environmental Study.

Scoping and Consultation

In early 2016 (April and May) the capacity scenarios and the topology for the grid connection, including its interconnectors, for the Regional Concept were consulted with stakeholders. The stakeholders consulted included TSO's and representatives of the Member States. The overall feedback was positive and agreed with the proposed purpose being that the locations of the RES for 2030 are intended only to provide a reasonable distribution achieving the capacities per scenario, and are not a reflection of any government policies or plans, which are subject to change.

In May 2016 a draft Scoping Report on the Baseline Environmental Study was published on the project website [www.beagins.eu]. This provided an overview and description of a number of features relating to the development of an energy system in the Irish and North Seas including:

- The institutional and legislative framework;
- The scope, objectives and conclusions of the existing national SEA studies relating to maritime spatial planning at national level;
- Key stakeholders;
- Key environmental aspects to be addressed in the Baseline Environmental Study and a description of the scope of the environmental baseline to be prepared; and
- Recommendations on specific impact identification and evaluation methodologies to be used.

As part of this Scoping Stage, each of the Member States were contacted and asked to contribute with reference to the draft scoping report. The Scoping Report was then used to inform the overall development of this Baseline Environmental Study.

In addition, during scoping the SEAs for the maritime plans within the Member States were reviewed and a summary included in **Appendix C**.

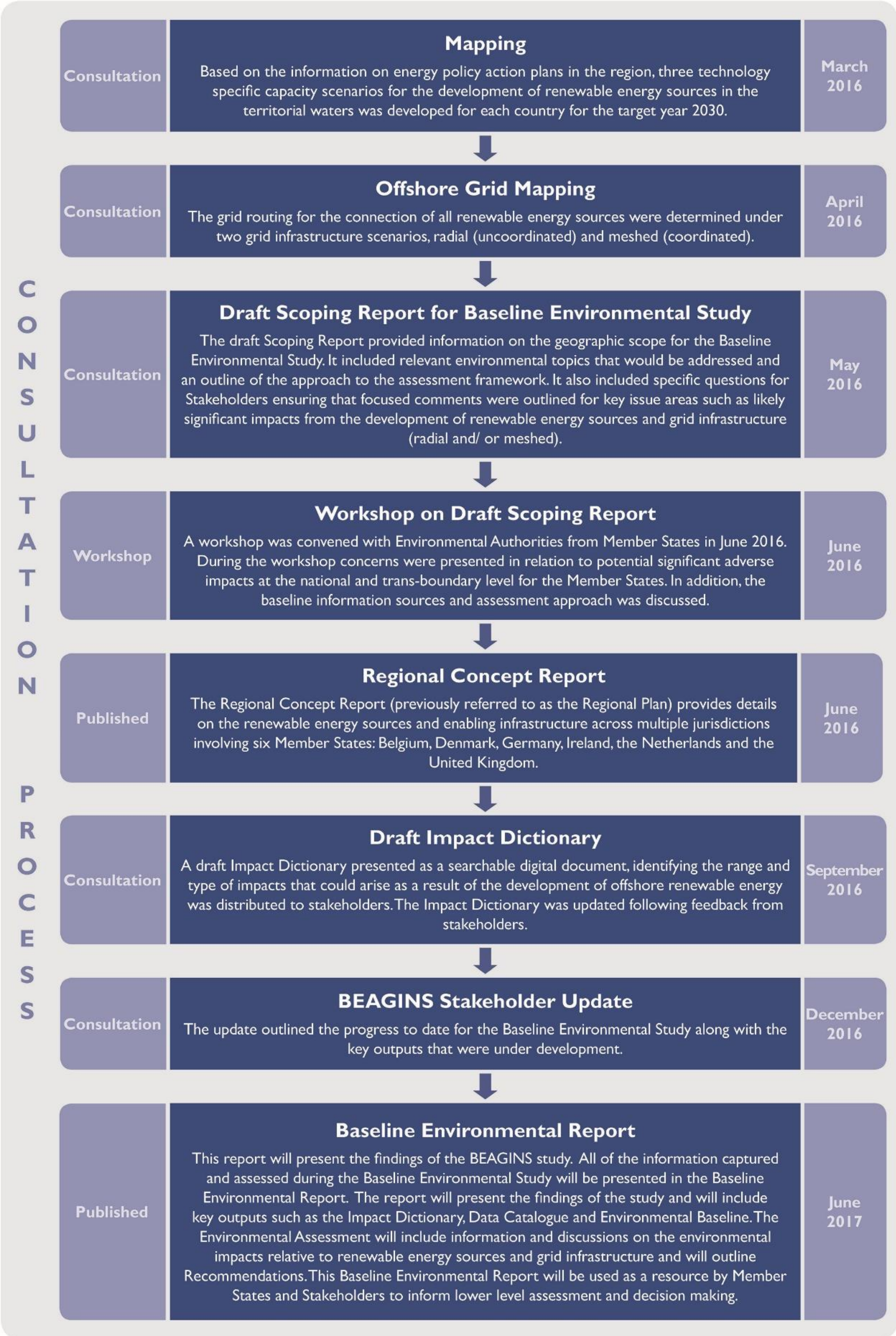

Figure 2-3 - Broad Approach to the Study

Workshop [17th of May 2016]

Environmental stakeholders from the Member States of Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom were invited to attend a workshop on the 17th of May 2016 in Brussels. The purpose of the workshop was to discuss the scope of the environmental topics required to develop a database of environmental risks, constraints and opportunities that may be employed to enhance and inform a future energy system in target Member States and to exchange information in relation to environmental scoping.

During the workshop the potential impacts associated with delivery of an energy system in the Irish and North Seas, the geographic extent of environmental constraints, interactions with other constraints and potential data sources and data gaps were discussed. The convening of the workshop provided an opportunity for the relevant Member States to come together to better understand and plan for cumulative and in-combination effects that may arise from implementation of such infrastructure.

The key issues discussed at the workshop included the following:

- Clarifications were provided in relation to their institutional and legislative frameworks;
- Suggestions were provided on other plans and programmes that may influence or interact with any future renewable development;
- A number of existing and forthcoming energy pipelines were discussed such as COBRA and the Viking Link;
- Judicial reviews in Scotland relating to the development of offshore wind farms were highlighted;
- It was identified that a number of research studies have been undertaken by Member States such as marine mammal studies in Denmark and migratory routes of birds in Scotland which may be of wider value;
- There was a question posed on whether the Regional Plan (now referred to as Regional Concept Report) should be called a plan or alternatively should it be named a strategy;
- It was suggested that the Scoping Report should not focus on impacts around specific renewable technologies;
- Current guidelines and documents outlining environmental impacts for offshore renewable energy developments were highlighted;
- Member States agreed that progress for offshore renewable development would require political support;
- The requirement for offshore monitoring was raised specifically in relation to water quality as concerns were raised on the lack of monitoring of existing offshore developments;
- It was suggested that an Environmental Management System should be implemented for offshore renewable energy developments; and
- There was general agreement on the potential environmental impacts that may arise from renewable energy development in the North Sea such as impacts to biodiversity, water, archaeology etc.

Online Consultation I [20th May to June 20th 2016]

In addition to the workshop, the draft Scoping Report was uploaded to the project website and stakeholders (statutory and non-statutory) were contacted and requested to provide feedback. Detailed feedback was received from organisations based in the following Member States:

- Belgium;
- Ireland;
- The Netherlands; and
- The United Kingdom.

The following provides a summary of the observations made through the submissions received:

- Specific information was provided in relation to Member State legislation;
- References to environmental studies along with existing SEAs was provided;
- Clarifications were provided regarding governance for certain energy matters per Member State;
- Certain Member States requested that specific organisations be included in any further consultations; and
- Identification of data holders which may contain further environmental baseline information;

Presentation [June 10th 2016]

On June 10th 2016, the Regional Concept Report and the draft Scoping Report were presented at the Regional Group Meeting for the North Seas Offshore Grid. The scope of the Baseline Environmental Study was discussed and recommendations made. These included that the regional concept should be revised to consider how the grid was currently developed in the Irish and North Sea rather than only look at either a radial or meshed grid solution. This would better inform the assessment work in the Baseline Environmental Study. A commitment was provided in the meeting to update the regional concept to reflect the existing grid configurations in the Irish and North Seas keeping in mind the study analyses the two extremes in offshore development: a fully radial and a fully meshed system. This is a common approach in long-term planning processes, which is also used by grid operators when making their long term projections on energy mix scenarios.

Environmental Baseline Reporting

There are a number of works streams and outputs making up the Baseline Environmental Report. The proposed approach and output for the main works packages are outlined below and presented in **Figure 2-4**.

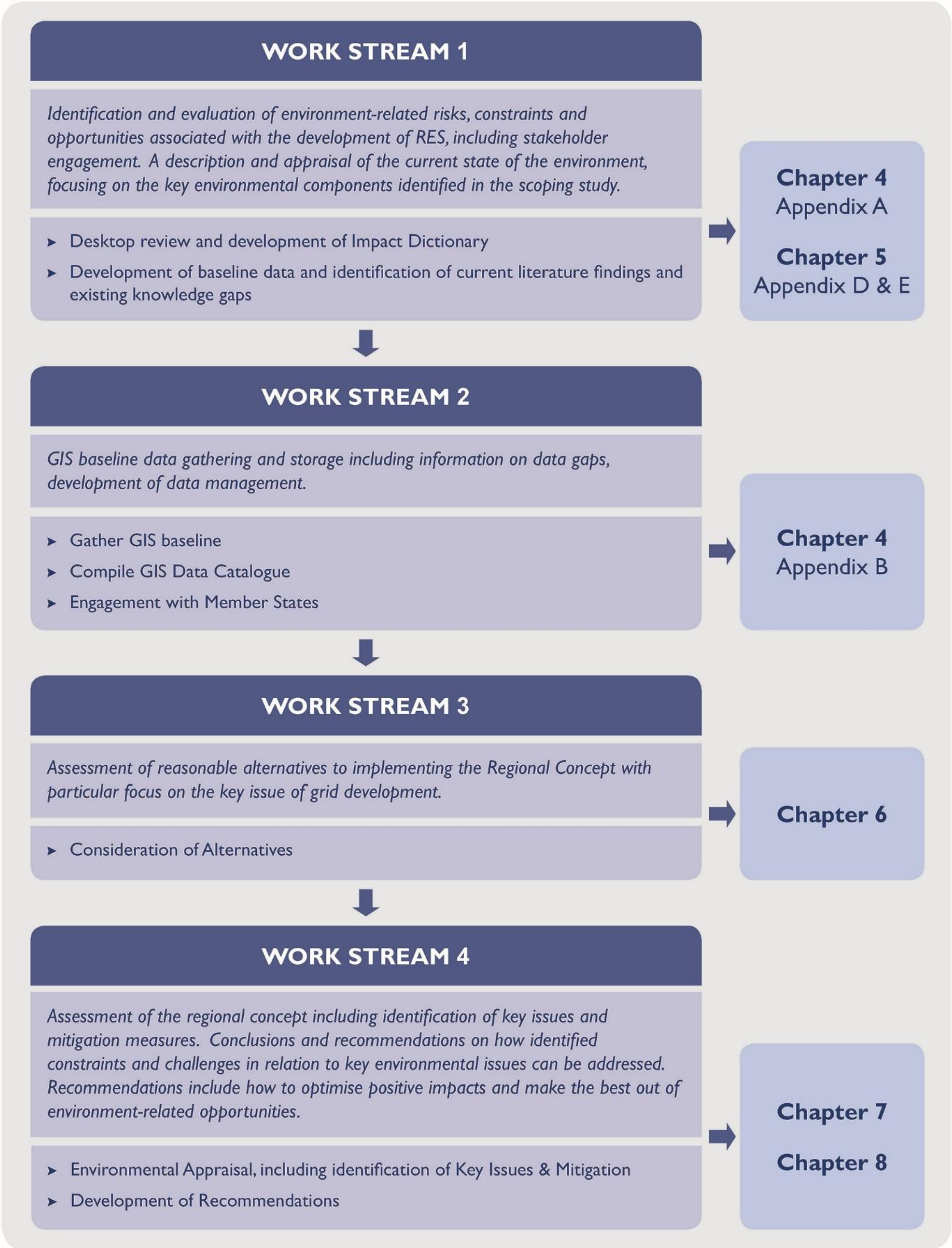

Figure 2-4 - Overview of Work Streams

Work Stream 1: *Identification and evaluation of environment-related risks, constraints and opportunities associated with the development of RES, including stakeholder engagement. A description and appraisal of the current state of the environment, focusing on the key environmental components identified in the scoping study.*

A desktop review of existing documents outlining general impacts of RES infrastructure across a range of environmental topics has been undertaken. Topic areas considered included population, human health, water, soils, biodiversity, flora and fauna, landscape, material assets and cultural heritage in line with Directive 2001/42/EC. The specific nature and impact pathway has been considered in each case. This has been supplemented by a review of the existing national SEAs as referenced and reported in the Scoping Report to ensure regional as well as more local issues are reflected. In addition, this element of the work has included focussed stakeholder engagement on impact identification. The output from this element of the work stream is presented in **Chapter 4** and **Appendix A** as an Impact Dictionary.

In addition, an environmental baseline was compiled which aligned with the environmental topics listed in the Impact Dictionary. This baseline is presented in a summary format within **Chapter 5** and in full within **Appendix D** and **Appendix E**. The data has been gathered from international and European sources as well as directly from the Member States. As part of the baseline, current issues, key trends, pressures and data gaps have been identified.

Issues in relation to data gaps have been explored for each environmental topic under Directive 2001/42/EC and a specific recommendation on priority areas to be addressed is included.

Work Stream 2: *Geographic Information System (GIS) baseline data gathering and storage including information on data gaps, development of data management.*

This work stream particularly focussed on developing a comprehensive baseline informed by the scope of impacts identified from the Scoping Report. A number of data sources were investigated and accessed. The first related to European Datasets collated from the European Environment Agency (EEA) and European Marine Observation and Data Network (EMODnet). The next source related to national authorities responsible for data holding and included engagement with all target Member States. The final data source related to listed data sources within national SEAs (from Scoping Report). These were also supplemented by general referenced web searches. The output from this work stream is presented in **Chapter 4**.

To ensure benefits to end users, particular consideration was given to a number of information delivery systems / approaches including a host server to be maintained centrally; and a searchable Data Catalogue holding all relevant data received as part this project. In addition issues in relation to data ownership; common principles of metadata and standards and requirements for jurisdictions at a regional level have been explored with specific recommendations on how to improve data management going forward in keeping with the Inspire Directive.

Work Stream 3: *Assessment of reasonable alternatives to implementing the Regional Concept with particular focus on the key issue of grid development*.

The work stream included consideration of strategic alternatives to delivery of renewable energy in the study area. As the target Member States have all developed relevant offshore and renewables plans, the focus of the alternatives in this report has been at the grid alternative, specifically radial and meshed alternatives. An assessment to determine potential constraints and opportunities in relation to the grid options was undertaken and the output from this work stream is presented in **Chapter 6** with overall conclusion provided.

Work Stream 4: *Assessment of the regional concept including identification of key issues and mitigation measures. Conclusions and recommendations on how identified constraints and challenges in relation to key environmental issues can be addressed. Recommendations include how to optimise positive impacts and make the best out of environment-related opportunities.*

In order to streamline the assessment process, broad themes based on the environmental topics listed in the SEA Directive were used in order to group large environmental data sets, e.g. human health, cultural heritage and climate/ air quality. The approach to the environmental assessment included a combination of qualitative and quantitative assessment along with expert judgement. The Impact Dictionary, Data Catalogue and Environmental Baseline were utilised throughout the assessment process. The output from this work stream is presented in **Chapter 7** and **Chapter 8**.

The approach taken to the assessment mirrors, to a certain extent the SEA process, required under Directive 2001/42/EC. It is acknowledged that this Baseline Environmental Study is not a formal SEA of the meshed capacity scenario as contained in the Regional Concept Report as there are no provisions within the existing legislation to facilitate a formal statutory SEA on a concept at the EU Regional scale. Rather, it is intended to provide similar information to that normally presented for such a strategic study with a view to it being practically applied at the Member State level as plans or projects arising from the Regional Concept Report come on-line and coordination of efforts across Member States is a necessity if projects are to be successfully delivered.

Environmental Baseline Consultation

Online Consultation II [26th September to 17th October 2016]

Following feedback from Consultation I, a second online consultation was undertaken with a particular focus on impact identification. The second consultation included a wider stakeholder base than Consultation I, taking into account suggestions from the first consultation as well as additional industry and environmental groups within each Member State. A draft Impact Dictionary on RES and grid development was provided along with a covering questionnaire to assist in focussing feedback. Organisations located within the Member States of Belgium, Germany, Ireland, the Netherlands and the United Kingdom provided feedback which then fed into an update made to the Impact Dictionary. In addition, one International organisation, BirdLife Europe and Central Asia provided a response during this consultation process.

The following provides a summary of the observations made on the draft Impact Dictionary:

- Further additions to the Impact Dictionary were provided;
- Suggestions were made in relation to the structure of the Impact Dictionary;
- Identification of the lack of current spatial planning in the Irish and North Seas;
- Life cycle analysis of projects, the acute environmental impacts resulting from construction as well as the chronic impacts resulting from operation were also flagged as important issues;
- Need for a centralised and collated database on the marine environment;
- Identification of datasets that are currently available;
- Identification of difference in standards, limit values across countries and environmental baseline datasets is noted as a significant issue in offshore development;
- It was identified that there are current knowledge gaps with regard to baseline data; and
- Links were provided to information resources, guidelines and scientific papers.

Online Consultation III [6th December to 20th December 2016]

Following the consultation stage to inform the development of an Impact Dictionary on RES and grid infrastructure, a third stage of consultation was undertaken to update stakeholders on the progress to date on the Baseline Environmental Study and to identify the key outputs that were currently being developed. This ensured that an overview was presented of the consultations stages along with a clear timeline for the publishing of the Baseline Environmental Report. **Figure 2-5** provides an overview of the Consultation Timeline that was included in the Stakeholder Update.

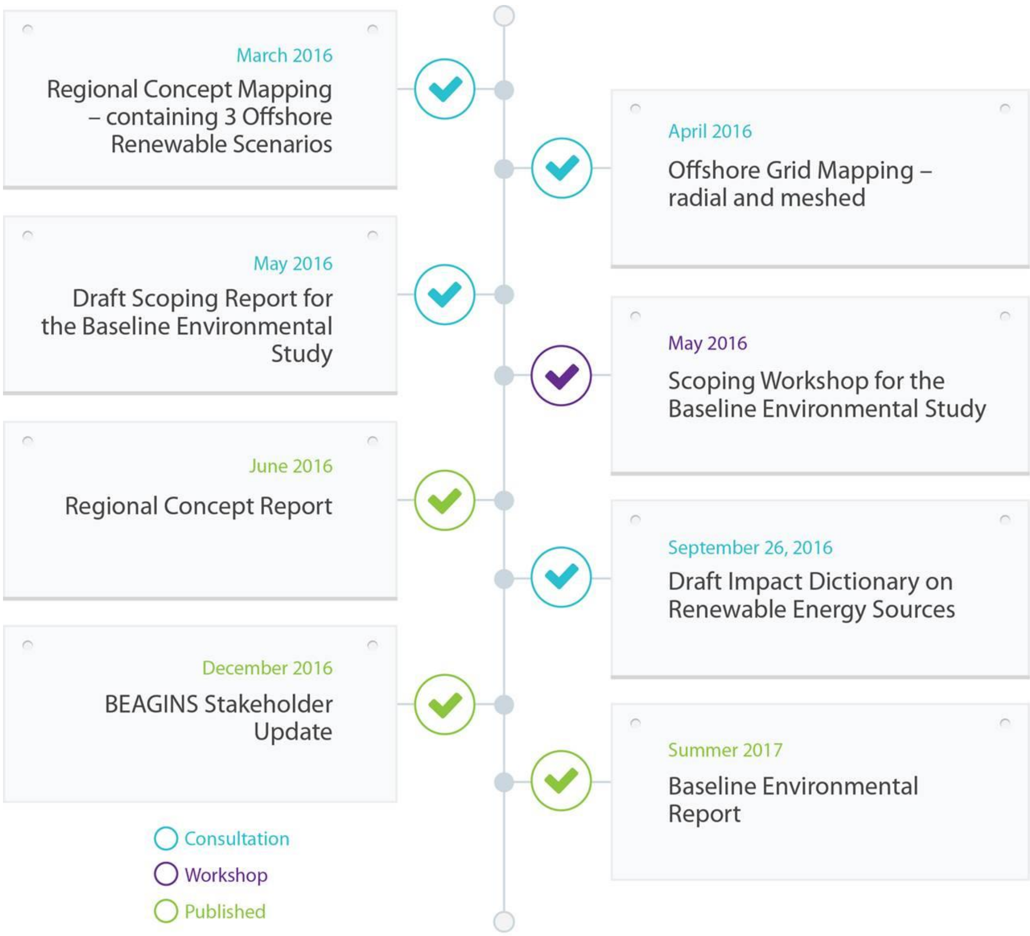

Figure 2-5 - Overview of Consultation Timeline

In addition to the consultation that was undertaken, the project team liaised with the North Seas Energy Working Groups who are undertaking tasks under the following areas:

- Maritime spatial planning;
- Development and regulation of offshore grids and other offshore infrastructure;
- Support framework and finance for offshore wind projects; and
- Standards, technical rules and regulations in the offshore wind sector.

The Working Groups were invited to provide feedback on the Recommendations (**Chapter 8**) of the Baseline Environmental Report in advance of finalising of the documentation.

3 CONCEPTS AND MAIN OBJECTIVES OF THE REGIONAL CONCEPT REPORT

3.1 Introduction

As part of the Baseline Environmental Study a Regional Concept Report has been prepared and this has also been subject to stakeholder consultation. It provides details on the renewable energy system across the six target countries, in the Irish and North Seas.

The objective of the Regional Concept Report is to develop a detailed plan of the combined energy infrastructure in the Irish and North Seas. The approach taken is consistent with current targets related to renewable energy and current network developments in the region. The level of detail is at single power plant resolution (e.g. offshore wind farms or wave power plants) and to a high level of detail for the grid infrastructure (e.g. number of cables in each corridor, technology specifications and ancillary equipment).

The Regional Concept Report does not intend to present a fully realistic projection of the system development roll-out. Rather, the study aims to show the impact of policy choices on system development by analysing the two extremes in offshore development: a fully radial and a fully meshed system. By focusing on two more extreme concepts the whole range of intermediate concepts is covered also. This is a common approach in long-term planning processes, which is also used by grid operators when making their long term projections on energy mix scenarios.

The Regional Concept Report varies on two aspects:

- The offshore generation capacity in place by 2030: ranging from business as usual to highly ambitious; and
- The grid design: ranging from no coordination (radial grid) to full coordination of wind farm connections and country interconnectors (meshed grid).

Some countries already coordinate their connections from offshore windfarms to shore through offshore (platforms/ hubs) e.g. Germany and the Netherlands. In the BEAGINS topologies all existing and decided hubs in Germany[24] and the Netherlands were included. Given that any grid development has its uncertainties, future projects for hubs, even those currently labelled as under consideration or in planning, have not been taken into consideration in the Regional Concept Report.

3.2 Content of the Regional Concept Report

The Regional Concept Report contains the following information:

Chapter No.	Content
Chapter 1	Introduction
Chapter 2	Capacity Scenarios
Chapter 3	Grid and Infrastructure Scenarios
Chapter 4	Conclusions and Recommendations
Appendix I	Overview of Cost Assumptions
Appendix II	Overview of Feedback

24 http://amscap.eu/amscapwebsite/wp-content/uploads/2016/12/German-offshore-wind-development-2015.pdf

3.3 Overview of Approach

The Regional Concept Report depends on two key factors, a) the renewable energy source (RES) deployment, and b) the grid development approach (meshed/ coordinated or radial/ uncoordinated). National objectives and targets up to 2020 are known and currently being executed. The development from 2020 to 2030 is subject to uncertainty since, except for Germany governments have defined goals but no clear targets for 2030 and beyond. Therefore, three scenarios for the target year 2030 (TY2030) are considered. For each of these scenarios two possible network development configurations (radial vs meshed) were identified and analysed in order to allow the comparative assessment of the environmental impacts of an uncoordinated versus a coordinated grid development. In line to these key tasks, the definition of the infrastructure contained within the Regional Concept Report is organised as follows:

1. *Definition of Capacity Scenarios:* based on the information on energy policy action plans in the region, technology-specific target scenarios for the development of RES and energy storage in the territorial waters of each country for the target year 2030 have been developed. All scenarios are mapped and concise locations of the RES and energy storage infrastructure in the Irish and North Seas are provided, respecting key constraints from exclusion areas.
2. *Definition of Grid Infrastructure:* in a first stage the grid routing for the connection of all plants, under two grid scenarios, radial (uncoordinated) and meshed (coordinated) was developed. The topology information was used to define the specifications and costs of the grid infrastructure and key (technical) characteristics for the different topologies.

It has been outlined in **Chapter 2**, that this Baseline Environmental Study and associated report may be used to inform future plans for renewable energy generation, energy storage, grid cables and associated equipment in the Irish and North Seas. The analysis of current policy documents, targets and key scenarios for 2030 as well as the stakeholder consultations revealed no potential for deployment of offshore energy storage technologies.[25] Therefore the conclusion is that it is unlikely that offshore storage sites will be developed and deployed in the foreseeable future, as their cost-effectiveness is low compared to onshore options. Therefore, offshore energy storage is not included in the Regional Concept and associated Baseline Environmental Report.

3.4 Definition of Capacity Scenarios

Within the Regional Concept Report three scenarios for the installed capacity of offshore renewables for the target year 2030 are considered. The adopted scenarios are based on adapted reference scenarios for the European offshore RES which are generally accepted by key stakeholders. For consistency, the scenarios in general maintain similar capacity levels as in the 2014 EC Study of the Benefits of Meshed Offshore Grid.[26]

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25 Results from European research projects such a ESTMAP (Energy Storage Mapping and Planning) looking at offshore energy storage potential outlined that there is currently only potential for onshore energy storage

26 Cole, S., Martinot, P., Rapoport, S., Papaefthymiou, G. and Gori, V. (July 2014) 'Study of the Benefits of a Meshed Offshore Grid in Northern Seas Region'. Retrieved: https://ec.europa.eu/energy/sites/ener/files/documents/2014_nsog_report.pdf

The scenarios are as follows:

1. *High Renewables*: This scenario refers to a high level of offshore renewables deployment, combining multiple sources. The offshore wind capacity development (2015) is based on the European Wind Energy Association (EWEA)[27] 'High' wind energy scenario for 2030.[28] The wave and tidal capacity (2011) is based on the European Commission (EC) Energy Roadmap 2050 'High Renewable Energy Source' scenario[29] combined with the country-specific offshore energy roadmaps of Ocean Energy Services (OES) and an IEA Technology Initiative.[30]
2. *PRIMES Reference:* This scenario is similar to NSCOGI scenario, but presents a stronger deployment of offshore wind energy development.[31]
3. *NSCOGI:* This reference scenario was developed in 2011 by The North Seas Countries' Offshore Grid Initiative (NSCOGI)[32] in collaboration with the TSOs, governments and regulators. In this scenario, the year 2020 is based on ENTSO-E EU2020 scenario, following the national RES targets defined. The 2030 scenario is based on the PRIMES model, and was adjusted to take into account the views of national authorities.[33]

Allocation of Capacity

The policy scenarios were broken down into specific projects assigned in specific locations. The placement of the RES was done taking into account key maritime spatial planning information in terms of designated areas and exclusion zones. National targets often have no specific allocation of capacity to a certain offshore zone. Offshore RES capacity is assigned to specific areas within each country based on the following priorities:

1. All operational and under construction projects in 2016;
2. Permitted zones;
3. Planned and priority zones, such as those with concessions granted and awaiting permits;[34]
4. Other planned sites, such as areas designated by national governments; and
5. Additional areas as needed – aiming for least constrained areas and taking into account the Levelised Cost of Energy (LCoE).[35]

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27 EWEA is now known as WindEurope. The scenario however is named the EWEA scenario and therefore we will remain referring to EWEA.

28 EWEA (August 2015) 'Wind Energy Scenarios 2030'. Retrieved: http://www.ewea.org/fileadmin/files/library/publications/reports/EWEA-Wind-energy-scenarios-2030.pdf

29 EC (2011) 'Impact Assessment – Energy Roadmap 2050 – Annex 1 Scenarios – Assumptions and Results'. Retrieved: https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1565_part2_0.pdf

30 Ocean Energy Systems: Annual Reports. Retrieved: https://www.ocean-energy-systems.org/library/countries-roadmaps/

31 EU Energy, Transport and GHG Emissions Trends to 2050 Reference Scenario 2013. Retrieved: http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf

32 North Seas Countries' Offshore Grid Initiative. Retrieved: http://www.benelux.int/NSCOGI/

33 PRIMES results were refined based on recent developments. During the stakeholder consultation process these were checked and approved.

34 The level of detail for planned zones varies between sites and there can be conflicting information between sources, particularly regarding the status of projects. Very large areas are divided into representative segments. A wind farm boundary is defined for all projects in the database, often with a known or expected capacity. In cases where the wind farm capacity is not known, it is estimated based on a relatively conservative density of 5 MW/km².

35 Sites have been selected outside of shipping lanes, taking into account cables, pipelines and environmental zones.

All offshore wind sites are allocated based on rankings of the relative costs, which are evaluated using the Ecofys Offshore Wind Cost Model as a basis, drawing from a database of actual costs from realised offshore wind farms. The cost model determines the optimal wind turbine, foundation and electrical infrastructure for any site, as well as calculating the costs in detail. With a combination of costs and estimated energy yield, the expected LCoE is calculated. The LCoE is a measure of the minimum price an operator needs to receive for every produced MWh in order to meet the required return on investment, and provides insight into the financial implications of developing the offshore wind farm. The total capacity allocated to each country is shown in **Table 3.1**.

Table 3.1 - Total Offshore RES Capacity Allocated per Country for the Three Scenarios

Country	Based on High Renewables; EWEA and EC Roadmap	Based on PRIMES Reference	Based on NSCOGI
Belgium	3.9	2.9	3.3
Denmark	6.8	1.6	0.6
Germany	20.8	18.9	15.3
Ireland	1.5	1.0	2.5
Netherlands	7.3	5.2	6.4
United Kingdom	36.3	26.0	19.0
TOTAL (GW)	**76.6**	**55.6**	**47.1**

The resulting map of one of the three scenarios of allocated capacities is presented in **Figure 3-1**.

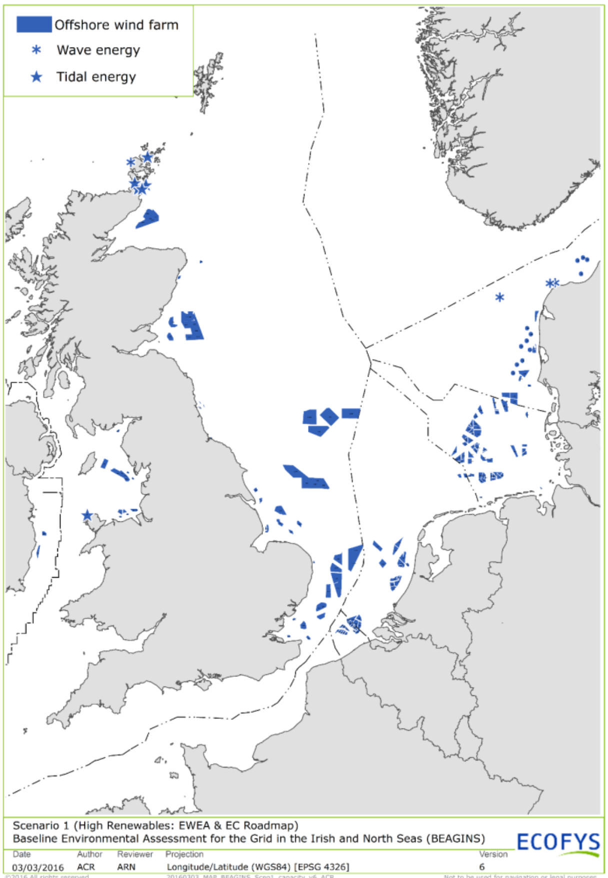

Figure 3-1 - Map of Allocated Capacity as per the High Renewables Scenario

3.5 Definition of Grid and Infrastructure Scenarios

The detailed locations of the RES, together with the respective installed capacities serve as basis for the grid design. Further, grid development scenarios per Member State with a 2030 horizon were considered, in order to map the expected grid developments, including expected shore-to-shore interconnectors.[36] The offshore grid routing was performed in two phases.

1. In the first phase, the onshore grid connection points were mapped and the respective hosting capacities were assessed. For consistency purposes, the hosting capacity levels estimated in the 2014 EC Study of the Benefits of Meshed Offshore Grid were used, which include all information from the related network development plans for target year 2030.26
2. In the second phase, the routing of the offshore projects was designed based on the two grid development scenarios, radial and meshed, as discussed in the next sections.

Radial Configurations

The design basis for the radial cases is that all offshore sites are developed independently and are connected radially to an onshore substation.26 In addition, known and planned offshore interconnectors are included as well as all existing and decided hubs in Germany[37] and the Netherlands.

The appropriate onshore substation for each project was chosen, based on closest distance and available transmission capacity. All sites are connected to a substation in the country to which they belong. The offshore and onshore cable length was calculated separately. The length of the export cable route from the offshore site to the onshore substation was calculated assuming that all projects are able to connect according to a reasonable route, without closer projects blocking connections to sites further offshore. For simplicity, the resulting maps show a direct connection between each site and onshore substation, although the length of each cable route includes average deviations based on current practice in the wind industry. An average estimate of the number of cable crossings was also calculated for each export cable.

Meshed Configurations

A meshed grid corresponds to a coordinated development that leads to a selective clustering of offshore projects when cost reductions compared to individual radial connections are observed. The meshed case therefore consists of some sites being connected radially to onshore substations, while others are connected to offshore hubs. These hubs are connected to onshore substations and/ or to other hubs via hub-to-hub interconnectors. This configuration also includes some shore-to-shore interconnectors and nearby German and Belgium wind farms have been connected to these. The resulting maps of one of the three scenarios of allocated capacities are presented in **Figure 3-2** (radial) and **Figure 3-3** (meshed).

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36 Based on the ENTSOE '10-Year Network Development Plan 2014' and 'Regional Investment Plan 2015 - North Sea region'.

37 http://amscap.eu/amscapwebsite/wp-content/uploads/2016/12/German-offshore-wind-development-2015.pdf

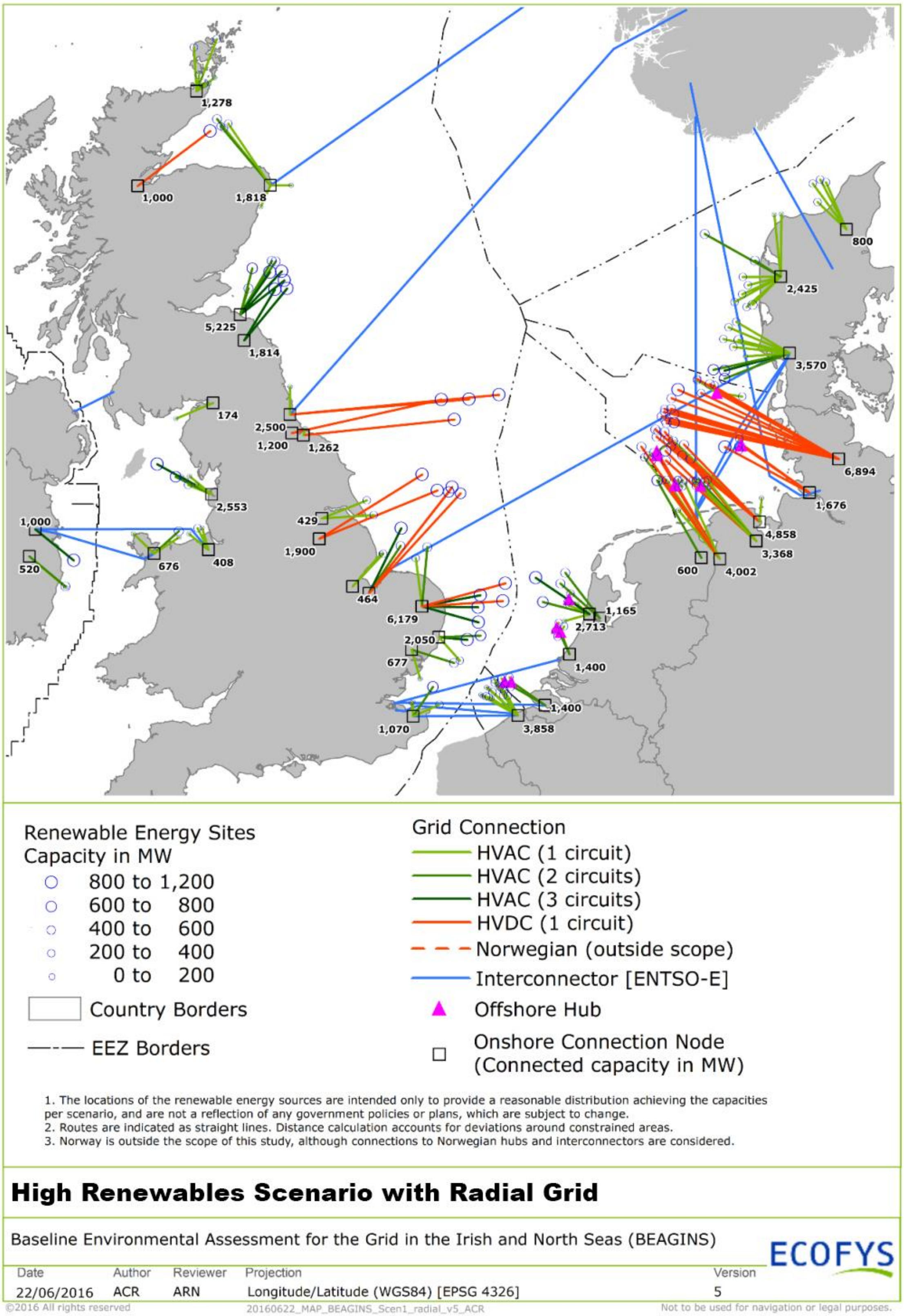

Figure 3-2 - Radial Configuration to Grid as per High Renewables Scenario

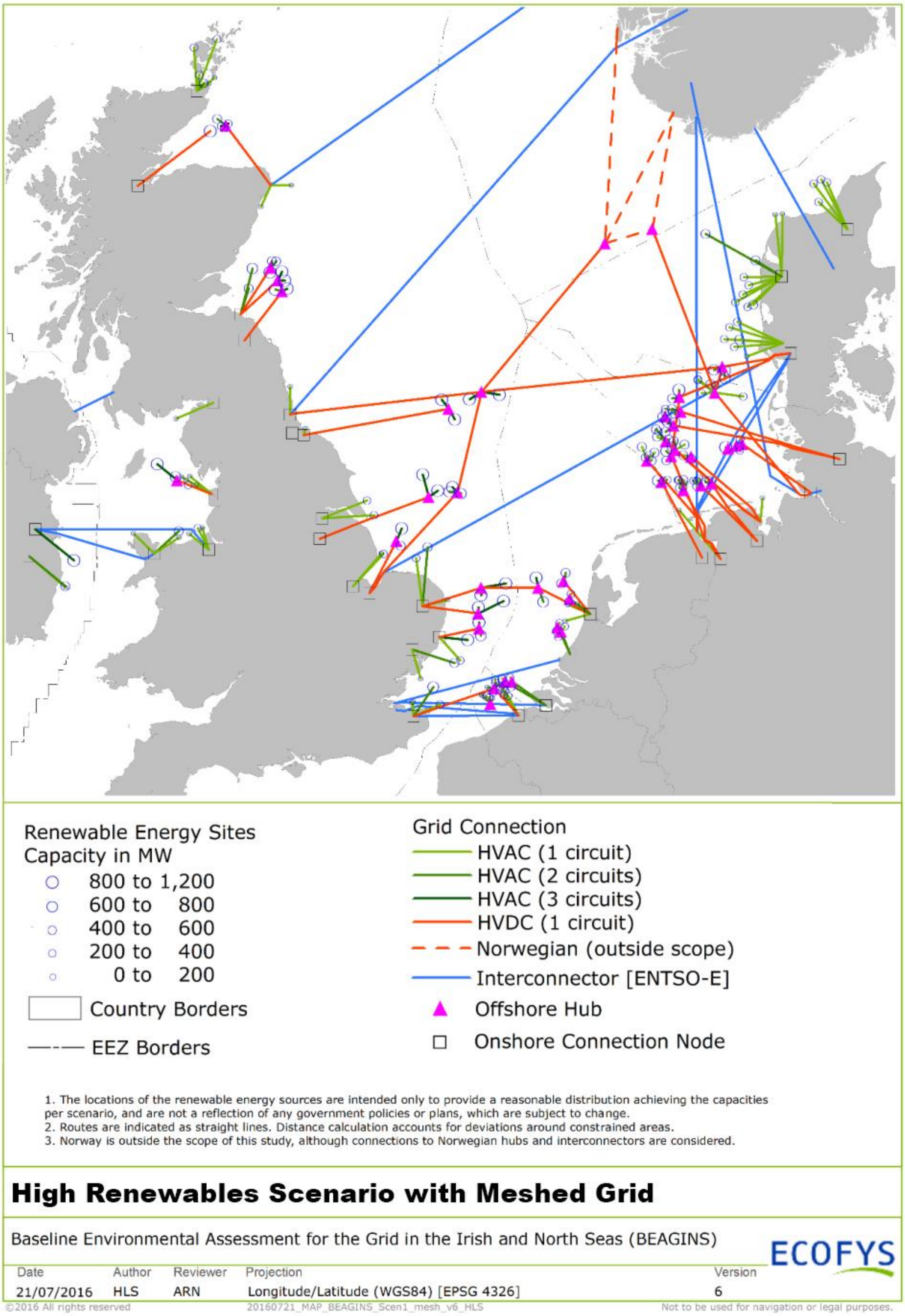

Figure 3-3 - Meshed Configuration to Grid as per High Renewables Scenario

3.6 Infrastructural Elements Considered in Baseline Environmental Study

This section broadly outlines the main elements associated with an offshore energy system to provide context for this Baseline Environmental Report. A summary of the infrastructural types considered is provided in **Table 3.2** with a visual representation of the infrastructure provided in **Figure 3-4**. The radial and meshed configurations, which are explained in detail in **Chapter 6** are visually presented in **Figure 3-5**.

Table 3.2 - Summary of the Infrastructural Types Considered in an Offshore Energy System

Element	Infrastructure	Definition
Energy Source	Wind turbine	A wind turbine is a machine that converts the wind's kinetic energy into electrical power.
Energy Source	Tidal and current generators	A machine that extracts kinetic energy from moving masses of water, in particular tides or water currents, and converts it into electrical power.
Energy Source	Wave energy generators	A device that captures energy from waves. There are different concepts in extracting the energy which can be differentiated by the location of the device (e.g. floating vs. connected to the seabed) and the power take-off system (e.g. oscillating water column which compresses air vs. rise and fall of swells which drive hydraulic pumps).
Energy Collection	Offshore high voltage stations	The station carries a transformer which collects the electricity from the offshore wind turbines, increases the voltage level to minimise transport losses and connects the wind farm to the main land or hub.
Grid	HVAC/ HVDC offshore cables	High voltage alternating/ direct offshore cables which transport electricity at more than 150kV and 100kV respectively.
Onshore Connection	Converter stations	Converter stations can either transform alternating current into direct current or the other way around. Through converter stations electric energy from offshore wind can be transmitted through HVDC cable lines to decrease losses and then integrated into the HVAC grid.

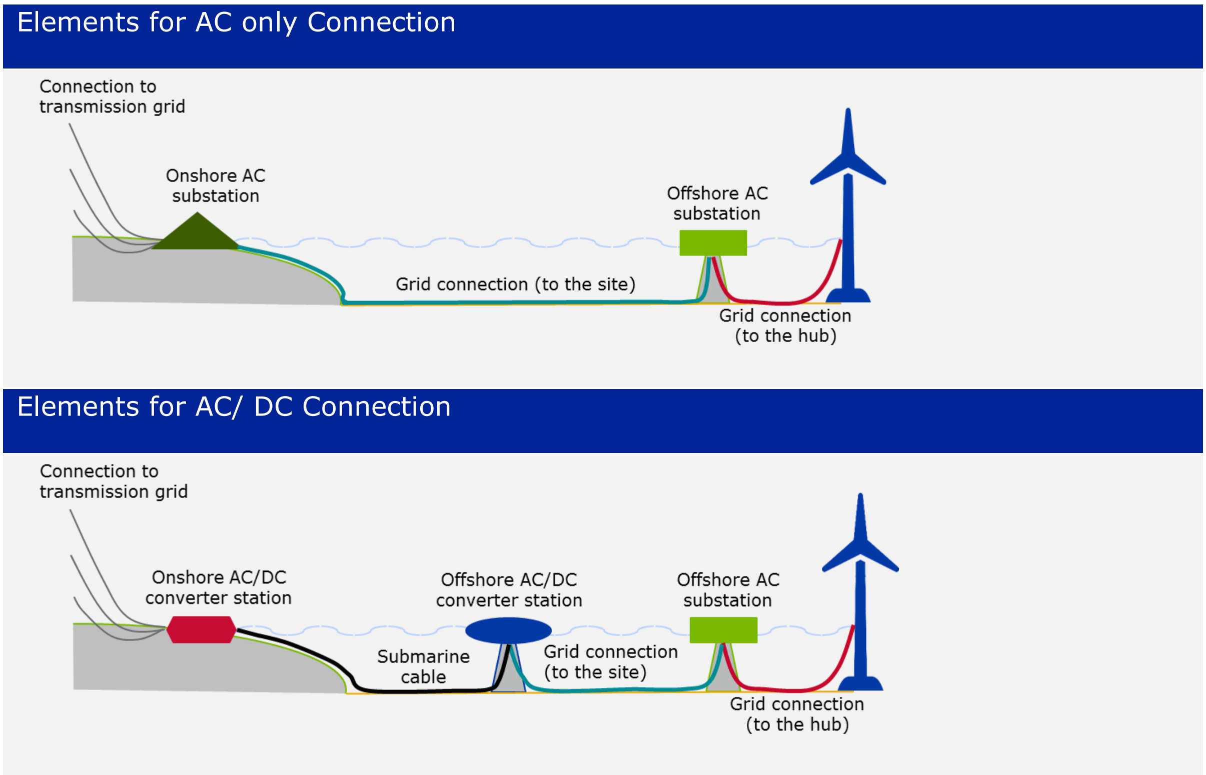

Figure 3-4 - Representation of the Infrastructural Types Considered in an Offshore Energy System

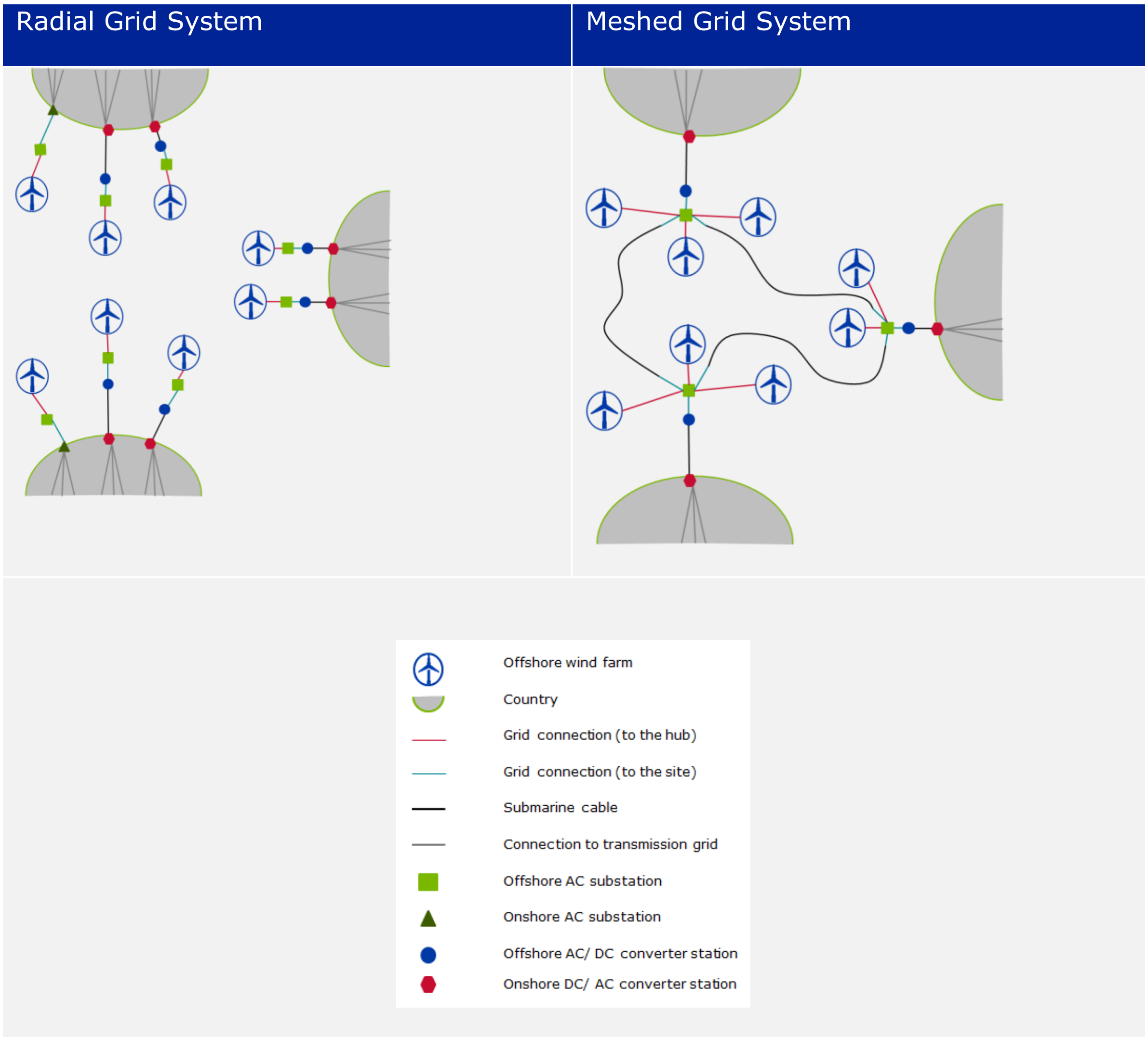

Figure 3-5 - Representation of a Radial and Meshed System

4 KEY ISSUES AND A GEOGRAPHIC INFORMATION SYSTEM DATABASE

4.1 Introduction

This chapter focuses on the identification of the key issues relative to an offshore renewable energy system. It also provides an explanation on the approach taken to the compilation of the geographic information system (GIS) database.

In order to inform the full scope of the Baseline Environmental Study, it was first considered necessary to identify the range and type of impacts that could arise as a result of the development of offshore RES and the grid. Alongside this it was considered necessary to compile a robust GIS database to inform the full scope of the Baseline Environmental Study.

4.2 Key Issues

The identification of key issues has been undertaken with reference to existing reference texts and assessments which have been completed across the target Member States. This review has attempted to collate, insofar as possible, the key generic pressures and impacts on environmental receptors that are considered relevant to the development of RES and the grid. An Impact Dictionary forms the key deliverable from this task and is provided in **Appendix A**.

Key SEAs of offshore renewable developments and maritime spatial plans from the participating Member States were identified during the scoping exercise undertaken in June 2016. These formed the starting point for the collation of environmental impacts. Overall, the SEAs are comprehensive, and the variety of activities in the Irish and North Seas is generally very well understood and as a result, similar types of impacts have generally been flagged across Member States. In order to fill any gaps, a general internet search was also undertaken as well as a review of relevant reports, research papers and guidelines to further inform the scope of impacts captured in the dictionary. The feedback received from Consultation II has also been incorporated into the dictionary as part of the continual process of refining and updating the study.

The Impact Dictionary is designed to be a searchable digital document that can be accessed by the majority of users; as such the dictionary has been set up in an Excel file. The key sensitivities and impacts are arranged by broad topics which are generally included in SEA, and following the outline of the Environmental Baseline (see **Chapter 5**) as follows: biodiversity, flora and fauna; population and human health; soils, geology and sediment; water; air quality and climatic factors; materials assets; cultural heritage; and landscape/seascape. Further, the broad renewable infrastructure type and the phase of development have also been included.

It is envisaged that the Impact Dictionary will be utilised in conjunction with the Environmental Baseline (**Chapter 5**) as well as the Data Catalogue (discussed in **Section 4.3: GIS Approach**) to inform developers and regulators with regards to environmental assessment (SEA and EIA) and Appropriate Assessment (AA) which will allow for environmental considerations to be incorporated into plans and projects early in the policy, design or planning processes.

The intention is that this will help flag key relevant impacts and environmental receptors for consideration at an early stage, or help to focus on the issue areas of particular relevance for an area. Further, the dictionary can serve as a checklist to ensure that all the relevant impacts have been scoped. It is acknowledged however, that the dictionary does not remove the need for site specific and project specific consideration at lower levels of planning. It is intended to be a comprehensive guide to the type of impacts that should be considered.

A summary of the key issues from the Impact Dictionary is provided in **Table 4.1** which provides the reader with a brief introduction to the range and type of impacts likely to arise. As identified the full dictionary is provided in **Appendix A**.

Table 4.1 - Summary of the Key Issues Identified in the Impact Dictionary

Topic	Environmental Receptor	Key Potential Impacts from an Energy System
Biodiversity, Flora and Fauna	Protected Habitats	• Disturbance or displacement from or physical loss of benthic habitat. • Adverse impact to habitat from changes to hydrography, sedimentation or turbidity. • Changes to biotopes/ alteration of community structure. • Pollution of sediment.
	Protected Species (including marine birds, mammals, fish, reptiles, bats, benthos and ecological balance [invasive species])	• Adverse physiological and or behavioural reactions from: noise; sediment smothering/ sealing effects; release or remobilisation of contaminated material; release of antifoulants; from produced or treated discharges; from marine litter; from use of explosives; from electromagnetic fields (EMF) emissions; from geophysical survey techniques; from changes to hydrology/ flow conditions; from changes to thermal, salinity, redox or nutrient conditions. • Barrier effects/ displacement from/ loss of feeding, foraging and breeding grounds. • Induction of flight/ scare response. • Collision risk from the physical presence of structures. • Physical loss of or disturbance to benthic habitats and species. • Changes to community structure (introduction of artificial substrate). • Introduction/ spread of invasive alien species.
Population & Human Health	Tourism & Recreation	• Visual intrusion from physical presence. • Exclusion from zones of recreational activity. • Restrictions to port, harbour, marina or terrestrial approaches. • Increased risk of ship-to-ship or ship-to-RES collisions. • Changes to wave energy/ tidal height.
	Settlements & Built-up Areas	• Adverse effects from emissions of noise and EMF, emissions of exhausts and impacts to air quality or impacted water quality.
Soils, Geology & Sediment	Soils	• Permanent loss of, or sealing, of soils.
	Geological Heritage	• Disturbance or physical loss of the

Topic	Environmental Receptor	Key Potential Impacts from an Energy System
		seabed or terrestrial landscape.
	Coastal Processes & Sediment Movements	• Physical loss/ permanent modification of the seabed. • Changes to sediment distribution/ coastal sediment budgets. • Turbulence and sediment load changes. • Disturbance or remobilisation of contaminated sediment. • Contamination of sediment (vessel losses). • Changes to biotopes. • Introduction of light. • Heating of sediment. • Changes to erosion and accretion rates.
	Hydrodynamics & Flow	• Changes to hydrodynamics and flow, influencing: velocity; salinity; stratification and nutrient flushing; tidal and wave regimes. • Changes to water levels and wave heights. • Scouring. • Wind shadow and wind drag effects. • Induction of wake effects.
Water	Water Quality	• Suspension of sediment/ turbidity. • Resuspension/ remobilisation of contaminated materials. • Leaching of chemical pollutants to water. • Disposal of litter to sea. • Loss of ship fluids at sea. • Changes to retention times. • Introduction of microbial pathogens.
	Flood Risk	• Impacts to wave height/ altered flow regimes and exacerbation of flood risk in other areas.
	Coastal Defences	• Impacts or modifications to coastal defence structures. • Potential conflict with landfall and future-proofing for climate change.
Air Quality & Climatic Factors	Air Quality	• Emission of exhausts from both land-based traffic and shipping.
	Climate	• Operational CO_2 emissions during all phases of development. • Increased flood risk as a result of altering the flow/wave regime via RES.
Material Assets	Cables & Pipelines	• Damage or disturbance to existing cables and pipelines. • Exposure of cables from changing sediment dynamics or disturbance. • Restriction of siting options for other cables and pipelines.
	Fisheries	• Adverse physiological damage from: survey techniques; smothering; changes to sediment types.

Topic	Environmental Receptor	Key Potential Impacts from an Energy System
		• Disturbance/ remobilisation of contaminated sediment (aquaculture safety). • Physical loss of shellfish beds. • Induction of scare/ flight response in fish. • Barrier effect to migration routes or to commercially targeted species. • Collision risk/ snagging of fishing gear. • Exclusion from fishing grounds.
	Shipping	• Changes to/ intensification of traffic flows. • Exclusion from sea lanes/rerouting. • Collision risk and resulting potential for loss of fuel/ oil/ hydraulic fluid etc. • Obstruction from other vessels/ platforms/ rigs etc. • Reduced access to ports/ adequate water depths. • Impacts of EMF on positional bearings. • Impacts to navigation channels from sediment redistribution.
	Military Activities & Aviation	• Exclusion from military areas/ rerouting. • Interference of EMF on civil/defence radar (shore and ship-based). • Interference from physical presence on radio systems. • Physical obstacle to aircraft.
	Hydrocarbon Extraction	• Exclusion from resource/ opportunity areas. • Restriction of access to subsea wells.
	Dredging & Aggregate Extraction	• Exclusion from resource/ opportunity areas.
	Marine Disposal	• Restriction of access to disposal sites. • Disturbance to contaminated, hazardous material or munitions sites.
	Carbon Storage	• Exclusion from storage opportunity areas.
	Emergency Services	• Impacts to maritime emergency response times from exclusion zones. • Restriction of take-off and landing safety zones. • Physical obstacle to aircraft (e.g. helicopters).
Cultural Heritage	Coastal & Submerged Heritage Features	• Disturbance, damage or destruction of submerged features. • Visual impact to perceived historical setting.
Landscape & Seascape	Landfall	• Physical disturbance to or loss of terrestrial landscape. • Visual intrusion from physical

Topic	Environmental Receptor	Key Potential Impacts from an Energy System
		presence.
	Landscape & Seascape Character	• Negative perception of character. • Physical loss, fragmentation or modification of landscape character/ coastal features. • Visual intrusion from: safety/ lighting features; silhouetting/flicker; obstructed views.

4.3 GIS Approach

GIS has been used as an integral part of this Baseline Environmental Study to ensure that all relevant datasets to an energy system are sourced and collated. ESRI ArcGIS, being a robust and widely used GIS system, was utilised as the main GIS software for the data storage. The approach taken to collate the spatial datasets involved key data holders, data clearinghouses, relevant studies/ projects and relevant departments in both the EU and target Member States.

A robust data incoming procedure was followed in order to validate all incoming datasets though the associated metadata. The required spatial data licencing, data usage agreements and disclaimers were followed and adhered to.

Data Collation and Identification

In order to collate the most appropriate GIS data for the project a staged approach to data collation was undertaken. Whilst it was established early in the Baseline Environmental Study that there were EU programmes for the collation of maritime data, this study undertook a structured data collation approach to further collate relevant data. A five stage process was adhered in order to obtain the data.

Stage 1 Review: Along with an overall review of information in relation to renewables, the SEAs of the maritime spatial plans for the Member States within the study area were identified and reviewed to establish available data.

Stage 2 Data collation: A three tiered approach (Massey, 2012[38]; RPS 2012[39]) was applied to the collation of the data. It involved the following steps:

Tier 1: Obtain easily accessible data from existing EU and national data holdings and available data from government organisations and agencies to allow rapid collation of data and large scale overview. For example, significant datasets held by DG Environment were downloaded through the EEA mapping portal and similarly relevant datasets held by DG Mare under the EMODnet were accessed and downloaded. Data portals with online links and/ or web mapping services were also prioritised.

In addition, user accounts were registered for online mapping portals which only allow data download to the registered users.

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[38] Massey (2012) Use of GIS as a tool for environmental risk assessment for the offshore oil and gas industry, University of Glasgow.

[39] RPS (2012) ISLES Project EU Environmental Constraints Report. Retrieved: http://www.islesproject.eu/wp-content/uploads/2014/09/3.0-Environmental-Constraints-Report-Northern-Isles.pdf

Tier 2: Apply formal data acquisition requests at an early stage to sources known to hold substantial data sets. Such requests were made, through email and phone conversations to national bodies and organisations such as Rijkswaterstaat (Ministry of Infrastructure and the Environment - Netherlands), Belgian Marine Data Centre, International Council for Exploration of the Sea (ICES) and the Irish Marine Atlas. It was recognised in this tier of the process that sources may require an appreciable period of time to provide the data. Lastly, permission was sought to use datasets already held by RPS and Ecofys.

Tier 3: Data acquisition requests were issued at an early stage to specific data holders. The requests were made with the expectation that whilst the data will be of sufficient quality only a proportion will respond favourably in the timescale available. Where such data was determined as unavailable or where impediments such as cost or licencing prevented use, the third tier included the acquisition and identification of other suitable data sources in order to achieve completeness and reduce gaps within the timeframe for the Baseline Environmental Study.

Stage 3 Data categorisation: The initial stage of categorisation involved a review of the data received, its coverage, quality and currency along with identifying if further data acquisition was required for gap filling. The next step involved an assessment of the completeness of the dataset along with categorisation of the data by theme. These themes were developed based on the structure presented in the SEA Directive and applied to the datasets. In addition, the data was discussed with energy regulators and organisations located in the study area to confirm the approach and establish that most available data was identified. Following this step the data was categorised and compiled into a Data Catalogue.

Stage 4 Data selection: Following the categorisation stage, the data held in the Data Catalogue was sorted in order to be able to present full coverage of the datasets for the scale of the study area. Data with only partial or single country coverage was identified. The focus of the data selection was towards presenting data that provided a similar level of detail and information between areas, nations and regions.

In general, the work undertaken by pan-European organisations, particularly the EMODnet programme provided a common framework of data for the study area. In addition, studies compiled at a larger marine ecosystem scale, such as the Mapping of European Seabed Habitats (MESH) data and International Council for Exploration of the Sea (ICES) datasets were also suitable for use in the Baseline Environmental Study. The aim was the selection/scaling of most suitable data for the study area to ensure maximum homogeneous coverage and comparable spatial scale in all jurisdictions.

Stage 5 Data classification and cross-referencing: As previously outlined in Stage 1, the SEAs of the maritime spatial plans for the Member States were reviewed. A comprehensive list of spatial datasets, presented in these SEAs and maritime spatial plans, was compiled indicating the context, extent and source of the datasets. In order to fill any gaps, further internet searches were conducted for relevant geoportals and data holders. Following the extensive data collation process the Data Catalogue was finalised, as presented in **Appendix B**. This Data Catalogue provides information for an environmental baseline as required by SEA and EIA processes.

In addition to the data classification process, the data was also cross referenced to the topics and receptors as identified in the Impacts Dictionary summarised previously in **Table 4.1** and provided in **Appendix A**. This classification allows the linking of potential data sources by SEA theme, impact topic and potential receptor.

Data Sources

The spatial data collated is broadly divided into the pan-European spatial datasets and the national datasets. A number of major spatial data clearinghouses such as EMODnet and EEA were contacted and/or accessed for the relevant data layers as previously outlined above under ***Data Collation and Identification***. A full list of the data sources at both levels are outlined in **Table 4.2**. Where possible spatial datasets were acquired in the GIS format (ESRI Shape files or MapInfo TAB files) and web mapping/ web feature service links were also accessed.

Table 4.2 - Data Sources

Data Source	Spatial Extent
The European Marine Observation and Data Network (EMODnet)	Pan-European
The European Environment Agency (EEA)	Pan-European
International Council for Exploration of the Sea (ICES)	Pan-European
Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP)	Pan-European
The Ramsar Sites Information Service (RSIS)	Pan-European
World Heritage Council (UNESCO Sites)	Pan-European
OSPAR Commission (Marine Protected Areas)	Pan-European
Protected Planet (United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC) with support from IUCN and its World Commission on Protected Areas (WCPA)	Pan-European
Joint Nature Conservation Committee (JNCC)	Pan-European and United Kingdom
Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	Pan-European and United Kingdom
Belgian Coastal Atlas	Belgium
The National Database for Marine Data (MADS)	Denmark
German Oceanographic Data Centre – BSH (Federal Maritime and Hydrographic Agency)	Germany
Marine Atlas Ireland National parks and Wildlife Service (NPWS) National Monuments Service and National Inventory of Architectural Heritage Environmental protection Agency Ireland	Ireland
Rijkswaterstaat (Ministry of Infrastructure and the Environment)	Netherlands
The MAGIC Database: MAGIC partners are: Department for Environment, Food and Rural Affairs Historic England Natural England Environment Agency Forestry Commission Marine Management Organisation	United Kingdom

Data Catalogue

In order to identify the range and type of spatial datasets that could be utilised in decision support for energy system development and to facilitate user friendly access a Data Catalogue was compiled and is presented in **Appendix B**.

This searchable Data Catalogue is intended to be available to users through an online web portal, potentially hosted by the European Atlas of the Seas (http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/).

The structure of the Data Catalogue is arranged as per the headings typically included in a SEA, in order to best facilitate Member States. The Data Catalogue holds information on the data format, data owner, links to full metadata and disclaimer and licence status. The Data Catalogue will give users the ability to:

- Search for and view metadata;
- Download data, where available;
- Request data from the original source; and
- Link data to the impacts.

All datasets contained within the Data Catalogue were evaluated for use at each scale, and relevant datasets extracted to form homogeneous coverage and provide bases for the assessment process, as discussed below under ***Data Use***.

Table 4.3 provides an overview of the structure of the catalogue along with a description of the datasets and accompanying data gaps and limitations.

Table 4.3 - Data Catalogue Format

Theme Heading	Description of Datasets	Data Gaps and Limitations
Context Data	This heading includes the datasets related to the bathymetry/topography, seabed features and background mapping e.g. GEBCO bathymetry. The heading also includes the Ecofys Capacity datasets which represent possible scenarios for the development of RES by 2030. They are based on country-level capacity levels from published references, allocated primarily to existing or planned projects, according to their expected priority (in terms of lowest cost of energy). The Ecofys Grid Infrastructure Datasets represent grid connection routes for different possible scenarios for the development of RES by 2030. They are based on the likely routes between sites and onshore grid connection points, for either radial or meshed grid connection.	The Bathymetry data is only available as Web Mapping Service therefore limited usage for the assessment. The Capacity datasets represent capacity distributions for various future scenarios. They are not prescriptive nor intended as a reflection of any government policies, targets or official plans. Any projections of future capacity are based on current information, and may be subject to change. The distribution of capacity is based on the assumptions described in the Regional Concept Report. The infrastructure datasets are representative grid connection routes for various future scenarios. They are not prescriptive nor intended as a reflection of any government policies, targets or official plans. Routes are indicated as straight lines; distance calculation accounts for deviation around constrained areas. The cable route definition is based on the assumptions described in the Regional Concept Report.
Population and Human Health	This heading includes data related mainly to cities and settlements e.g. built-up	The population data from Eurostat is based on the classification of territorial units

Theme Heading	Description of Datasets	Data Gaps and Limitations
	areas/high density clusters, major population centres and population density.	for statistics, known by the acronym NUTS. For this Baseline Environmental Study NUTS-3 level is used. The full metadata should be referred to for individual data sources because in some instances the data classification at the Pan-European level might differ from the national level. e.g. the Bathing Water Quality classification is at transitional stage therefore the data presented in this project is only using the EMODnet classification. There is limited data available on tourism and recreational activities.
Biodiversity, Flora and Fauna	This heading includes the datasets on protected areas, habitats and species e.g. Natura 2000 sites, MPAs, Ramsar sites, OSPAR threatened and declining habitats and species and OBIS Seamap species ranges.	The Pan-European datasets are in a homogeneous coverage but the national datasets have various spatial references and file formats.
Soils, Geology and Sediment	This heading includes the datasets relevant to soils and offshore geology e.g. offshore lithology/bedrock geology, European Nature Information System (EUNIS) predicted seabed sediments.	While broad sediment types have been mapped at a strategic level by EMODnet, there may be data gaps or generalisations applied.
Water	This heading includes the datasets relevant to water e.g. bathing water sites, locations of coastal defences and aquaculture facilities.	Limited data available on coastal defences.
Air and Climate	This heading includes datasets relating to air quality monitoring i.e. air quality zones.	There is limited data on air quality for maritime areas. The only data available is the zones for air quality as established under the Ambient Air Quality Directives (2008/50/EC and 2004/107/EC).
Landscape and Seascape	This heading includes datasets relevant to landscape and seascape e.g. coastal types, International Union for Conservation of Nature (IUCN) protected landscapes and national parks.	No homogeneous dataset of sensitivities is available. Some national datasets are available for the seascape/landscape assessment based on topography and location of potential receptors (population, viewpoints etc.).
Cultural Heritage	This heading includes the datasets for heritage resources e.g. UNESCO World heritage Sites, shipwrecks and	There are national datasets available for shipwrecks in the study area. However there are inconsistencies between the

Theme Heading	Description of Datasets	Data Gaps and Limitations
	listed monuments.	datasets with some having shipwreck locations while others have attributed heritage importance.
Material Assets	This heading includes the datasets relevant to on-going users of the sea e.g. existing RES, ports, cables, pipelines, locations of finfish, shellfish fisheries and military areas.	There is limited data on commercial fisheries, traffic separation schemes and shipping density.

Data Use

The information collated through the Data Catalogue has been utilised to inform the baseline environment (**Chapter 5**). The layers in the Data Catalogue have been numerically coded and tagged with search words and this will allow linkage to the Impact Dictionary. This has also allowed rapid identification and visualisation of the baseline and potential interactions and impacts to the various development scenarios, plans and regional plans considered in this Baseline Environmental Study.

The Data Catalogue has facilitated the generation of a suite of static maps included in this Baseline Environmental Report and the environmental assessment contained within **Chapter 7**. Through the use of GIS the complex interplay between the datasets can be visually displayed and spatial analysis can be conducted with respect to the capacity scenarios presented in the Regional Concept Report. In addition, a specific recommendation has been outlined in **Chapter 8**, in relation to Data Management and Storage as identified in **Recommendation #4**.

5 ENVIRONMENTAL BASELINE (SUMMARY)

5.1 Introduction

This section of the Baseline Environmental Report provides a summary of the relevant significant issues of the current state of the environment in relation to: biodiversity, flora and fauna; population and human health; soils, geology and sediment; water quality; air quality and climatic factors; materials assets; cultural heritage; landscape and seascape. Section 5.4 presents an overview under each environmental topic, identifies existing environmental pressures and problems and finally identifies potential data gaps. The data gaps presented have been identified through a combination of review of Member State strategic assessments of offshore renewable energy, review of literature and stakeholder feedback. It is acknowledged that in some cases data may exist at project level within different jurisdictions and this chapter should be seen as an opportunity to share data and research across the target Member States with a view to maximising efficiencies of scale across the region to fill the gaps. A comprehensive Environmental Baseline can be found in **Appendix D**.

5.2 State of the Environment Overview

Europe's natural environment represents one of the EU's most essential assets however pressures have increased significantly both on land and in the marine environment. It is estimated that over 40% of Europe's population live in coastal regions. In the EEA's recent State and Outlook Report, the EU identified priority challenges for the environment which, if addressed successfully, should benefit the present and future quality of the EU's environment.[40] These comprise: protecting natural capital in a sustainable way for both the environment and human well-being; stimulating a resource-efficient, circular and sustainable low-carbon economy; and to safeguard against environmental risks to health. These challenges and their relevance to the development of an offshore energy system in the Irish and North Seas are summarised in **Table 5.1**.

Table 5.1 - Key Challenges and Relationship to Offshore Renewable Energy Development

Challenge	Relationship to an Offshore Energy System
Protecting, conserving and enhancing natural capital It is considered that the natural capital of Europe is still not being conserved in line with the 7th European Environmental Action Programme (EEAP), nor the aim to halt biodiversity loss by 2020. Many protected habitats and species across Europe are considered to be in unfavourable conservation status (77% and 60% respectively). While some biodiversity targets are being met, projections indicate pressures, from climate change in particular, are likely to intensify which has implications for biodiversity loss.	Renewable energy source (RES) and grid infrastructure will have positive effects in relation to climate change by and offsetting the use of fossil fuels. The aim of the Baseline Environmental Study is to provide a knowledge base for the current understanding of the environment as it relates to an offshore RES and grid, along with identification of the potential impacts. This will help facilitate the protection of habitats and species and allow provision of mitigation measures to offset potential impacts of an offshore energy system.

[40] European Environment Agency (2015) State and Outlook Synthesis Report

Challenge	Relationship to an Offshore Energy System
Resource efficiency and the low-carbon economy Short-terms trends for Europe are promising - greenhouse gas (GHG) emissions in Europe have dropped 19% since 1990 levels, given that economic output increased 45%. Other environmental pressures have also declined, including decreasing use overall of fossil fuels, reductions in some transport and industry-related pollutants, improved recycling rates across Europe and less waste generated overall.	Europe's aim of a resource-efficient and low-carbon economy will have positive impacts for climate change. Whilst environmental pressures have decreased it is still imperative that RES are developed ensuring continued output of renewable energy.
Safeguarding against environmental risks to health Bathing and drinking water quality has seen great improvement over the past few decades with levels of some hazardous pollutants also seeing reduction. While improvements have been made regarding air quality, both noise and air pollution continue to cause impacts to health, in particular in urban centres. Particulate matter (specifically $PM_{2,5}$) was estimated to have caused approximately 430000 premature deaths across Europe in 2011. Environmental noise exposure has also been implicated in contributing to about 10000 deaths per year from strokes and coronary heart disease. The presence of some chemicals in consumer products has been tied to endocrine disorders in humans. Over the coming decades, improvements in air quality are not expected to completely prevent impacts to human health; additionally climate change impacts are anticipated to increase.	It is acknowledged that the manufacturing of materials for RES and grid infrastructure, as well as the transport of those materials will incur a carbon toll and there will be emissions to air from land vehicles and shipping traffic, however it is not foreseen that offshore renewable energy development will have significant adverse impact on human health. Movement of vehicle also contributes to the problem of noise in urban areas but noise generated by shipping activities offshore should not have any impact on human health.

Protecting, Serving and Enhancing Natural Capital

The EU and its Member States have implemented many pieces of legislation to protect, conserve and enhance ecosystems and their services, examples of which include: the 7th Environment Action Programme, the Biodiversity Strategy to 2020, the Common Fisheries Policy and the Marine Strategy Framework Directive (MSFD). Biodiversity continues to undergo loss due to human activities with overexploitation of natural resources underpinning the majority of impacts to biodiversity via loss, fragmentation and degradation of habitats. The article 17 assessments (2007-2012) for the Habitats Directive 92/43/EEC (herein after referred to as the Habitats Directive) highlighted that a higher percentage of habitats and species in terrestrial ecosystems are in favourable condition, compared to freshwater and marine ecosystems. Land use change and intensification of use which results in degradation, fragmentation and unsustainable use of land, are the two greatest drivers of soil biodiversity loss. Soil sealing, erosion and contamination were highlighted as three of the most persistent problems. Run-off from agricultural practices can reach the marine environment and contribute to the problem of eutrophication. Erosion of soils can increase sediment inputs to rivers which are also major sources of sediment for the sea as well.

On average, rivers and transitional waters are in worse ecological condition than lakes and coastal waters primarily due to diffuse pollution sources (e.g. agricultural run-off). Chemical pollution (in particular polycyclic aromatic hydrocarbons or PAHs, nitrate and heavy metal pollution) have also been identified as a major threat. Although Europe’s water quality has greatly improved over the last 25 years, eutrophication due to nutrient pollution remains a major issue. Urban sprawl and diffuse settlement are two key forces increasing land-take rates and leading to biodiversity loss and degradation. These forces reduce land-use efficiency and better spatial planning is required to mitigate this.

Emissions from the transport, power generation and agriculture sectors have resulted in high levels of acidification, eutrophication and ozone pollution. Although there have been reductions in emissions, the exposure of ecosystems to these pollutants has not always improved proportionally. The main risks to conserving marine ecosystems and biodiversity (and therefore achieving GES by 2020) are overfishing, sea floor damage, pollution by nutrient enrichment and contaminants, introduction of invasive alien species, and the acidification of Europe's seas. Climate change affects marine, freshwater and terrestrial ecosystems and the provision of all of the associated ecosystem services. Adaptation strategies to mitigate for the impacts of climate change are crucial and have been implemented in 21 EU countries. The focus of adaptation measures is ensuring that the functionality of the different assets that sustain humans (e.g. built infrastructure, the natural environment, and our culture, society and economy) is maintained, even under changing conditions.

Resource Efficiency and the Low-carbon Economy

Europe’s consumption patterns remain resource-intensive by global standards. Increasing resource efficiency and reducing greenhouse gas emissions have been key strategic policy priorities in recent years with the EU working towards a circular i.e. zero-waste economy. Since July 2013 there are 28 Member States in the EU, referred to interchangeably as the EU or EU-28; data and statistics reported by Eurostat, the EEA and other organisations are often referred to in terms of ‘EU-28’ in order to distinguish statistics which do not include data from candidate countries or other EEA countries such as Sweden and Norway. Current EU-28 data indicates that waste generation is declining, with improved waste management and declining associated greenhouse gas (GHG) emissions as a result.

In terms of climate change, the EU has aimed to reduce GHG emissions by 80-95% below 1990 levels by 2050 (and 20% by 2020). While the EU has made significant advances in decoupling carbon emissions from economic growth, current projections estimate that existing measures will be insufficient to achieve a 40% reduction in emissions by 2030, which would be required to stay on course for the 2050 target. Fossil fuels account for almost 80% of Europe's GHG emissions, transport being the most significant contributing sector. Current targets aim to increase the use of renewable energy up to 27% of final energy consumption and to reduce total energy consumption by 27%, by 2030.

Industrial emissions have decreased in Europe since 1990, even with sectoral economic outputs increasing. Despite this, industry continues to contribute significantly to air pollution e.g. sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and particulate matter ($PM_{2,5}$). Additionally, rebound effects may occur where pressures alleviated in one area may increase pressures elsewhere e.g. better fuel efficiency has led to an increase in driving. There remains a need to address production-consumption systems that can fulfil societal demands in an integrated way.

Environmental Risks to Human Health

A wide range of negative health impacts have been linked to environmental pollution, climate change and biodiversity loss. Water quality, quantity and ecological status can all affect human health; although the majority of the European population receive their drinking water from a municipal water supply, some 22% receive water from smaller water supply systems. The other major issues are: reducing chemical pollution at source; reducing eutrophication and harmful algal blooms; and implementing management plans to tackle water scarcity and drought issues - climate change is set to further exacerbate water shortages.

Air pollution has been shown to impact human health in a number of ways. Although atmospheric concentrations of lead, sulphur dioxide and benzene have been brought under control, other pollutants still present major health risks. Even though air pollution is causing thousands of premature deaths a year there still remains no dedicated policy framework that links safety, health, energy efficiency and sustainability. Noise pollution is also a public health issue, with road traffic being the greatest contributor, particularly in urban areas. The impacts of climate change on health relate primarily to extreme weather events, changes in the distribution of climate-sensitive diseases and changes in environmental and social conditions; however the impacts of climate change are not equally distributed. Emergent technologies and chemicals have increased in recent years and therefore risk management strategies must account for these. People are being exposed to a rapidly expanding array of substances and physical factors which have, at present, largely unknown environmental and health effects.

5.3 State of the Seas Overview

Similar to the Environmental Action Programme, Europe's Blue Growth Objectives aim for increased but sustainable use of the marine environment's potential. As such, the EEA has published the State of Europe's Seas which examines whether Europe is meeting its objectives in relation to the quality of the marine environment.[41]

[41] EEA (2015) State of Europe's seas.

The EU has numerous policies in relation to planning and sustainable use of the marine resource such as the ecosystem-based approach to protect and manage the marine environment, the MSFD (2008/56/EC). This forms an integral component of maritime planning within the EU and requires Member States to develop a strategy to achieve or maintain GES in their marine waters by 2020; the main goals for Europe's seas are to be clean, healthy and productive. The SOES report finds that while Europe's seas are certainly productive, they are neither wholly healthy nor clean.

Healthy Seas

The 'health' of the marine environment is considered with respect to the biodiversity of the marine environment as well as its resilience, and in whether each aspect of marine biodiversity is achieving the target of GES under the MSFD. Loss of biodiversity is also linked to loss of ecosystem resilience, or the capacity of an ecosystem to resist changes to normal functioning or its ability to recover when disturbance does occur. Biodiversity loss can result in irreversible loss of ecosystem resilience. This can be seen through reductions in species abundance and loss of habitat range, or loss of habitat altogether.

The SOES Report finds that marine biodiversity has been insufficiently assessed with biodiversity degradation seen across all European regional seas, indicating that the marine environment cannot be considered healthy. Similar to the terrestrial situation, the most recent assessments (2007-2012) required under the Habitats Directive reporting indicate that 66% of marine habitats and 27% of marine species were found to be at unfavourable conservation status. Part of the problem lies with uncertainty in the first instance, along with the difficulty in assessing and understanding some habitats and species e.g. water column habitats.

Biogeographical assessments conducted by Member States under the Habitats Directive reporting requirements indicates that invertebrates are not at GES, and invertebrates remain under intense pressure in certain parts of European seas. In parts of the North Sea, invertebrate benthic communities have been shown to be impacted by heavy-beam trawling. Some areas of the North Sea are intensively fished in this way each year (e.g. the German part of the North Sea), with recovery time ranging from 7 to 15 years.[42] Of the commercial fish stocks which have been assessed, a majority (58%) are considered not to be at GES, with the remainder unassessed. It should be noted that GES calculations are derived from figures on the EU's commercial stock, most of which comes from the North-East Atlantic and Baltic Seas and as such there is a significant fraction of unassessed stocks.

Even given the issues for marine biodiversity, Europe's seas are still thought to have considerable resilience. With the right measures and interventions, GES can be achieved. Some improvements are being noticed and there is evidence that the European marine environment can recover. For example in the North-East Atlantic, which borders the North Sea, overfishing has reduced and in parts of the Baltic and North Seas there are signs some areas are recovering from eutrophication.

[42] OSPAR (2010) Quality Status Report.

Clean and Healthy Seas

In European seas, many of the pressures impacting the marine environment are driven by human activities, including:

- Physical disturbance and damage to the seabed/seafloor;
- Intensity of commercial fishing particularly with regards to bottom-trawl gear;
- Fish and shellfish extraction: some sustainable fishing and signs of recovery in some assessed fish stocks. However indirect effects results from by-catch of non-target fish e.g. unintentional catching of large predators which can affect trophic levels through altering predator/prey relationships. Bycatch levels have remained at about 30-40% since the 1970s in the North Sea;
- Introduction of non-native invasive species: at present the main mode of introduction is via shipping, followed by aquaculture activities;
- Eutrophication, with knock-on impacts from oxygen-depleted zones: European sea regions have different responses to nutrients. The North Sea receives high nutrient loads but its open nature means there is a low residence time. The main sources are derived from various diffuse and point load sources as well as atmospheric deposition. Algal blooms are a problem in the North Sea, which can experience blooms in the shallow coastal waters from Germany to France, given the high nutrient content in the southern and eastern North Sea in particular. The OSPAR eutrophication assessment (2010) also notes that the coasts around Denmark, Germany, the Netherlands and Belgium are problem areas;
- Hazardous substances/contamination in the marine environment: results regarding chemical status assessments under the MSFD are mixed, with Member States frequently reporting 'unknown';
- Marine litter (plastic in particular): the current state of understanding marine litter in Europe is limited and has not been reported in a consistent fashion under the MSFD. The main sources come from terrestrial activities with plastics making their way to the marine environment, or from abandoned or lost fishing gear. Litter can have serious impacts to marine wildlife, for example 95% of beached fulmars from the southern North area were found to have plastics in their stomachs. Also poorly understood is the effect on marine organisms (as well as humans) of chemical additives in plastics (e.g. bisphenol A, phthalates etc. added to plastic containers); micro-plastics (particles <5mm) are also a concern as these are easily ingested by marine life;
- Underwater noise and other energy inputs (i.e. from shipping, renewable energy, hydrocarbon extractions and military activities): OSPAR data has indicated that the North Sea could have relatively high levels of underwater noise due to the level of human activity, which is expected to increase as development continues; and
- Marine climate change: many marine organisms respond to changing sea temperatures. Ocean warming can trigger trophic cascades; in response to increasing temperatures, species have a tendency to move northwards in European seas (e.g. pipefish, cold water plankton).

Productive Seas

Europe's seas represent a massive environmental, social and economic resource. Maritime activities are estimated to contribute just under €500 billion per year as gross value added to the European economy.[43] The following lists the main activities:

- Offshore renewable energy;
- Land-based activities;
- Commercial fishing;
- Aquaculture;
- Mineral and aggregate extraction and disposal;
- Transport and shipbuilding;
- Tourism and recreation;
- Man-made structures in coastal and marine waters (e.g. cables, pipelines, defence structures etc.);
- Research and surveying activities; and
- Military activities.

Most of these activities are expected to increase into the future, particularly in relation to shipping and offshore renewable energy development. Some of these activities directly depend upon the integrity of the seas' "natural capital" (e.g. fishing, seabed resource extraction), and at the same time create pressures on it (seafloor disturbance, alien species introduction etc.).

5.4 Environmental Characteristics and Problems in the Study Area

The following baseline information is prefaced for each environmental discipline by clarification on the nature and extent of effects considered for that discipline in relation to the Baseline Environmental Study. The baseline information is then summarised in relation to the identified scope. It is acknowledged that the knowledge base on the environment is changing and being updated all the time. As such, the data presented in the following sections is intended to represent an overview of the current state of the environment.

This section examines at a high level the relevant aspects of the current state of the environment within the study area in relation to: biodiversity, flora and fauna; population and human health; soils, geology and sediment; water; air quality and climatic factors; materials assets; cultural heritage; and landscape/seascape. These issue areas reflect those typically included in SEAs undertaken on plans/ programmes. Detailed information for each topic is provided in **Appendix D**.

Data gaps have been identified as outlined in various sources including specific SEAs and impact assessments of plans and renewable energy developments, as well as other relevant reports. While these have been identified at a strategic level, or where specific examples are detailed, these are not intended to be an exhaustive list for any given issue area and they have focused on the key data gaps. This also does not preclude the relevant surveys, modelling and other data gathering exercises which would need to be undertaken at the next level of assessment or could be required under relevant national guidance.

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[43] Based on data from the Blue Growth Study 'Scenarios and drivers for sustainable growth from the oceans, seas and coasts' (ECORYS, 2012). Retrieved: https://webgate.ec.europa.eu/maritimeforum/content/2946

Furthermore it is acknowledged that data exists in a wide range of settings, many of which are not readily accessible and as such some of the data gaps identified in the following sections may in fact be (or have been) the subject of study. Opportunities to share existing published and unpublished studies by each Member State should be explored as a matter of priority in order to rationalise the data gaps as much as possible. Opportunities will also need to be explored to undertake jointly funded studies. In **Chapter 8**, **Recommendation #6** outlines the key data gaps which should be addressed as a priority.

Biodiversity, Flora and Fauna

Biodiversity is the variety and variability of plants (flora) and animals (fauna) in an area and their associated habitats. The importance of preserving biodiversity is recognised from an international to a local level. Biodiversity is important in its own right and has intrinsic value in terms of quality of life and amenity. The natural environment is also critical in delivering ecosystem services such as providing clean air and water, food and raw materials, as well as cultural benefits. All of these contribute towards the concept of 'natural capital'. The European Commission's EU Biodiversity Strategy to 2020 has a headline target *to halt the loss of biodiversity and ecosystem services by 2020, to restore ecosystems in so far as is feasible and to step up the EU contribution to averting global biodiversity loss.*

As part of this Baseline Environmental Study, a number of designations at various levels have been considered. These include: international sites (Ramsar Sites, UNESCO Biosphere Reserves, World Heritage Sites and OSPAR MPAs); European sites (SAC, SPAs and Natura MPAs); and those at a national level (e.g. National Parks, Nature Reserves etc.).

The following topics are therefore discussed in detail in **Appendix D**:

- Designated sites;
- Protected habitats and species;
- OSPAR List of Threatened and Vulnerable Species and Habitats;
- Benthic flora and fauna
- Birds;
- Marine mammals;
- Fish (including elasmobranchs) and shellfish;
- Turtles;
- Bats; and
- Invasive alien species.

In terms of biodiversity, flora and fauna, there are a number of potential impacts to habitats and species which can result from the development of an energy system. The key impacts to habitats include: physical loss of seabed; alterations to habitats which can arise a result of changes to sedimentation and hydrography; changes to biotopes i.e. introduction of non-native habitat types as a result of the placement of artificial hard substrate as part of cable-protection measures or foundations; and pollution of sediment as a result of remobilising contaminants via direct or indirect disturbance to disposal sites or legacy sites.

There is a suite of potential impacts to species. The most significant impacts would be likely to occur during the construction phase of development (and also decommissioning, if structures or cables are required to be physically removed). Impacts also occur during the operational phase, which are generally related to barrier and displacement effects. This can involve: displacement and habitat loss of feeding and foraging grounds, particularly for marine mammals and sea turtles; and barriers to migration for birds, bats, fish and marine mammals. Direct impact to the seabed or from changes to sedimentation and hydrodynamics can impacts on spawning and breeding grounds (e.g. via smothering effects or loss of preferred habitat). Underwater noise is an issue for marine mammals and reptiles, with impacts that are greatest during the construction phase and particularly in relation to pile driving activities. There is potential for behavioural impacts from electromagnetic field effects, as well as physiological impacts resulting from changes to water quality or pollution (including from ship losses, marine litter etc.). Collision may result in injury of death, and can arise from collisions with ships, mooring lines or turbines (e.g. in wave and tidal devices). The introduction of artificial hard surfaces can change community structure, attract other animals such as fish (artificial reef effect) and has the potential to introduce or spread invasive or alien species.

Existing Environmental Pressures/ Problems: Biodiversity, Flora and Fauna

Existing Pressures
The main pressures on biodiversity, flora and fauna, as noted by the EEA in their most recent European Environment State and Outlook Report (2015), and which are relevant to energy system development include: habitat and species loss; habitat degradation and fragmentation; and over-exploitation of natural resources. These are mostly underpinned by human-induced changes to the environment. The continued development of renewables is going to increase in coming years and decades and overall this is anticipated to have generally positive impacts in terms of resource consumption. The presence of conservation designations in the study area however does not expressly preclude the ability to develop an energy system, however development may be subject to additional regulatory process or licensing and may require specific mitigation and monitoring that would make their avoidance preferable from both nature conservation and development perspectives. Under the Article 6(3) of the Habitats Directive, "any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment" (AA). It should be noted that both in-situ and ex-situ impacts need to be considered. Where negative impacts to protected habitats and/or species are identified, planned developments must, as a minimum, consider alternatives and may be subject to additional licensing or regulation which may jeopardise the success of the development. In circumstances where no alternative solutions exist and where adverse impacts remain, a case for IROPI (imperative reasons of overriding public interest) may need to be demonstrated and compensatory measures identified, before planning can be achieved. The study area includes a number of protected habitats, designated under EU and national legislation, e.g. coastal lagoons, reefs, large shallow inlets and bays. These habitats are home to both sedentary and mobile marine species, some of which are afforded protection also, under EU and national legislation, e.g. common (harbour) porpoise, grey seal. Where sedentary marine organisms are concerned, e.g. coral, avoidance should be the first mitigation strategy considered and alternative routes and/or processes (for the development) must be considered to ensure protection due to the species inability to move from the location of impact. Mobile marine species e.g. birds and marine mammals, on the other hand, often have distribution ranges which can span large spatial regions, often extending beyond the boundaries of designated sites.

Protected/ designated sites may also be designated for resident, summer and winter visitor species and these species must still be afforded protection. This protection must therefore take consideration of migration routes, calving/ birthing/ haul-out/ spawning grounds and foraging routes for the more mobile species in the study area. Impacts of particular concern for mobile species relate to construction disturbance and underwater noise.

Due to the development of RES and grid infrastructure in the study area, marine mammals in the study area are at risk as a result, inter alia, of habitat destruction and disturbance. The risk is further complicated by the often complex life cycles of certain marine species e.g. salmon, which may include a number of life cycle stages. There is potential for each stage to be impacted individually and the survival of the species to be impacted cumulatively over the life cycle by installation of infrastructure. As a result, an AA would need to be conducted before permitting such development.

Seasonal constraints on marine survey, construction and maintenance work, particularly in spawning and nursery grounds and feeding areas for particular sensitive species (such as basking sharks) may be an issue for development of an energy system. Where these sensitive areas occur, working times may be reduced to off season time, and therefore construction time and costs may be increased. In addition, in sensitive areas, maintenance may be limited by these conditions which could affect the response and correction time for any required maintenance offline periods, and it is expected that this would be more appropriately explored at the site / project level.

It is likely that additional marine SACs or extension of SACs with marine components will occur in the near future as survey work identifies areas of importance for marine habitats and species. Increased numbers of SACs and SPAs in onshore and offshore areas may result in delays to potential future developments due to the provisions of certain legislation and the requirements for assessment i.e. EIA, AA, SEA. Constraints to development should not however occur if the provisions of the legislation are duly applied.

Under the MSFD, marine areas are divided into regions and sub-regions and assessed against the GES criteria, with the aim of achieving GES in marine waters by 2020. In addition there is a Programme of Measures for Protected Areas which is intended to include measures for the spatial protection of MPAs. In addition the marine waterbody assessment will determine the risk and condition of marine waterbodies and protected areas may produce further constraints to potential future development.

The Common Fisheries Policy which determines fisheries policy for all quota species; it has undergone various updates the latest of which was in January 2014. The current policy stance is that fishing should occur in a sustainable way in order to support fish stocks, and that catch limits should be set between 2015 and 2020 to help achieve this.

Outlook and Future Trends

The State of the Environment Report (2015) reports that some biodiversity targets are being met however overall loss of biodiversity continues. Freshwater and terrestrial biodiversity is in unfavourable status in both the short and long-term. From the 2007-2012 Habitats Directive Article 17 reporting, just 23% of flora and fauna and 16% of habitats were considered to be at favourable status. The complete status and trends is difficult to quantify as many data gaps exist and it remains unknown whether increased deteriorations seen between the previous assessment period in 2001 and 2007 are down to improvements in the knowledge base or because of 'real' trends in deterioration. The ultimate driver of biodiversity loss is globalisation and an increasing per-capita consumption, placing pressure on natural resources and materials as well as urbanisation and developments which increase habitat fragmentation and loss.

The report from the EC to the Council on the first phase of implementation of the MSFD (2014) reiterated that across Member States, there was agreement that Europe's Seas are currently not reaching GES. The report considers that the main drivers of this are overfishing, marine litter (particularly plastics), continued levels of hazardous pollution in some areas, and climate change. The EC considers that more efforts are required to reach GES by 2020. The Commission also notes that Member States should address, as soon as possible and by 2018 at the latest, any shortcomings and improve "the quality and coherence of their determinations of GES, their initial assessments and their environmental targets, to ensure that the second round of implementation yields greater benefits". The State of the Seas Report (2015) reiterates these pressures, and notes that the short-term trend is unfavourable and the long-term outlook being a mixed picture. The majority of protected marine species and habitats were found to be in unfavourable conservation status, with just 7% of assessed marine species and 9% of marine habitats at favourable status under the Habitats Directive Reporting.

The SOES indicative assessment of key trends for healthy seas, clean and undisturbed seas, and productive seas indicates that overall the trends are mixed or generally deteriorating in the 5-10 year outlook. In many cases, information quality and availability is just not available and there are many knowledge gaps regarding the marine environment e.g. pelagic habitats, invertebrates, litter, underwater noise and other energy inputs.

Potential Data Gaps Identified: Biodiversity, Flora and Fauna

- The scale of the presence and migration routes of bats is a current knowledge gap; information on the extent to which bats cross the open ocean to forage and/or migrate is very limited.
- There is little information on the exact number and distribution of subsea cables which could be emitting EMF.[44] Further, the effects of subsea cables and electromagnetic fields (EMF) emissions on the behaviour of migratory species are poorly understood and there is a lack of monitoring or field studies on operational subsea cables.[45,]52 A report by NIRAS Consultants (2015) notes that there also remains little data on the impacts of cable EMF on fish ecology, as well as any targeted monitoring of the distributions of crustaceans and molluscs and whether cables impact these, or whether there are any thermal effects on benthic habitats.[46] It has been noted that there is little data on the impacts of EMF emitted from cables related to tidal devices on elasmobranchs in United Kingdom waters, or the potential for EMF barrier effects on electrosensitive species.[47]
- Under the MSFD, measuring underwater noise has been identified as a priority for assessment and monitoring.44
- Information on the exact location of maerl beads (in United Kingdom waters) is lacking; however data gathering is probably more suitably undertaken at project level.[48]

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[44] EEA (2015) State of Europe's Seas. Retrieved http://www.eea.europa.eu/publications/state-of-europes-seas

[45] OSPAR (2009) Assessment of the Environmental Impact of Subsea Cables.

[46] NIRAS Consultants (2015) Renewables Grid Initiative: Subsea Cable Interactions with the Marine Environment.

[47] Roche, R. C., Walker-Springett, K., Robins, P. E., Jones, J., Veneruso, G., Whitton, T.A, Piano, M., Ward, S. L., Duce, C. E., Waggitt, J. J., Walker-Springett, G. R., Neill, S. P., Lewis, M . J. and King, J. W. (2016) Research priorities for assessing potential impacts of emerging marine renewable energy technologies: Insights from developments in Wales (UK). *Renewable Energy*, 99, pp. 1327-1341.

[48] Department of Energy and Climate Change (2016) Environmental Report, UK Offshore Energy Strategic Environmental Assessment - OESEA3.

- High tidal areas are potentially very important for some cetaceans and seals - better knowledge of their distribution and densities would better inform any potential disturbances and collision risk for the eventual wider rollout of tidal devices; there is also a data gap with respect to the interaction of birds, other marine mammals and fish with surface and submerged wave and tidal stream and range generation devices.[48]
- There may be a lack of good data on seabird movements, especially further offshore. In an example from the Irish experience[49], there were found to be temporal gaps in coverage due to the migratory nature of many species which risk being undercounted by surveys. Adverse weather conditions may also impact on numbers of species present and whether they are successfully recorded. Larger and more remote areas (such as islands, which are often ideal seabird colonies) are by their nature more difficult to monitor or for surveyors to reach. There may also be 'deliberate' gaps e.g. some species may be considered as 'optional' to count (such as gulls and terns), or only monitored during certain seasons.54 The United Kingdom offshore SEA also notes similar data gaps exist for offshore seabirds in relation to their distribution and foraging ranges, as well as a lack of modern survey data on waterbirds in offshore areas.[48]
- The SEA for Offshore Wind Energy in Scottish Territorial Waters notes there is a knowledge gap on the broad scale movements of birds.[50]
- The Scottish Offshore Wind SEA also notes that information is required on the extent to which marine mammals and certain fish species respond to industrial marine noise, vibration and EMF, allowing frameworks to be developed to assess the population consequences of acoustic disturbance and the potential benefits of different mitigation techniques.
- Further, the Scottish SEA states that information is required on the potential nature conservation benefits that will occur as a result of the provision of additional habitat, associated navigation safety zones and changes to fishing practices caused by the presence of offshore structures. Consideration should be given to experience from the construction of other offshore structures in terms of improvements to biodiversity e.g. the construction of offshore reefs in the United Kingdom for coastal defence purposes have in some areas increased shrimp populations.
- The SEA of the Belgian Marine Spatial Plan flags several data gaps with respect to birds: the importance of the current Belgian wind farm zone as a foraging area for birds from breeding colonies on the Belgian and Dutch coast; the avoidance behaviour of local birds as a result of the wind farms in the current Belgian Wind Farm zone; the barrier effect and the impact on the accessibility of breeding and wintering areas in Belgium and the Netherlands; changes in migratory routes; the impact of collisions of birds with turbines on population level; and the change in the food supply within wind farms.53
- The Belgian Marine Spatial Plan also notes that it is unclear what potential impact increased biomass on artificial hard substrate would have on the abundance of fish.53
- Impact of the increasing presence of IAS on the marine ecosystem of the Belgian North Sea represents another gap.53
- Further the United Kingdom Offshore SEA notes there is insufficient data on cetacean abundance to assess population trends in many areas of the United Kingdom.[48]

[49] AECOM and Metoc (October 2010) Strategic Environmental Assessment of the Irish Offshore Renewable Energy Development Plan.

[50] Marine Scotland (2010) Strategic Environmental Assessment of the Draft Plan for Offshore Wind in Scottish Territorial Waters.

- There is relatively little data on how birds, mammals and fish interact with submerged RES devices such as wave and tidal arrays, given the relative sparsity of large-scale commercial deployments to date. Marine Scotland recommends conducting studies at the project level regarding faunal interactions particularly for single devices or small arrays to help inform larger developments.[48]
- There is little data on how the loss of inter-tidal habitat (e.g. for tidal range developments) affects bird populations (particularly waders) at the population level.[48]
- Measuring the acoustic environment around wave and tidal devices is acknowledged as being technically difficult given the very fast moving flows. The United Kingdom Offshore SEA notes that near-field particle velocities, while important for many organisms, are not typically measures around wave and tidal devices even though such devices have the potential to create complex velocity fields.[48]
- In the German part of the North Sea, detailed designation of biotope networks cannot be made at present, so no concrete locations are known.[51]
- The SEA of the Belgian Marine Spatial Plan noted data gaps with respect to the effectiveness of several nature management measures53; the United Kingdom's OSEA3 also notes that a strategic level understanding of biodiversity and its patterns (in United Kingdom waters) in particular for the species and habitats and features which are used as the bases for Marine Conservation Zone/ MPAs identification and designation, to inform considerations of site integrity and the assessment of proposed activities impinging on sites.48
- In the German part of the North Sea, the effects of gravity foundations on sediment, benthos and biotope types is not considered to be fully understood.51
- Exact migration patterns of sea mammals in the search areas and how these might be influenced by monopile hammering. There is little data which identifies how the offshore environment in the German Spatial Plan areas is used for migration, foraging and breeding by sea mammals and how this will be affected by the presence of wind turbines;[52] the Irish IOSEA4 notes a similar gap for the offshore environment.54
- The German Offshore Grid Plan notes a data gap with respect to the effects of operational wind park noise on sea mammals,51 and in the Irish IOSEA4, for general operational noise impacts.54
- The Dutch Wind op Zee SEAs note data gaps with respect to the effects of hammering monopiles and operational wind parks on fish populations.52 The Belgian Marine Spatial Plan notes it is unclear what the impact of increased biomass on artificial hard substrate is on the abundance of fish.53
- The amount of migratory birds and bats, and the exact migration patterns through the Dutch part of the North Sea, is noted as an uncertainty.52
- The SEA of Belgian Marine Plan notes that the impacts of noise to marine mammals is difficult to quantify, particularly with regard to the impact of reoccurring disturbance and piling for multiple wind farms at the same time; further the effectiveness of pingers and acoustic deterrents as part of 'soft-start' procedures are not sufficiently known.[53]

[51] Federal Maritime and Hydrographic Agency (2013) SEA of the Spatial Offshore Grid Plan for the German EEZ of the North Sea.

[52] RWS Water, Transport and Environment (2014) SEAs of the Rijksstructuurvisie Wind op Zee (WoZ) Netherlands.

[53] Arcadis (2013) Environmental Impact Report for the Belgian Marine Spatial Plan.

- The main body of knowledge on cetaceans does not include the collation of existing Marine Mammals Observers (MMO) reports from seismic surveys, which could result in existing cetacean data gathering being changed if the methods were coordinated and developed.[54]
- The SEA of the Offshore Renewable Energy Development Plan remarks that data collected via research undertaken by marine and nature agencies needs to be publicly available so it can be accounted for by developers. This will include collation, management and dissemination of available data.[55]
- Marine Scotland56 has compiled a list of data gaps with respect to marine mammals and offshore RES. Research and information gaps include: fine-scale marine mammal behaviour and habitat preferences; behaviour of seals in high energy tidal environments; mammal avoidance behaviours with respect to tidal energy sources; electrosensitivity of small cetaceans; more studies in relation to noise exposure (seal pups whose mothers were exposed to noise, protein markers, hearing damage as a result of PCB exposure).[56]
- To date, electrical sensitivity has not been investigated for any cetacean species found in United Kingdom waters; Marine Scotland has identified this as a research gap and notes that as there are no captive cetaceans in the United Kingdom, international collaboration is required to fill this gap.56
- The Dutch Wind op Zee SEAs note that the exact effects of EMF induced by sub-sea cables on marine species is a data gap.52
- The Annex IV State of the Science Report states that to date, there have been no reported instances of marine macrofauna (birds, mammals or fish) colliding with operational tidal turbines. As these environments are inherently dynamic with high natural energy, this hampers a consistent approach to monitoring.[57] The majority of research to date has however focussed on impacts from wind farms, with the effects of tidal and wave devices less well-understood. Tidal rapids are important hunting and foraging areas for marine mammals and so monitoring should be at an appropriate fine-scale so as to detect changes to subpopulations, as well as populations.[58]
- It is preferable to focus monitoring effort at offshore renewable developments which have previously been subject to a lot of monitoring, rather than spreading resources over many sites - this contributes to building up a robust picture of the baseline understanding and better impact assessments.56
- Key findings following monitoring studies at Horns Rev flagged several issues to be aware of with regards to offshore wind development, including: awareness of the potential for cumulative impacts with other sectors/uses of the sea i.e. fishing and the issue of by-catch; and there is a need for more data on porpoise prey distributions.[59]
- There is a lack of research in general regarding sea turtles and quantifying the impacts as a result of RES developments.57

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[54] Xodus Group and Aquefact International Services Ltd. for the Department of Communications, Energy and Natural Resources (2011) Fourth SEA for Oil and Gas Activity in Ireland's Offshore Waters: IOSEA4 Irish and Celtic Seas.

[55] AECOM Environment, METOC and the CMRC for the Sustainable Energy Authority of Ireland (2010) SEA of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland.

[56] Thompson, D., Hall, A. J., McConnell, B. J., Northridge, S. P. and Sparling, C. (2015) Current state of knowledge of effects of offshore renewable energy generation devices on marine mammals and research requirements. Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, no. MR 1 & MR 2, St Andrews, 55pp.

[57] Copping, A., Sather, N., Hanna, L., Whiting, J., Zydlewsk, G., Staines, G., Gill, A., Hutchison, I., O'Hagan, A.M., Simas, T., Bald, J., Sparling C., Wood, J. and Masden, E. (2016) Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.

[58] Booth, C.G. (2015) The challenge of using passive acoustic monitoring in noisy, high energy environments: UK tidal environments and other case studies. The Effects of Noise on Aquatic Life II (Eds A.N. Popper & A.D. Hawkins), Springer, New York.

[59] Dong Energy, Danish Energy Authority and the Danish Forest and Nature Agency (2013) Danish Offshore Wind - Key Environmental Issues, a Follow-up.

- Characterising the risk of collision of diving birds with tidal devices is not well understood given the high-energy and dynamic nature of such environments and the difficulty of monitoring in these sites.47
- Longer-term tracking and monitoring on a wider range of bird species would be useful to inform assessments of the impacts of offshore developments.[60]
- The JRC's EASIN database on IAS is currently not downloadable as a spatial file but the data is searchable online by species and environment (i.e. terrestrial and marine).[61] The Belgian Marine Spatial Plan acknowledges that the increasing presence of IAS and their distribution in the EEZ is a data gap.53
- Vast deployment of renewable energy itself may have an overlooked cost in terms of biodiversity loss as an unintended impact of climate change mitigation. There is currently a knowledge gap in terms of a global assessment of the impacts of offshore renewables. One such global assessment has been commissioned by the Cambridge Conservation Initiative and began in September 2015. The results of this assessment are expected to be available in early 2017.60
- OBIS-SEAMAP data is not publicly available at the genus or species level at the scale of the study area. The public data can be grouped by broad animal group only (i.e. marine birds, mammals, reptiles and cartilaginous fish/elasmobranchs), however at this scale it is noted that many species from the various animal groups are often recorded for the same grid cell, or data appears absent for an area. At the project level, more detailed data or specific study and survey results collated by OBIS-SEAMAP can be requested directly from the relevant data holder(s), at which point access may or may not be granted.

Population and Human Health

Population and human health are broad topic areas which encompass consideration of the presence of people, their activities, their use of the receiving environment and their wellbeing. Population distribution and growth forecasts are important indicators of both pressure on infrastructure and resources, and potential exposure to pollution and risk. In terms of health and wellbeing, these can be affected by a number of direct and indirect environmental pathways, typically through emissions to air and water. These emissions are generally considered in the context of reference to international and national standards of safety in doses, exposure and risk. Population levels are increasing, and there is significant pressure on coastal areas due to expansion of coastal cities, especially given that they are desirable locations for living. In addition, coastal communities often rely on the landscape, land and maritime resources for employment through fisheries, shellfisheries and aquaculture/ mariculture industries, ports and shipping, tourism and recreation etc. This increases the potential for conflict with the types of RES and grid infrastructure proposed. There is also potential for conflict with associated coastal infrastructure to support population centres, e.g. roads, utilities, coastal defences etc., particularly close to landfall sites. However there is also the potential for positive effects on human population through provision of alternative sources of employment and power.

Therefore for the purposes of this Baseline Environmental Study, the following topics are therefore discussed in detail in **Appendix D**:

- Population distribution;
- Population and Economic Forecasts; and
- Human Health.

[60] BirdLife Europe and Asia response from the second round of BEAGINS Consultation (October 2016). Retrieved: http://www.conservation.cam.ac.uk/collaboration/impacts-renewable-energy-global-biodiversity-%E2%80%93-overlooked-cost-climate-change

[61] European Commission Joint Research Centre Invasive Species Resource. Retrieved: http://easin.jrc.ec.europa.eu/GeoDatabase

For human health, the main concern generally regards electromagnetic fields (EMF), which is primarily of interest in the context of existing and future RES infrastructure and the cabling required to connect offshore RES infrastructure to landfall points, and from there to onshore substations via overhead powerlines or undergrounding.
For Population and Human Health, there are a number of potential key issues. Impacts to air quality can occur from both plant emission from the manufacture of RES and grid infrastructure, and from the combustion of fuel to transport materials by both land and sea. Such traffic can also result in noise emissions, as well as operational noise generated by RES. EMF is emitted from power cables in the form of both electric and magnetic fields, and while the no one epidemiological study has proven conclusive, concerns persist over about the effects of long-term low-level exposure on health and general well-being. Recreational activities may also be impacted in the short-term by the presence of vessels during different stages of RES development, and longer-term via exclusion from areas given over to RES development or resulting from adherence to exclusion zones or rerouting of ship traffic.

It is also recognised that the topic of Population and Human Health shares a number of interrelationships with other SEA topics, therefore the impacts to human health from air quality factors are dealt with in detail in **Section 5.4: Air Quality and Climatic Factors**, and recreation is dealt with in **Section 5.4: Material Assets**.

Existing Environmental Pressures/ Problems: Population and Human Health

Existing Pressures

Human health can be impacted particularly in urban areas where a number of pressures are found together; on the other hand, settlements which are compact spatially are more efficient with regards to making resources and provision of services more easily available. Air quality across Europe is generally good but there remain problem areas, again in particular urban areas, where levels of some pollutants are elevated above EU and WHO limits and which are having an impact on human health. A RES is not foreseen to impact on population dynamics or human health in any significant sense; increasing use of renewable energy can help offset use of fossil fuels which has positive impacts overall. The manufacturing of materials for RES and grid, as well as the transport of those materials both on land and via shipping to offshore development sites will incur a carbon toll and there will be emissions to air from land vehicles and shipping traffic. The impact of EMF on human health is probably negligible but the link with other epidemiological trends such as cancer risk remains inconclusive. Offshore cables will have no impacts to human health in terms of EMF and cables at landfall points are generally buried which diminishes field effects. Additional overhead line connections may be required to link grids, and the addition of converter stations to landfall points could constitute a visual impact.

Overall, the existing pressures in relation to population and human health include:

- An increasing population places demands on space and energy consumption;
- Land fragmentation;
- Elevated levels of NO_2 and PM_{10} in urban areas, mainly from road traffic;
- Noise pollution in urban areas;
- Urban sprawl;
- Limited green space in urban areas for recreation and enjoyment.

Outlook and Future Trends

The State of the Environment Report states that there have been improvements in housing and end-pipe emissions however urban areas by their nature can impact on vulnerable populations such as children and the elderly. Climate change is expected to exacerbate pressures on human health and well-being. Over the long-term (20+ years) an increasing population is expected to increase demand for land uptake as well as increase habitat fragmentation, which in turn impacts on ecosystems.

While levels of noise exposure remain fairly stable in Europe, currently there is not enough data to consider what the long-term trends are in terms of noise exposure and the implications for human health. The amount of noise emitted to the marine environment is expected to continue to increase, especially given the plans for expanded offshore renewable energy/grid developments, as well as continued projected growth in the tourism, transport and other energy extraction sectors.

Potential Data Gaps Identified: Population and Human Health

- There are some information gaps regarding EMF, both for humans and their effects on marine biota. There are a number of review documents available regarding the potential health effects of EMF, prepared by national and international health protection bodies such as the World Health Organisation (WHO) and the International Agency for Research in Cancer (IARC). Extensive research studies have also been conducted regarding EMF and health. In general there seem to be limited to no effects on human health from EMF according to the latest data and guidelines. Despite this, there is still concern from the public, especially with regard to high voltage overhead lines. Contradictions and limitations between studies in relation to cancer risk however indicate there remains a data gap in understanding both the link and the mechanism for causing any adverse impact.
- The Belgian Marine Spatial Plan notes that the cumulative effects of multiple EMF with different characteristics and scattered across the seabed represents a knowledge gap.53

Soils, Geology and Sediment

Soils, geology and sediments make up the physical characteristics of an area or landscape, both onshore and offshore. On the terrestrial side, soil is a valuable resource that performs many ecosystem services: production of food; production of biomass; storage, filtration and transformation of nutrients and water; carbon storage and cycling; and contributes to the landscape and cultural environment. Consideration of soils is important for RES and grid development as some terrestrial coastal development is likely where cables make landfall or where there is a need to make a further inland connection to reach a substation for instance. The coastal and offshore bedrock geology and bathymetry are key factors in the siting of offshore infrastructure, as the depth of water affects ease and costs of installation and operation. The bedrock geology can exert control over sedimentary processes, affect both physical and biological habitats at the seabed, and influence decisions on the types of foundations or moorings utilised, depending on the type of RES infrastructure. Contaminants are widespread in the marine environment and can be found in marine biota, the water column and marine sediments. Coastal processes are also highly complex involving sediment budgets, sediment transport links between areas and constantly changing flow conditions.

A number of sites within the study area are also designated for their geological features which represent sites of outstanding landscape character or particularly illustrative examples of geological processes. Many such sites occur in coastal areas and comprise natural heritage value for geology as well as flora and fauna.
The key areas which have been considered as part of this Baseline Environmental Study include the physical characteristics of the marine environment and marine processes.

The following topics are therefore discussed in detail in **Appendix D**:

- Soils;
- Bathymetry and hydrology;
- Marine and coastal geology;
- Coastal processes;
- Geological heritage designations;
- Seismic activity; and
- Contamination and sediment quality.

From a RES and grid perspective, soils may be disturbed, moved, sealed-in or lost as a result of the siting of terrestrial infrastructure such as converter stations or the footprint of pylons from any additional required overhead powerline links, or disturbance and compaction from the undergrounding of cables. Offshore, the physical presence of structures on the seabed causes direct disturbance to the seabed from both the preparation of a site and from the footprint of any structure(s). The presence of RES structures can also alter sediment dynamics and local flow conditions. Further, contaminated sites, legacy dumping sites and dredge spoil sites may also be directly disturbed by cable-laying activities and RES structures causing remobilisation or resuspension of previously settled materials. Indirect impacts can occur via altered hydrodynamics, changes to coastal processes and natural sediment movements.

Existing Environmental Pressures/ Problems: Soils, Geology and Sediment

Existing Pressures
The significant existing pressure in terms of geology and sediment is contamination from synthetic and non-synthetic chemicals and heavy metals which can be present in the water column, in biota and in marine sediments.
Outlook and Future Trends
OSPAR data indicates that, overall, trends in contaminant levels have shown decreases across Europe however each member state has localised areas where contaminant levels exceed background levels (usually OSPAR background assessment concentrations) in sediments. These areas are generally ports, harbours, estuaries and dredge dump sites. These are areas of high human activity and riverine inputs to the marine environment; for the latter, in particular from of urban wastewater discharges and sludges, and industry emissions, which are the primary sources. Concentrations of contaminants are expected to drop off in the open seas away from highly developed areas, where the main significant inputs are from atmospheric deposition and shipping.

Potential Data Gaps Identified: Soils, Geology and Sediment

The body of information on the physical, geological and bathymetric setting of the Irish and North Seas is extensive and generally well-understood however there are data gaps with regards to specific areas in terms of the sediment type as well as data gaps in the understanding of how RES development can affect coastal processes (particularly from wave and tidal technologies). Some of these data gaps include:

- The EMODnet substrate mapping characterises sediments well at the strategic level, however there could remain areas where the sediment is not well characterised. For example the sediments off the south coast of Ireland are not well characterised.[49]
- The United Kingdom's OESEA3 notes that for some areas there is excellent data on seabed topography and texture from multibeam mapping undertaken under various programmes. It is noted that there remains significant gaps in coverage with a recommendation to prioritise areas of industrial and conservation interest.48

- The effects of wave and tidal structures on coastal processes, and in particular far-field effects, are not well understood. The United Kingdom has the most deployments either operationally or as test sites and much of the data on the effects to coastal processes comes from modelling exercises.[48] In the Belgian Marine Spatial Plan, an energy 'island' is proposed however as there are as yet no concrete plans to develop such a structure, it is considered that the impacts to tides and sedimentation dynamics would be more appropriately explored at project level.53,[62]
  - The SEAs for the Dutch Rijksstructuurvisie Wind op Zee also notes a knowledge gap with respect to wake effects from neighbouring wind farms, with the current understanding based on modelling rather than practical monitoring; future monitoring is expected to fill this gap.52
  - Characterising the tidal resource has been flagged as requiring urgent research, including how the physical environment is altered inside and outside tidal lagoons e.g. through improved hydrodynamic modelling, sediment transport pathways, seasonal variability, mixing rates etc.48
- The effect of wind turbines on the natural processes of the sea and sea bed (soil erosion, currents, etc.) are considered a data gap, as well as uncertainties regarding wake effects from neighbouring wind farms;52 there are also uncertainties with regards to the physical processes associated with large and multiple site development as well as the cumulative impacts of those large developments on physical processes.[63]
- The regeneration capacity and speed of regeneration of the seabed, local habitats and benthos communities after disruption is noted as a data gap in the SEA of the Belgian Marine Plan; further, the degree to which the frequency, duration and level of increased turbidity is acceptable to filter feeding organisms is also a knowledge gap.53
  - The Scottish Offshore Wind SEA flagged a data gap with respect to seabed features: in some areas, seabed mapping/ classification should be undertaken to identify and avoid geologically important features. Certain biodiversity issues for instance are strongly linked to geology e.g. Annex II reefs, maerl beds and herring spawning grounds.50

Water

Water is essential for all life on earth and as such management of the water resource is a significant issue nationally and within Europe. Overall, surface water quality has improved significantly since the 1970s, mainly due to the implementation of various EU directives in relation to the environment. The three main challenges for water quality management are to eliminate serious pollution associated with point sources; to tackle diffuse pollution; and to use the full range of legislative measures in an integrated way to achieve better water quality. However continued pressures from diffuse agricultural run-off, continued urbanisation and climate change means achieving and maintaining satisfactory water quality and status under both the Water Framework Directive (WFD) and the MSFD will remain a key issue for Europe. To date, water protection efforts have succeeded in reducing the extent of serious pollution in rivers but there remains a need to improve the status of others which are currently at less than good ecological status as reported by the EEA in 2012. Status has been improved to date mainly through a focused effort on tackling emissions from point sources, such as inadequate or poorly performing wastewater treatment plants. A key development in meeting the requirements of the WFD has been the publication of River Basin Management Plans and now the MSFD plans, which address coastal waters and the marine waters which fall within Member State jurisdictions. These plans have provided a coordinated approach to water management across Europe.

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[62] FPS Health Food Chain Safety and Environment (2012) Initial Evaluation for the Belgian Marine Waters. Strategy Framework Directive for the Marine Environment Article 8, Paragraphs 1a & 1b.

[63] BMT Cordah Ltd. (2003) Offshore Wind Farm Development: Strategic Environmental Assessment (R2 Wind).

The plans address many of the pressure on water however it will take time to fully resolve all the issues and residual pressures will remain. The key areas which have been considered as part of this Baseline Environmental Study include how water bodies are dealt with under the WFD and MSFD, water quality (encompassing acidification, eutrophication, contaminants and marine litter) as well as flood risk.

The following topics are therefore discussed in detail in **Appendix D**:

- Water classification;
- Water Framework Directive Protected Areas;
- Marine Protected Areas;
- Surface Water Quality;
- Bathing Waters;
- Eutrophication;
- Contaminants in Biota and Water;
- Marine Litter;
- Ocean Acidification; and
- Flood Risk and Coastal Defence.

In terms of energy system development, the main issues for water and water quality relate to shipping and the bringing of materials to and from developments sites. Potential indirect impacts include the accidental or intentional dumping of wastes from ships and contribution to marine litter. Additionally, accidents at sea can cause the accidental loss of fuel, oils or hydraulic fluids to the water column (from both vessels and energy devices e.g. oil-filled cables). Pollution may result from the release of antifouling compounds and corrosion protection compounds (e.g. copper and aluminium). The setting of structures on the seabed, as a result of foundation construction or cable-laying activities for example, can potentially remobilise contaminated sediments or disturb munitions or legacy dumping sites. This can result in an increase in suspended sediments/increased turbidity within the water column.

Existing Environmental Pressures/ Problems: Water

Existing Pressures
All users of the sea are responsible for nutrient, litter and contamination issues; land-based activities (e.g. agricultural runoff, industrial emissions, urban wastewater) as well as sources at sea (e.g. shipping, fishing, hydrocarbon and mineral extraction, dumping of wastes) all contribute to suppling contaminants, nutrients and litter to the marine environment. There are a number of existing issues regarding water quality in the study area. While Europe overall has made progress in decreasing nutrient inputs, particularly riverine inputs which ultimately reach the sea, eutrophication remains an ongoing and major problem in the North Sea; the entire coast from France to Belgium is listed by OSPAR as a problem area for eutrophication, with parts of the North Sea suffering recurring algal blooms. Nitrogen loading to the North Sea area is also a transboundary issue, as atmospheric deposition is a major pathway for this nutrient. Both synthetic and non-synthetic contaminants can be present in sediments, seawater and marine biota. Significant reductions in contaminant levels have been made since the 1970s owing to tighter regulations on human activities from EU, OSPAR and MARPOL policies, regulations and legislation. Despite this, contaminant levels remain high in some sediments and biota, particularly historically-polluted and highly industrialised coastal sites. Contaminants can also enter the water column via leaching of antifoulants coatings on ships, rigs and some RES devices, as well as corrosion of sacrificial anodes.

Marine litter can negatively impact on fauna such as birds, mammals, fish and turtles, by causing adverse effects via injury, entanglement, health impacts and death. Litter also has landscape and visual impacts through the physical presence of litter, can present a danger in and of itself (e.g. dumped munitions can also be considered a form of litter) and can have long-lasting temporal impacts as previously buried or covered litter becomes exposed or gets washed ashore. The economic costs of clearing litter from beaches can be very high, running into the millions.

Outlook and Future Trends

The State of the Environment Report (2015) notes that trends in water quality over the short-term (5-10 years) are favourable, reflecting the improvements in water quality, however there are still problem areas which are impacting on status and eutrophication will continue to be an issue in some areas. The long-term outlook (20+ years) predicts a mixed-picture, especially for areas with intense agricultural activities which will put pressures on receiving waters and the marine environment. The Urban Wastewater Treatment Directive and the Nitrates Directive have led to some improvements since implementation however diffuse nitrogen in particular remains a problem.

For hazardous substances and contaminants, OSPAR has compiled an outlook of the cessation targets to 2020 of 26 substances (OSPAR List of Chemicals for Priority Action, March 2010). A third of substances will reach cessation targets by 2020, including: all 6 listed pesticides (e.g. lindane, endosulfan), tributyl tin, short-chain chlorinated parrafins, some brominated flame retardants, and some phenols. Three substances have unknown outlooks (a phenol and 2 pharmaceuticals), while the remainder have unfavourable outlooks for cessation (e.g. lead/cadmium and their associated organic compounds, as well as polychlorinated biphenyls, polycyclic aromatic hydrocarbons, phthalates etc.).

Marine litter is a transboundary issue and constitutes a serious problem for the health and quality of the world's oceans; litter which originates in one country or in the open seas can end up on the shores of another country. Plastics are by far the most common litter type in Europe's seas and production globally continues to grow; the State of the Seas Report (2015) states that the global amount of plastic predicted to enter the oceans will double between 2015 and 2025. Litter is however a recognised issue under the MSFD and measures have also been developed and are being implemented by the Regional Seas Conventions.

Flood risk will very likely be exacerbated by climate change, involving more frequent and intense precipitation and storm events which have implications for land run-off and urban drainage, as well as coastal defences and coastal erosion affected by rising sea levels. The state of the Environment reports that for the long-term outlook (20+ years), the trends are mixed/unfavourable as extreme events such as flooding and droughts may become more commonplace and adversely affect water systems and human health. Increased flood risk also has economic impacts, via damages to dwellings and businesses and/or loss of personal effects.

Shipping activities are likely to continue apace; the State of the Environment Report notes that over the coming 5-10 year period, the transport, shipbuilding and energy production (including renewables) sectors will continue on an upwards trend in terms of intensity of activity.

Potential Data Gaps Identified: Water

- OSPAR note that better information is needed to understand the sources and pathways for contaminants, including improved tracking of the fate of substances (e.g. pharmaceuticals), as it is possible trace amounts of some substances could cause adverse ecological impacts in the marine environment.42
- There is also a concern that while some substances are being phased-out, replacement chemicals themselves have the potential to cause adverse impacts, particularly if their emissions are not carefully monitored e.g. extensive use of copper to replace Tributyltin (TBT) as an anti-foulant, with increased emissions to the marine environment, particularly from fish farms/aquaculture. There are also major research and monitoring gaps with respect to microplastics; while some impacts are well-documented (e.g. bisphenol is acutely toxic to humans and some organisms), there are knowledge gaps with respect to quantifying the impacts to marine biota (e.g. distinguishing the impacts of microplastics in facilitating uptake of contaminants versus 'natural' bioaccumulation of contaminants).42
- In terms of water quality, the impact of aluminium deposition from monopile corrosion protection on total aluminium levels in sea water is unknown.52
- In the offshore environment, there is little water quality monitoring taking place.[64] To date, studies of water quality impacts indicate that effects to water quality and marine life in the vicinity of RES are negligible. These conclusions are drawn primarily from short-term studies and possible long-term impacts are yet unknown. Use of antifoulants and the effects on water quality is thought to be the best understood of the various chemical elements of water quality, as the chemicals used are regulated at EU level.

Air Quality and Climatic Factors

Air pollution is the single largest environmental health risk in Europe. It shortens people's lifespan and contributes to serious illnesses such as heart disease, respiratory problems and cancer. On a larger scale, climate change is real and it is largely caused by human activities, primarily greenhouse gas (GHG) emissions from fossil fuel burning, but also from other activities such as agriculture and deforestation. Therefore for this Baseline Environmental Study, the topics of air quality and climatic factors have been addressed and are discussed in detail in **Appendix D**.

The development of an energy system has the potential for short-term emissions during the construction and development stages of the project. These emissions will include both indirect emissions derived as a result of the manufacturing of the infrastructure components (cables, etc.) as well as the direct combustion emissions associated with plant operation, material transport and laying the cables (through road transport, shipping, etc.). Manufacturing and road transport can have impacts for local air quality and human health, emissions of acidifying gases and GHG emissions.

Outside of the short-term construction phase there are no predicted direct positive or negative impacts for air quality or climate from the development of a RES and grid infrastructure. However, there are a number of indirect impacts anticipated as a result of the development of a RES and grid. The primary indirect impact would be a positive for both climate and air quality and would arise from the development of the infrastructure resulting in the potential for a reduction of direct emissions derived from fossil fuel electricity generation by enabling the development of RES infrastructure.

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[64] BEAGINS Scoping Workshop, May 2016.

Furthermore, the decarbonisation of the electricity generation sector will result in potential further positive indirect impacts through the implementation of electric vehicles and a reduction in tailpipe emissions in the transport sector. EU policy includes the deployment of electric vehicles as part of an alternative fuels strategy to break the over-dependence of European transport on oil. Given that the baseline environment in the six Member States show that the electricity generation and road transport sectors are key pressures for both air quality and climate, the development of an energy system is anticipated to be positive. Other sectors such as residential and commercial may also experience indict positive impacts for climate and air quality as a result of the RES and grid development.

The net impact for climate will be significantly positive in the long term from the deployment of large-scale renewable infrastructure allowing Member States to reduce the reliance on carbon based fuels and facilitate the transition to a low carbon economy.

Existing Environmental Pressures/ Problems: Air Quality and Climatic Factors

Existing Pressures

Air pollution remains a serious environmental health risk in Europe responsible for more than 430000 premature deaths in Europe. While levels of pollutants have declined significantly since 1990, there are still areas where the ambient limit values for the protection of human health are regularly exceeded (typically urban areas). Similarly, most of the six Member States report some exceedance of the national limit values with potential for broader transboundary air quality impacts. The key sources of air emissions across the six Member States show similar trends with energy and transport the key sources.

Climate change is a recognised issue with serious implications for economies, biodiversity, weather conditions and sea levels. Overall, RES development will contribute to achieving targets for renewable energy generation in all jurisdictions by facilitating a transmission network for harnessed renewable energy. Increased usage of RES and grid infrastructure would contribute to offsetting some usage of fossil fuels, which in turn would have positive impacts in terms of reducing emissions from oxides of nitrogen (NO_x), oxides of sulphur (SO_x) and particulate matter (PM).

Some air quality issues may arise as a result of the manufacturing of energy system components (e.g. cables) and infrastructure (e.g. turbines), the road transport of materials and shipping emissions from cable laying, etc. during the various phases of development however this is generally considered to have localised and temporary air quality impacts, which can be mitigated at project level.

However, there are potentially a range of indirect positive impacts where RES enables the shift away from fossil fuel combustion and a resultant reduction in emissions. The decarbonisation of the electricity generation sector will have significant co-benefits for air quality through the reduction in NO_x, SO_x and PM emissions with positive impacts for human health and ecosystems. The decarbonisation of the electricity sector coupled with the continued roll out of electric vehicles will also reduce the potential for tailpipe emissions from the road transport sector.

Outlook and Future Trends

The State of the Environment Report (2015) notes that trends regarding air pollution and ecosystem impacts over the short-term (5-10 years) are favourable, reflecting emissions reductions over the past 2 decades, and a lessening of the impacts of acidification and atmospheric nutrient sources (eutrophication) to ecosystems. Over the longer term (20+ years), the outlook is a mixed picture as eutrophication issues will persist in some areas, with EEA projections to 2020 indicating that the issue will remain widespread in Europe. Hence the need for further improvements in air quality.

Air quality in Europe is improving but oxides of nitrogen, particulate matter and ground-level ozone are particular problems. The outlook in both the short- and long-term is a mixed picture. While many EU countries are currently meeting emissions targets, some countries are not in compliance with the ambient air quality limits, and compliance levels are even lower when the stricter WHO air quality guidelines are considered. Levels of air pollution are predicted to continue to cause adverse effects to human health beyond 2030.

Climate change has a severe impact on ecosystems; for example, the oceans are the largest CO_2 sinks on earth and as atmospheric levels rise, ocean acidification is exacerbated damaging biota and habitats (e.g. reefs). Ocean temperatures are also increasing. Climate change also causes stress through impacting population envelopes whereby species tend to move to higher latitudes or altitudes in order to adapt to changing conditions. For many species, this change occurs too fast for species to adapt adequately. There is also the possibility that invasive species will take advantage of changing conditions and out-compete native species. Coastlines will become more vulnerable to both sea level rise and altered erosion rates, altering near-shore habitats.

In terms of the health impacts from climate change, the EEA predicts that deteriorating trends will dominate in both the short- and long-term. The main impacts to health and well-being from a changing climate relate to the effects of extreme weather events (including flooding), extreme temperature shifts especially in summer and winter (heatwaves/snowstorms), as well as changes in the occurrences and outbreaks of infectious diseases. The effects of climate change effects will continue to worsen, even with current mitigation measures, as even modest warming scenarios alter global balances.

Even though the EU strategy on adaptation to climate change was agreed in 2013, and if all anthropogenic emissions were halted immediately, the climate would continue to change for some time as a result of historic emissions and knock-on effects which have already been set in motion (e.g. ice sheet melting, ocean warming, altered precipitation patterns etc.). The EU has cut emissions to about 19% on 1990 levels and is on track to exceeding the 2020 target. With current measures, the EEA notes however that the EU is not currently on track to meeting the 40% reduction target by 2030 nor the 'decarbonisation' target of 80-95% emissions cuts by 2050.

Potential Data Gaps Identified: Air Quality and Climatic Factors

- The knowledge base for air quality across Europe is well developed and comprehensive. It is an area which is very well understood in terms of its impacts as there are regulations in place to protect against certain emission levels. Overall there are considered to be no major knowledge gaps with respect to air quality.
- There is extensive research being undertaken in terms of climate with model accuracy increasing all the time. In a strategic sense, the broad scale impacts of climate change are well understood.
- The SEA of the Belgian Marine Spatial Plan notes that the ways in which port expansion and energy system infrastructure (e.g. the proposed energy atoll for Belgium) are realised may have subsequent impacts on the sea defence system, especially with regard to likely impacts from climate change (e.g. rising sea levels). Further, the Belgian Plan notes the potential impacts of climate change on the physical/ coastal processes is unknown.53 Therefore it is likely that such unknown impacts will be relevant to other Member States within the Baseline Environmental Study.

Material Assets

The term 'material assets' is not clearly defined in the SEA Directive or indeed the EIA Directive, which has led to a wide range of interpretations by environmental practitioners and environmental regulators alike. Material assets are generally understood to relate to the infrastructural assets that enable a population or an area to function as places to live and work. The term can be taken to mean infrastructure including transport, utilities and energy resources. As such, for this Baseline Environmental Study, material assets are therefore taken to encompass the following:

- Existing renewable energy infrastructure;
- Cables and pipelines;
- Shipping, ports and harbours;
- Fisheries;
- Recreation;
- Military activity;
- Hydrocarbons;
- Aggregates; and
- Dredging and disposal.

Carbon capture and storage and emergency services are not discussed in this report as these are considered outside the scope of this study, where the major activities and uses of the seas are considered. The United Kingdom has currently cut funding for carbon capture storage contracts, with Norway being the other major player with respect to carbon capture storage in the North Sea. Further, there is no easily available comprehensive spatial dataset relating to emergency services however hydrocarbon installations can be used as a proxy to some extent as many are only accessible by helicopter. They have been flagged as possible environmental receptors however and have been included in the Impact Dictionary.

Each of the broad categories of material asset listed above is discussed in detail in **Appendix D**. It is also acknowledged that there are clear interrelationships to be considered with other environmental constraints e.g. recreation and population, fisheries and biodiversity, coastal defence structures and water. Material assets represents a major topic of consideration for the Baseline Environmental Study, given that there is such a density of activity and multitude of uses of the sea from various sectors and industries in the Irish Sea and in North Sea in particular.

In terms of material assets, the development of an energy system will involve a number of activities which have varying degrees of impact over the course of construction, operation, maintenance and decommissioning. Overall, the key issues relate to increased competition for physical space and interactions with existing activities, as well as the licensing/opportunity areas associated with those activities. The main conflicts with other users of the sea relate to: ship rerouting and further densification of existing shipping routes; additional costs incurred as a result of rerouting or increased travel times; and exclusion from operational or opportunity areas e.g. from military exercise areas, fisheries, offshore recreational activities, mineral/aggregate extraction, maritime disposal sites etc.

There are a suite of potential issues associated with shipping in particular and the presence of ships with respect to RES and grid development. There would be increased levels of shipping associated with all stages of RES and grid development which will be required in order to bring construction materials to/ from development sites and during the maintenance and decommissioning phases. Deployment of cables via ships will also be required in order to link RES infrastructure to other structures and to landfall points. Ships have also been identified as a major source of marine litter in the North Sea. There is also potential for ship-to-ship and ship-to-RES collisions which can result in loss of fuel and hydraulic fluid etc., as well damage to RES structures.

Anchoring and deployment of mooring lines from ships and platforms/rigs also have the potential to damage existing subsea cabling or energy system elements placed on the seabed. There would also be increased levels of underwater noise during surveying activities (e.g. from use of seismic, sonar), during construction (foundation-laying, movements of vessels, pile-driving etc.) and noise associated with operation and decommissioning.

Some level of seafloor disturbance is also inevitable as a result of developing an energy system whereby sediments become disturbed from the physical footprint of offshore structures, also contributing to loss of benthic habitat. Contaminants may also be disturbed or remobilised and there could be encounters with both known and unknown munitions or unexploded ordnance.

Existing Environmental Pressures/ Problems: Material Assets

Existing Pressures
Pipelines, wells and subsea infrastructure transfer important and potentially dangerous resources across the seafloor. The laying of cables is protected under International Law on the Sea (UNCLOS) and telecommunication connectivity is generally given a high priority in maritime planning. Cables are potentially dangerous if disturbed during any maritime operations. Damage to pipelines can lead to serious accidents or significant environmental damage. Locations of cables are recorded by International Cable Protection Committee (ICPC), however, cables can be snagged and moved, and legacy cables (old telegraphic network and lost sections of other networks) may be encountered and can still present a hazard. Microwave and radar transmissions (radio, television etc.) are predominantly operated by line of site and interference can affect a wide range of users. In the case of military or marine applications, these links are often for safety communication between vessels, platforms or mobile units. The international and national telecommunications industry is set to grow significantly as existing services are expanded, new services provided and consumer demand for internet access and use increases. There are several telecom and power cables planned within the study area. Additionally, future marine renewable energy development both on and offshore in will require significant upgrades to the electricity grid system, necessitating the development of high voltage interconnector cables linking these projects to major grids and markets and will result in an increased number of subsea cables. In general, fish catches within the EU are also declining; the main pressure continues to be intensive fishing coupled with fishing techniques which damages seabed and benthic habitats (i.e. bottom trawl). The level of impact is related to the scale of operations and the numbers of fish extracted. Disposal of bycatch or the catching of non-target or sensitive species is another pressure. Aquaculture also puts pressure on the marine environment via effluent release, eutrophication from fish feed and fish waste, predator control and introduction of disease. Maritime resource extraction is expected to continue as usual to meet the demands of current and future development and construction. Seabed mineral and aggregate extraction results in localised sediment plumes and elevated suspended solids in the water column, as well as potential loss and redistribution of the resource during movement for transport away from the site. Disposal of hazardous waste at sea has been banned by the London Convention since 1993 however there is the possibility of disturbing or remobilising contaminants from existing disposal sites by cable and pipe laying, foundation preparation and construction. Hydrocarbon production and extraction on the other hand has been decreasing within Europe, while imports remain high. Despite this, a number of pipelines are proposed in the North Sea with several under construction.

The main impact from the construction of pipelines involves alterations to the seabed and loss or destruction of benthic habitat. Oil spills are a major health and environmental hazard and can occur from damaged pipelines or via ship collisions and are also associated with loss of well control and blowouts as well as leaks or insufficient capping for natural gas or CO_2 storage.

Shipping is a major user of the sea and the levels or ship traffic, ship building and ship maintenance activities are expected to grow in coming years to keep pace with development. Ship-to-ship collisions are uncommon but still occur. Shipping is also associated with noise impacts to the environment and the North Sea in general is recognised as having high levels of background shipping noise.

Tourism creates pressures on the environment directly through visitor impacts to sensitive landscapes and creating underwater noise from recreational boating, and indirectly through emissions from land, air and sea transport. Coastal tourism requires structures to be built (visitor centres, public toilets etc.), modifies the existing environment (building of harbours, piers and sea walls) and puts pressure on those structures to expand into the marine environment.

The magnitude of the effects of EMF on marine life is uncertain; EMF is known to affect swimming direction in migrating eels and possibly other fish, but the effects are considered to be temporary. The degree to which EMF affects marine life is uncertain and remains a significant knowledge gap.

Outlook and Future Trends

Across Europe, there has been some decoupling of resource usage and economic growth- resource productivity (an indicator of efficient use of material resources) improved from €1.52/kg in 2002 to an estimated €1.95/kg in 2014. However the recession in 2009 is thought to have contributed somewhat to this. Europe has made good progress in reducing CO_2 emissions per capita - 10.5 tonnes CO_2 equivalent (CO_2eq) per capita in 2000 to 8.9 tonnes CO_2eq in 2012. However energy dependence increased from 47.4% in 2001 to 53.2% in 2013 despite the uptake in RES (15% share in 2013).[65]

The long-term outlook therefore sees increased globalisation, growing populations and demands for resources which could see this decoupling trend start to reverse. Europe's consumption patterns are still considered resource-intensive by global standards, with fossil fuel use continuing to dominate the energy sector. Full implementation and regulation of energy efficiency policies and action plans would be required to meet the EU's 2020 target. The financial crisis of 2008-2009 also reduced demand for transport however the long-term outlook is for deteriorating trends and sustainable transport would require major modal shifts.

Of the commercial fish stocks which are assessed, 58% are not at GES under the MSFD. Total fish landings reached peak numbers in the 1970s but have been declining since. Declining numbers of top predators coupled with commercial fishing of smaller prey fish has led to changes to food webs. As such Europe's fish stocks are currently considered to be unhealthy. There are signs that fish stocks are starting to recover however maximum sustainable yield objectives are not being met.

The State of the Seas indicative assessment of key trends indicates mixed or generally deteriorating trends in the 5-10 year outlook. In terms of productive seas, over this timeframe the majority of human activities in the marine system are projected to continue growing on current trends (i.e. extraction and production of resources both living and non-living, tourism, transport and shipbuilding, production of energy including renewables, as well as research and surveying); only military activities are predicted to decline over the same period.

[65] EU Resource Efficiency Scoreboard 2015. Prepared by Ricardo Energy & Environment with guidance from the European Commission Directorate General for Environment (2016)

Potential Data Gaps Identified: Material Assets

- Information on underwater noise generated by tidal devices remains limited; this is down to technical reasons such as the variety of designs and the limited deployment on large scales.[48]
- For the German part of the North Sea, it is recognised that both fisheries and military activities are traditional users of the sea, but currently specific spatial designations for this particular use are difficult or cannot be established. Mariculture is a rapidly growing industry worldwide but the establishment of such industry within the German EEZ is not yet fully realised[66]. The Belgium Marine Spatial Plan noted uncertainty regarding the potential feasibility of certain activities within a zone (e.g. for aquaculture).53 The Irish IOSEA4 noted there is insufficient information regarding the use of the marine environment by small vessels (e.g. inshore and static fisheries).54
- Recreational activities can be hard to quantify; there are very few spatial datasets available (either at national or European level) and it can be difficult to assess the scope and variety of activities occurring in an area. The exact amount of recreational boating and their movement in the Dutch North Sea for instance is estimated based on the number of ports and harbours that are nearby52; there are also unknowns with regards to the impacts on recreation and tourism income as a result of exclusion of these activities from potential renewable development sites.63
- At a national scale, the Scottish Offshore Wind SEA recommends undertaking cumulative impact assessment to include assessment of all offshore developments on sea-based recreational routes e.g. in order to understand the displacement of recreational craft into commercial routes and the consequent risk to safety. At the regional level, the SEA notes there is a requirement for a comprehensive navigation/ traffic assessment, if not already being carried out by developers, to understand safety hazards associated with potential interaction of offshore wind development with the shipping industry. The objective would be to fully understand the potential impacts with respect to safety and navigation, rights of innocent passage, commercial and carbon implications etc. with full cognisance of the potential benefits that a strong wind industry can bring, in order that robust and equitable mitigation measures may be developed. The development of a steering group may be required to progress this action.
- As they are a finite resource, hydrocarbon extraction activities are likely to decline over time. Exact information on how long current and future oil and gas activities will continue in the areas is uncertain.52
- No research has been conducted on the potential decrease of fisheries in the Dutch North Sea and the potential economic effects52; the United Kingdom's OESEA3 also flags this as a data gap.[48]
- No research has been conducted in order to take into account any jobs that might shift from other industries.52
- The Belgian Marine Spatial Plan SEA flags several data gaps with respect to shipping safety and the risk of oil contamination, including: the exact definition and location of the new developments at sea (e.g. energy atoll, offshore grid connection, port expansion, Mermaid Wind Farm) that determine possible effects on shipping; the uncertainties in modelling risk of collisions and the associated pollution; and the cumulative effects of altered shipping routes/flows and changes in ship types.53
- The United Kingdom's OESEA3 raises a data gap on the precision on the offshore distribution of navigation data (AIS data coverage typically only extends 80km from shore).

[66] BSH (2012) Spatial Offshore Grid Plan for the German Exclusive Economic Zone of the North Sea and Non-technical Summary of the Environmental Report.

Cultural Heritage

Coastal and maritime cultural heritage is characterised by traditions of travel and commerce and influences community identity, language and livelihood. Coastal areas and inland waterways have always been important for human habitation as means of transportation and for water supply; some historic coastal sites in the United Kingdom for instance date back up to 900000 years old. The cultural heritage in the study area is evidenced by the presence of prehistoric underwater archaeological remains, shipwrecks, aircraft and submarine losses, coastal architectural conservation and protected areas, local food, holy sites and more. Cultural heritage along coastlines typically features structures such as promontory forts, shell middens, defensive structures, tombs, burial grounds and batteries. Offshore, there exists a wealth of maritime heritage features, a significant amount of which may be unrecorded.

Of particular relevance for the marine environment are wrecks, which are usually defined as sunken ships (anything from prehistoric wooden boats to civilian and military vessels lost as a result of war, collision or adverse conditions. Wrecks can also include aircraft and in more recent times, submarines, as well as any items or materials associated with those vessels. The prehistoric submarine archaeology of the study area is largely a matter of conjecture, as no remains have been found. During and after the last Ice Age, early settlements in study area are likely to have been initially dominated by the degree of ice cover and access routes to and from Britain and Ireland to mainland Europe.

As such, the main topic areas which have been considered for the Baseline Environmental Study, and which are discussed in detail in **Appendix D**, include:

- Sea and Land Heritage;
- Maritime Heritage and Historic Wrecks; and
- Coastal Archaeology.

The main issues for archaeological, architectural and cultural heritage associated with an energy system is the resulting potential for both direct and indirect impacts on features of interest and their settings. The development of an energy system has the potential to impact on known underwater archaeological features during construction of new structures and/or infrastructure upgrades. Potential impacts can also arise for previously unknown archaeological features during the installation of new structures and/or infrastructure upgrades. The physical presence of RES and associated infrastructure (e.g. platforms and converter stations) also has the potential to impact negatively on the perception of a historic landscape of the character of the archaeological setting.

Existing Environmental Pressures/ Problems: Cultural Heritage

Existing Pressures
Cultural heritage in coastal and marine areas comes under threat from both human-driven and natural sources. Natural factors include coastal and seafloor erosion from storms, tidal surges and changing sea levels, exacerbated by the impacts of climate change. Human activity which can pose a threat to submarine heritage includes resource extraction (aggregates, minerals and hydrocarbons), pipe and cable-laying, as well as RES development. Maritime developments interact with a wide range of archaeological and cultural heritage aspects. The study area has historically been used for a high level of ship transit and naval action. As a result there are large numbers of wrecks recorded and a likelihood of many more unrecorded wrecks. In addition to protected wrecks and marine graves, there are a number of wrecks that may be classed as dangerous, either due to their position or cargo e.g. fuel, munitions or other contaminants that could be released if disturbed.

Further marine sites may be identified at project level as part of the development of RES and grid infrastructure.

Development has the potential to place pressure on sites or features of architectural, archaeological or cultural heritage interest via direct pressure on this resource, where it is in proximity, or where it increases the potential to interact with known or previously unknown sites and features. Together with existing pressures on landscape and visual resources, this can result in an impact on the overall cultural heritage resource.

Outlook and Future Trends

Cultural heritage is expected to continue to exist in much the same way it has for hundreds and thousands of years. Losses from ship collisions and air craft losses are much less likely in modern times given technological advances, mainly down to collision detection, aircraft monitoring and linked communications systems. More heritage features are likely to be discovered in the offshore environment as a result of surveying, sampling and offshore development activities.

Potential Data Gaps Identified: Cultural Heritage

- Much of the underwater heritage resource has not been discovered or fully characterised. The North Sea is and historically has been an extremely busy area for ship and air traffic. Given the area covered by the Irish and North Seas and the range of water depths and sediment types, knowledge of the number and distribution of underwater heritage features therefore is limited by what surveys have been conducted, the accuracy of historical reports and military knowledge of downed or wrecked craft, as well as the rate of discovery by divers and specific site investigations.
  While modern surveying techniques are highly accurate, in the past GPS positioning was less accurate and the positional accuracy of some features may differ to their actual spatial location on the seafloor.49 Potentially, very small features or items also may be missed by surveying techniques.
- Information is sparse regarding the archaeological and cultural heritage of the marine environment for the Irish and Celtic Seas, as well as Dutch North Sea.52
- No spatial data could be accessed on terrestrial or coastal archaeology for Germany and the Netherlands. If such data exists it is recommended it be added to the BEAGINS data portal to allow access and interrogation by stakeholders.

Landscape and Seascape

Landscape and seascape are defined by physical elements, features and characteristics whereas visual amenity is specific to human interactions (i.e. views). Areas of high visual amenity have value to other disciplines such as tourism, human health and cultural heritage. Landscape/ seascape and visual amenity indicates the value of an area in terms of the character of the coast or landscape and the visible features of an area of land. These include the physical elements of landforms, water bodies such as rivers, lakes and the sea, living elements of land cover including indigenous vegetation, human elements including land uses, buildings and structures and transitory elements such as lighting and weather conditions.

Landscape and Seascape are discussed in detail in **Appendix D**, but broadly speaking, landscapes are areas that are perceived by people which are made up of a number of layers:

- Landform: which results from geological and geomorphological history;
- Land cover: which includes vegetation, water and human settlements; and

- Human values: which are a result of historical, cultural, religious and other understandings and interactions with landform and land cover.

The main issue for landscape and seascape character associated with the development of an energy system is the resulting potential for both direct and indirect impacts on the physical setting as well as visual perception. For the former, impacts relate to direct physical changes to landscape features (the presence of structures alters the landscape or coastline). Indirect impacts relate to the presence of physical structures which can alter the perceived character of an area or impact on natural heritage resources and tourism assets which are dependent on the adjoining landscape setting. Visual impacts can occur where the presence of RES is considered visually intrusive (e.g. the long vertical profiles of turbines, safety lighting etc.).

For the grid component, subsea cables do not represent visible features. Grid infrastructure can however impact on coastal settings via the siting of structure(s) required in order to connect the offshore grid to the terrestrial grid e.g. converter stations or overhead line connections to existing transmission/ distribution powerlines.

Existing Environmental Pressures/ Problems: Landscape and Seascape

Existing Pressures

Impacts to landscape and seascape from an energy system is usually considered in terms of the visual intrusion of a structure or structures in a coastal area and the wider viewshed, or the geographic area which is visible from any given location. The distance to the visible horizon at sea is dependent on the height from which it is observed and by the sight line dependant on the curvature of the Earth. As a result, in determining the impact of RES in particular on seascape, the vantage point, colour, number and height of any installation, and the height from which it is observed are used in the determination of the significance of any impact on seascape.
When viewed from the shoreline (at 1.8m above the ground or average head height) the horizon appears 5km away, and therefore installations at a greater distance from the coast may not be visible. However, seascapes of high amenity value are associated with geological features such as sea cliffs or mountains, and at a 200m height the horizon appears over 50km away.

Outlook and Future Trends

The State of the Environment Report notes that fragmentation of natural habitats and areas as an ongoing issue, driven by increasing populations and demands for spaces for development, housing and recreation. Urban land-take and intensification continues, with about a third of Europe’s landscape considered to be highly fragmented35. The current target is for there to be no net land-take in Europe by 2050, which would help to minimise or halt the impact of development to the landscape. The location of landfall is an important consideration as additional infrastructure may be required in order to connect offshore grids to terrestrial grids via converter stations and additional pylons, all of which incur a footprint on the landscape.

Coastal defence in Europe is a significant and well-established industry, which is likely to continue to grow in the long-term outlook in keeping with mitigating future impacts from climate change; land reclamation is widely utilised in the study area, notably by the Netherlands and also Belgium. Both practices alter the natural state of the coastal environment and consequently potentially alter the perception of the nearshore and coastal landscapes. The continued growth of the offshore renewables sector and increasing utilisation of renewable resources will present challenges to preserving the character of the local and wider landscape.

Potential Data Gaps Identified: Landscape and Seascape

- The European Landscape Convention requires that signatories aim to improve the knowledge base of the landscape and identify the pressures acting on it. While some countries (e.g. the United Kingdom) or local authorities (e.g. some in Ireland) have undertaken landscape character assessments, other countries currently have no consistent approach at national or regional levels for undertaking landscape character assessments. Going forward, implementation of the Landscape Convention should help to standardise the approach and allow better comparison of designations across borders.
- Under the internationally-recognised IUCN protected areas system, there are no Category V 'Protected Landscapes and Seascapes' for Belgium, Germany or Ireland. It should not be assumed however that the absence of such a category implies the absence of such features or coasts, as other national, regional or local designations may cover many of the same requirements. This does however limit a transboundary assessment of similar landscape types, but at project level, all available protected areas and known landscape designations should be considered.
- There is uncertainty regarding the degree of visibility of offshore wind parks at night due to turbine nacelle lighting.52

6 CONSIDERATION OF ALTERNATIVES

6.1 Introduction

This chapter considers possible strategic alternatives in the context of the Regional Concept Report. The alternatives considered are referenced to the overarching objectives of the study i.e. to provide a concept for an integrated offshore electricity transmission network across multiple jurisdictions. Any consideration of alternatives at this strategic level does not in any way preclude further consideration at the Member State level within other related processes including SEA, EIA and AA of plans, programmes or projects.

It is recognised that much decision making has already taken place as a result of higher level and/ or supporting EU policy as well as through Member State plans for development of offshore renewable energy sources (RES) and as such this limits the study commentary. The focus of alternatives has therefore been at the grid alternative, specifically radial and meshed alternatives.

6.2 Grid Solution Alternatives

Each of the three capacity scenarios presented in **Chapter 3** will have to develop grid configurations to ensure optimal connection to RES. There are two principle types of grid connection configurations for offshore renewable energy, namely radial and meshed, and there are levels of coordination between these two extremes at national and international level. This Baseline Environmental Study has had regard for these two main approaches whilst recognising that the reality could be partial meshed which would display a combination of both radial and meshed configurations. **Figure 6-1** presents a visual overview of the types of configurations that can be generated through the radial and meshed concepts.[67]

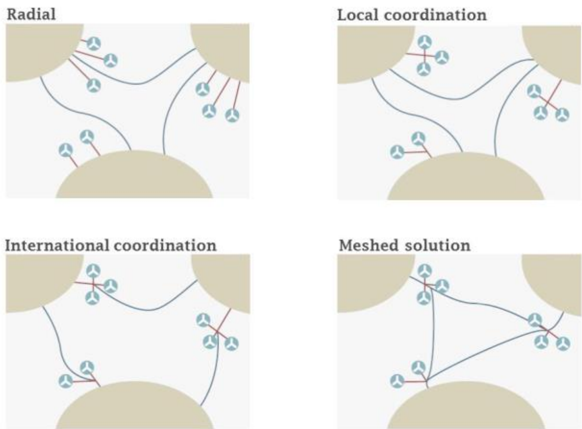

Figure 6-1 - Potential Configurations for Radial and Meshed Grid Development

As is shown in the figure, there are a range of configurations that can be developed from the overarching concepts of radial and meshed grids.

[67] Working Group 1 - Grid Configuration (2012) 'North Seas Countries' Offshore Grid Initiative'

Radial Grid Development

For a radial configuration there is very limited coordination as each offshore renewable energy project is developed independently and thus the pattern that develops is one of point to point connection. In this type of configuration the offshore energy resource e.g. wind farm substation is connected directly to the onshore substation. All of the energy sites are connected to a substation in the country they belong to. As such it is the simplest form of approach and only facilitates local markets.

Radial was the development situation in the study area up to 2009. Following announcements in 2007 a number of interconnectors were developed to allow energy trading and distribution as well as sales of renewable energy units beyond local markets. This is predominately the situation within the study area as of 2016. DG Energy's (2015) Mid-term Evaluation of the Renewable Energy Directive[68] concluded that to date (as of 2015) there had been very little use of the Co-operative Mechanisms of Articles 6-12 of the directive. Likely causes included:

- A general preference to achieve the targets domestically (and retain benefits locally);
- Uncertainty about the need to back Renewable Energy Strategy domestic achievement with cooperation mechanisms in order to reach the targets;
- Uncertainty about quantifiable costs and benefits, and design options;
- Insufficient interconnection capacities between Member States or Member States and third countries, and legal barriers; and
- Uncertainty about the continuity of the EU framework beyond 2020 as a decisive investment condition for joint projects and joint support schemes.

Presently energy markets are very well integrated around the North Seas (day-ahead markets coupled, and intra-day/balancing market integration ongoing). However RES units remain closely linked to a single national bidding zone, on whose RES incentives it depends and to whose RES targets it contributes. As a result there is currently limited (cross border) coordination of RES unit and interconnector deployment. The system topology is led predominantly by market forces with only local and national strategy oversight. If no further drivers or incentives are instigated at EU or other level then this is the most likely development alternative should no other action be taken.

Meshed Grid Development

Meshed grids are a coordinated onshore, offshore and interconnected design approach for offshore energy transport and interconnection. This approach allows for interconnecting of renewable energy clusters, offshore platforms, offshore development zones and countries, optimised for an overall economic and efficient design. This means that the meshed design for the whole of the North Seas region could be implemented from a series of major offshore hubs.

The level of coordination observed on the ground will dictate to a large extent the future expression of a meshed grid in the Irish and North Sea. The reality is more likely to be in a range from local coordination to greater international coordination rather than any wholesale shift to fully meshed. As such local and international coordination are also considered under the meshed grid alternative.

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[68] DG Energy (2015) Mid-Term, Evaluation of the Renewable Energy Directive, A study for REFIT, prepared by Delft, 2015, accessed via https://ec.europa.eu/energy/sites/ener/files/documents/CE_Delft_3D59_Mid_term_evaluation_of_The_RED_DEF.PDF

Local Coordination is the localised coordination of hubs and shoreline connections from a number of arrays. European renewable energy policy and increased maritime spatial planning provide the potential for centralised hubs occurring in the Irish and North Seas. To an extent this is already occurring as market forces drive windfarms into phased projects, such as those along the coastlines of Germany and the Netherlands. These phased developments have diversified from single projects to having potentially several investors building arrays and delivering power through centralised hubs. As more coordinated and structured maritime spatial planning is introduced in the region, project development through minimising submarine cabling and allocating a single mainland connector will become much more appealing for developers as it will ease planning and cost considerations.

Despite the current limited development of combined platforms as a concept, co-location of devices can realise significant benefits with respect to infrastructure. The most attractive combined natural resource in existence in Europe is combined wind and wave resource, and this presents a large opportunity. There are two principal benefits of co-locating devices (e.g. an array of wind devices and an array of wave devices either exist in the same area or in closely adjacent areas):

- Joint utilisation of a single electrical infrastructure (which will allow cost reductions and smoothing of power output from the combined farm); and
- Potential joint utilisation of operational and maintenance teams, vessels and infrastructure (this relates closely to the 'offshore service hub' concept previously outlined).

Technology development has progressed in co-location for floating array technologies. Full sized demonstration projects are already deployed in Northern United Kingdom and Norway to evaluate long term deployment and productivity. However, there may also be merit in investigating the deployment of wave or tidal arrays within existing windfarms.

International Coordination combines interconnector requirements with offshore hubs and arrays to maximise development locations whilst minimising landfall requirements. It combines the interconnection with the RES hub providing direct connectivity between the home country and the market and visa versa. Because interconnections open up new electricity supplies and potential buyers, they make it easier to shift power around on a minute-by-minute basis when there is a surplus or a shortfall. Examples of international coordination can be found in the wider region and include projects such as Kriegers Flak in the Baltic Sea which will is proposing to connect the Danish region of Sjaelland and German Mecklenburg-Western Pomerania and the COBRA project linking Netherlands and Denmark.

Denmark has numerous interconnectors to neighbouring countries where there is a strong supply of renewables, such as Germany and Norway. Currently 43% of its electricity comes from wind energy. Denmark is aiming to be 100% fossil fuel-free by 2050 and much of this will be supplied by advanced interconnection to meet this target. In addition, one project presented by Ofgem in 2015, is the NSN Link from Blyth in the United Kingdom to Kvilldal in Norway, currently in Phase 1 operation where there is an abundance of hydroelectric power. When wind generation is high and electricity demand is low in the United Kingdom, the NSN Link will allow up to 1400MW of power to flow from the United Kingdom, conserving water in Norway's reservoirs. When demand is high in the United Kingdom and there is low wind generation, up to 1400MW can flow from Norway.

Renewable energy policy reports from: the EU; the Offshore Grid Project; the North Seas Countries Grid Initiative; the European Network of Transmission System Operators for Electricity (ENTSO-E); Greenpeace; and the North Sea Trans-National Grid project generally agree that internationally co-ordinated grids or supergrids would be technically feasible and efficient, and financially viable although there are challenges to their delivery.[69]

6.3 Assessment of Grid Alternatives

The current business as usual approach to the development of offshore electricity infrastructure is characterised by limited coordination through a radial configuration (albeit with local examples of coordination). As grid cables have a long lifespan, (typically 40 to 50 years67) the decision on their location is critical in relation to ensuring that energy resources are adequately captured and environmental footprints are reduced. In addition, as the North Sea is dominated by a number of important activities such as shipping, fishing and the oil and gas industry, future planning for a renewable energy grid needs strategic planning to minimise conflicts with existing operations as is presented in **Figure 6-2**.

A key consideration for the future approach to grid configurations is reflection of the length of cable required for radial and meshed configurations. Cable lengths are generally shorter for the meshed configuration than for the radial due to the use of more substations, however there is a greater requirement for hubs to allow the network to connect offshore. **Table 6.1** provides an indicative outline of the cable lengths required for a radial and meshed configuration for each of the three capacity scenarios presented in the Regional Concept Report.

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[69] Mehos, D. C. (2015) Smart Regulation for Far and Large Offshore Wind Integration: Toward a Transnational North Sea Meshed Grid. Flow Project, Report P201101-009-TUD.

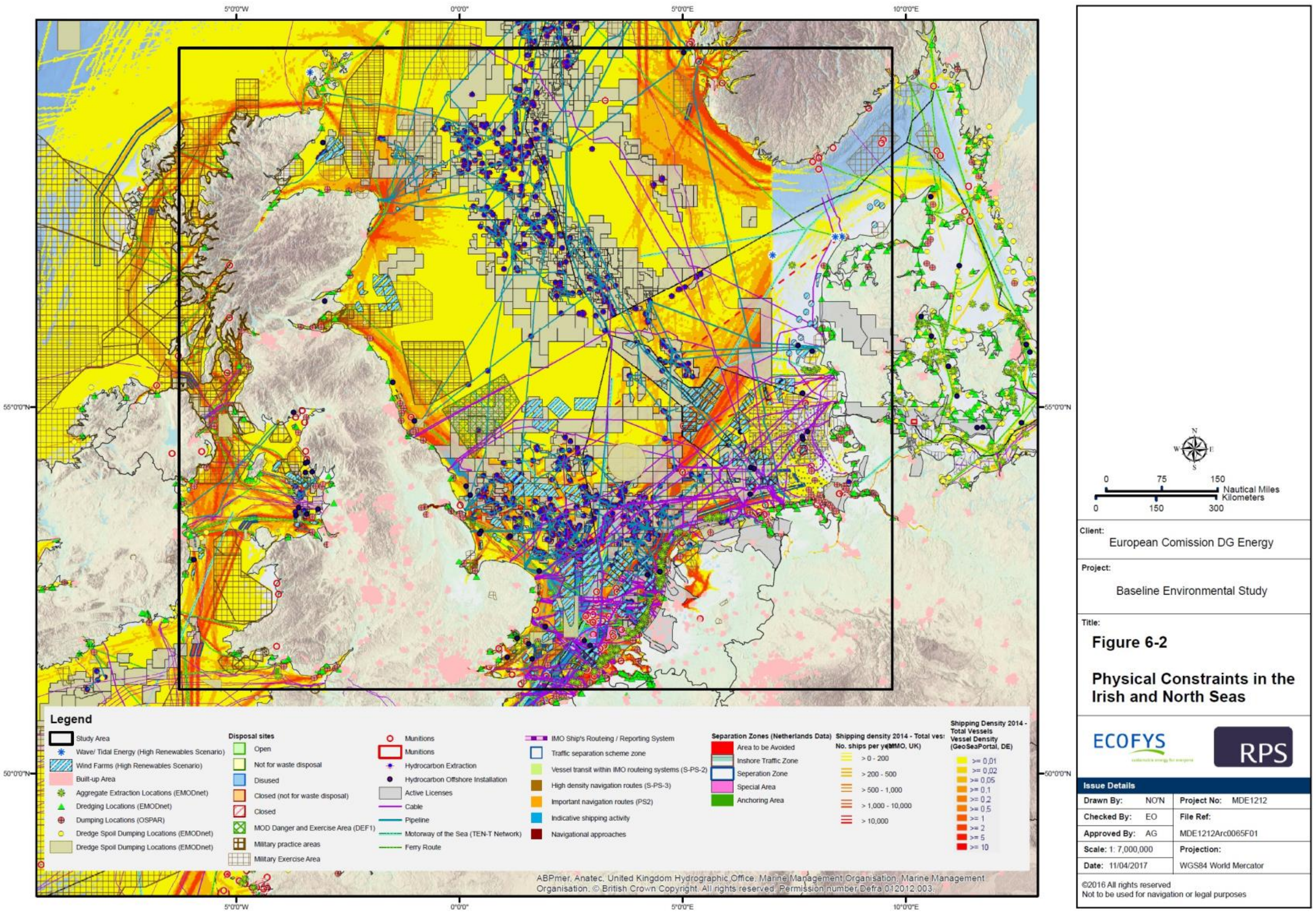

Figure 6-2 - Physical Constraints in the Irish and North Seas

Table 6.1 - Future Cable Lengths for Radial and Meshed Grid Connection

	High Renewables		PRIMES Reference		NSCOGI	
	Radial	**Meshed**	**Radial**	**Meshed**	**Radial**	**Meshed**
Offshore Cable Length	12952	8831	10422	6164	8351	6226
Number of hubs	13	42	13	33	13	25
Number of landing points	173	113	128	84	112	82
Number of offshore substations (HVAC and HVDC)	342	363	262	231	219	231

Due to the additional complexity of a meshed grid there will be enhanced challenges in relation to construction and operational process, however it is clear that offshore cable length for a meshed grid is reduced for all three capacity scenarios detailed with the Regional Concept Report.

Whilst there is a significant reduction in the quantity of cable required for a meshed scenario there are similar costings to that of radial due to the need for more hubs and offshore substations. The meshed approach has a high capital cost requirement due to additional offshore infrastructure but it is recognised that meshed depends to a large extent on HVDC technology costs and future anticipated cost reductions could bring a significant cost reduction for the development of a meshed configuration. The investment does pay for itself through strategic benefits that are enabled through a coordinated network development. Such benefits include the opportunities for energy trading between Member States, resulting in better integration of offshore wind capacity, greater resilience for individual offshore wind farms and more confidence in ensuring security of supply. Therefore the meshed configuration offers greater flexibility, efficiency and assurance of optimum utilisation of the network.

However, whilst the meshed grid provides an overarching opportunity to optimise an international network for movement of energy it requires regulatory coordination between the relevant Member States. The approaches to development of a radial or meshed strategy for a grid connection network represent extreme ends as it is likely that any integrated offshore grid will develop incrementally and it must be recognised that there is already current ongoing development in the Member States demonstrating evolution toward coordinated solutions.

The following sections broadly consider, under key environmental headings, the constraints and opportunities associated with the two configurations - meshed and radial. The starting point in each case is that the radial configuration would have more cable and need more landfall points, while the meshed configuration would require more connector and hub infrastructure.

Biodiversity, Flora and Fauna

Generally speaking, in the case of biodiversity, flora and fauna, sensitive siting of grid cables, hubs and landfalls at the project level is more relevant than the length of overall cable or number of landfall points. That stated, the larger cable footprint associated with the radial alternative as outlined in **Table 6.1** has greater potential to impact on sea bed communities and habitats where it is laid. This risk is somewhat reduced with meshed grid. Similarly, the radial grid requires a greater number of landfalls, increasing the risk of damage and/ or destruction of sensitive coastal habitats and species. Coastal areas are important for birds and this is reflected in the SPA and Ramsar designations particularly along the coastlines in the study area. For example, the Scottish coast supports approximately 60% of the world's great skuas (*Stercorarius skua*), approximately 50% of the world's northern gannets (*Sula bassana*), and about 90% of the world's Manx shearwaters breed off British and Irish coasts. The Wadden Sea is significant area for seabirds; its extensive mud flat habitats are important feeding and rest areas for migratory birds. In winter, Denmark hosts the Svalbard population of migratory brent geese. The reduced number of landfall points required under a meshed alternative reduces the potential for such conflict, albeit recognising the need for site selection at the project level.

A meshed grid requires more hubs and depending on the location of the hubs, these too represent a risk to biodiversity flora and fauna, albeit more localised, however there are a number of sensitive habitats a considerable distance offshore including areas such as the Dogger Bank SAC, a large sandbank in United Kingdom, Dutch and German Waters which is home to a variety of species both within and on the sandy sediment. These areas has already been the focus of planning for renewable energy generators and additional infrastructure such as hubs could lead to cumulative effects on designated habitats and species in the area. One operational hub under the radial solution intersects with three overlapping designated sites in the German EEZ: Sylter Außenriff SAC (DE), Östliche Deutsche Bucht SPA (DE) and Sylter Außenriff/ Östliche Deutsche Bucht MPA (DE). These SACs are designated for sandbanks and reefs as well as shad, European river lamprey, grey seal, harbour seal and porpoise. It should be noted that the hub is located on the very western edge of these sites.

The location and number of landfall points is related to the grid solution applied, with a higher number of connections for the radial (173) in comparison to meshed (113). The reduced footprint of nearshore cabling utilising the meshed solution has greater potential, in combination with sensitive siting, to reduce habitat displacement and avoid sensitive coastal sites. The Walney Extension Wind Farm is an example of this where directional drilling was utilised instead of open trenching, to avoid the only healthy colony of belted beauty moth in the United Kingdom which resided at the export cable landfall site.[70]

Table 6.2 compares the radial and meshed grid alternatives under the High Renewables Scenario in terms of protected habitats types which are present within the study area.

[70] 4C Offshore (2016) Walney Extension Offshore Wind Farm. Retrieved: http://www.4coffshore.com/windfarms/walney-extension-united-kingdom-uk63.html

Table 6.2 - International and European Protected Sites Intersected by Radial and Meshed Grids

Protected Habitats/ Sites	High Renewables Footprint[71]	Radial Grid	Radial Hub	Radial Landfall	Meshed Grid	Meshed Hub	Meshed Landfall
Ramsar Site	0	30	0	18	28	0	16
UNESCO World Heritage Site	0	0	0	0	0	0	0
UNESCO World Heritage Marine Site	0	1	0	5	1	0	5
UNESCO Biosphere Reserve	0	3	0	3	3	0	3
OSPAR Marine Protected Area	10	60	1	27	58	4	24
OSPAR List of Threatened or Declining Habitats	50	961	0	26	345	1	12
Natura 2000 - SAC	5	94	1	27	81	3	23
Natura 2000 - SPA	6	69	1	28	64	0	24

Population and Human Health

The application of either the radial or meshed grid alternative is particularly important in the context of population. Under a high renewables scenario outlined in **Table 6.1**, the radial alternative has a total cable length of approximately 12,000km compared to approximately 8,000km under the meshed alternative. The dispersed nature of the radial approach defines a higher risk for conflict in the inshore/ nearshore zones in particular where tourism, recreation and employment conflicts may arise. Similarly, the increased number of landing points onshore for storage or connection to the grid landfall points require with radial (173 compared to 113) has greater potential for conflict with coastal population centres, supporting infrastructure such as roads and rail, onshore tourism and economic activities etc.

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[71] Footprint includes proposed and operational wind, wave and tidal developments.

Air Quality and Climate

In terms of laying cables, it is assumed that the fuel/ vessel and cable-laying operations will be largely identical for both the radial and the meshed alternatives. The other key variable will be the length of the cable installed under each alternative as the distance travelled by the vessel will have a direct and proportional impact on fuel consumption and hence emissions.

It is evident from **Table 6.1** that the radial scenario requires more cable than meshed, and as such, the activity of any vessel to install this option will require an additional of input i.e. distance travelled and fuel consumed. As a consequence, the radial scenario will have a greater impact to air quality and will have a higher GHG footprint and climate impact than the meshed alternative.

Water

Similar impacts are anticipated from meshed and radial grid alternative in terms of water quality, however the larger footprint from radial configuration would lead to potentially greater risk than with the meshed alternative. This would be the case for contamination and release of suspended solids as a result of more sediment disturbance during installation, accidental losses of fuels or other contaminants, disturbance of dump sites and munitions, disturbance of coastal defences and from the generation of marine litter.

Soils, Geology and Sediments

Both radial and meshed grid scenarios would have to cross some offshore fault lines, and there are areas, particularly around north-east England and Scotland where there have been recorded tsunami events (e.g. in the Firth of Forth and Moray Firth). As with **Water** above, the radial configuration would give rise to more sediment disturbance during installation due to the larger footprint and as a result there would be increased risk from contamination and release of suspended solids.

Material Assets

Both radial and meshed alternatives have the potential to impact on material assets, particularly through conflicts with boating, fishing, shipping etc. The reduced footprint of the meshed alternative reduces the potential for such conflicts when compared to the radial alternative.

Physical presence may cause disruption to fishing and shipping industries, and also disruption to, exclusion from or restriction of access to aggregate industries. The laying and burial of cables on the seafloor can disturb historically contaminated sediment, or dredge spoil piles. For example, the radial grid intersects 37 dump sites compared to 34 sites intersected under the meshed scenario.

Across the study area, the radial grid alternative also intersects more existing cables (approximately 181) compared to the meshed alternative (174). Both radial and meshed grid scenarios also traverse major shipping lanes and there are potential interactions between existing ship movements and the need for ships to install grid cabling. The level of disruption would be less under the meshed scenario.

Cultural Heritage

As with natural heritage within the study area, there is a diversity of marine and terrestrial cultural heritage. Both radial and meshed alternatives have the potential to impact on the cultural heritage resource, e.g. underwater archaeology including shipwrecks, which are often associated with coastal areas and shallower seas. Similarly, onshore coastal areas are associated historically with forts, settlements, pilgrim pathways, lighthouses etc. which increases the risk for conflict.

Seabed preparation can have a negative impact on cultural heritage via damage or destruction of features during trenching of the seafloor. A meshed grid alternative should potentially have a smaller impact than radial, as less cabling requirements mean less seafloor disturbance. The pre-historic submarine archaeology of the Irish and North Sea is largely unknown and there are likely to be areas which have potential for submerged and partially submerged landscapes which were historically dry land as a result of relative sea-level changes. This unknown archaeology is a risk under both the radial and meshed alternatives.

The main impacts to consider at landfall relate to: visual intrusion of infrastructure; any perceived negative impacts to the cultural landscape character or the overall historical setting; disturbance or destruction of unknown heritage features. This potential for impact is very much related to the number of landfall points required and as such a meshed grid would result in fewer landfall points compared to a radial grid.

Landscape/ Seascape

Subsea cables do not represent visible features and have a low to negligible impact on landscape and seascape character and as such the meshed and radial alternatives are equal in this regard. There can be temporary effects associated with the presence of vessels during installation, with more expected for the radial alternative, although it is acknowledged this would be a temporary effect.

Both radial and meshed alternatives have the potential to impact on the landscape and visual aspects of the receiving environment as a result of landfall in particular. The meshed alternative offers the greatest potential to avoid conflict, due to the reduced number of landfall points required compared to a full radial alternative.

6.4 Conclusion

Broadly speaking the preferred alternative is towards the meshed configuration as it offers the greatest potential to avoid or reduce environmental conflict. This is however subject to sensitive routing and siting of infrastructure, regardless of the final configuration chosen at local level.

7 ENVIRONMENTAL APPRAISAL OF THE REGIONAL CONCEPT

7.1 Introduction

As described in **Chapter 3**, the Regional Concept Report outlines three capacity scenarios related to: High Renewables; PRIMES Reference; and NSCOGI. The High Renewables Scenario refers to a high level of offshore renewables deployment, combining multiple sources, and is considered for the purpose of this Baseline Environmental Study to broadly represent the highest intensity deployment. As such, it is considered the most appropriate scenario to explore in terms of opportunities and constraints as both PRIMES Reference and NSCOGI would have reduced footprint in comparison and could reasonably be considered to have also been addressed as a result.

This chapter is supported by two digital appendices. **Appendix A**, discussed in **Chapter 4**, contains an Impact Dictionary which outlines the nature and type of impacts arising from the infrastructure proposed in the Regional Concept Report under key environmental topic headings and with reference to both the type of infrastructure and the stage of development. The Impact Dictionary builds on the generic and specific impacts identified from Member State maritime spatial plan SEAs and places the focus on the likely significant pressures as they apply to RES infrastructure and the grid concept. For maximum benefit the Impact Dictionary is searchable.

Appendix B, also discussed in **Chapter 4**, is a searchable Data Catalogue which includes links to GIS data at both the pan-European and national Member State levels. These datasets have been integrated to inform the environmental baseline and to provide detail in relation to specific constraints and opportunities within the study area.

It is noted that an environmental appraisal of the conceptual scenarios presented introduces limitations in the detail of the appraisal. It is therefore clearly stated that further environmental assessment and evaluation has been anticipated at multiple levels in the planning and delivery of any portion of such a system, with increasing levels of detail possible as more information on location and design becomes available. This further environmental assessment and evaluation is likely to involve SEA and AA by the various Member States at the strategic planning stage down to EIA and AA at the project development stage. At these formal assessment stages, specific considerations and surveys would be carried out to determine the specifics of routing and construction practices. The following appraisal is intended to be a precursor to such detailed assessment, signposting potential opportunities and constraints at a high level, and informing the topics which should be considered when determining the adequacy of environmental considerations going forward, see **Chapter 8 Recommendation #1-3** for further information on the roll out of the High Renewable Scenario.

7.2 Appraisal Scope

Figure 7-1 presents the High Renewables Scenario using a meshed grid system. This broadly reflects the preferred grid solution alternative discussed in **Chapter 6**. In viewing the figure it is important to note the presence of the RES and grid which are already operational or in construction; as these elements of the High Renewables Scenario have already been realised at Member State level. Furthermore, in most cases the broad zones and locations for RES have already been identified at Member State level through national plans. As outlined in **Appendix C**, the majority of these plans have undergone SEA and AA at the Member State level and mitigation has been included to offset the negative impacts identified. As such, this appraisal does not seek to rewrite those plans but where significant conflict is identified, commentary is provided.

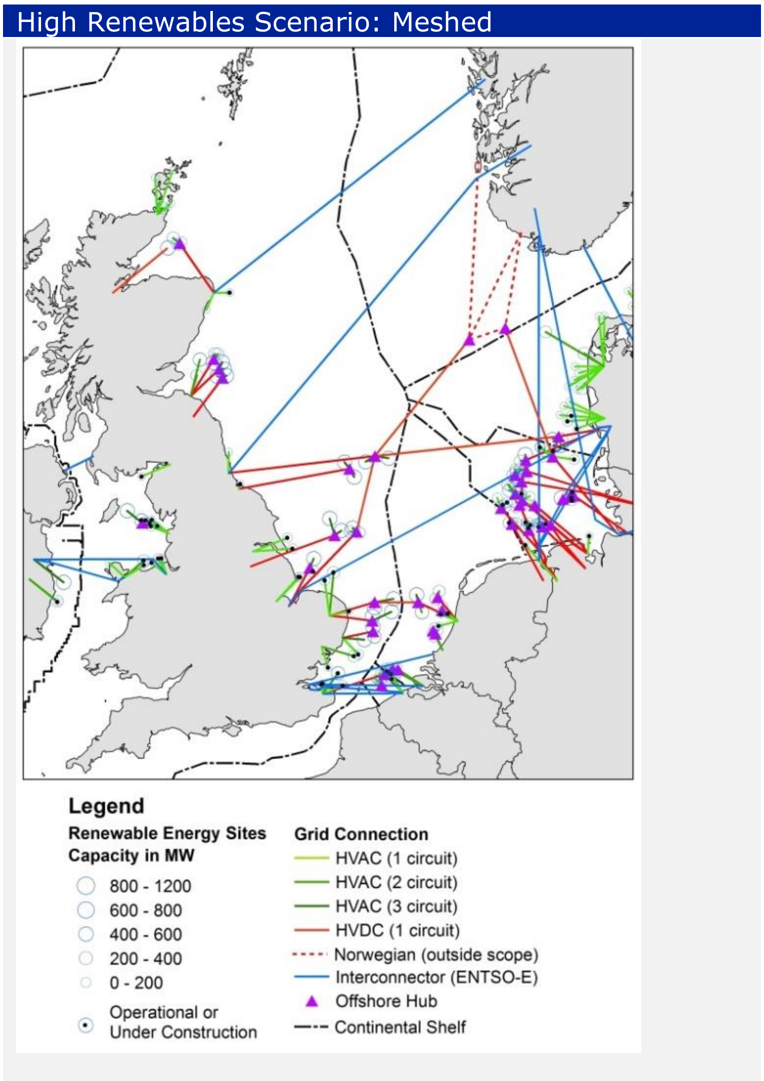

Figure 7-1 - High Renewables Scenario under a Meshed Grid Solution

The delivery of the High Renewables Scenario would see the deployment of up to 76.6 GW of renewable energy in the Irish and North Seas as outlined in **Table 7.1**. The vast majority of this would be in the form of wind energy although there are also concentrations of wave and tidal energy anticipated off the northwest coast of Scotland and along the Danish coast. The total offshore renewable energy capacity per Member State ranges from 1.5 GW in Ireland up to 36.3 GW for the United Kingdom. **Table 7.2** outlines the different elements of the grid as it applies to the High Renewables Scenario.

Table 7.1 - High Renewables Scenario: Capacity by Member State

Member State	High Renewables Capacity (GW, based on High Renewables, EWEA and EC Roadmap)	High Renewables Footprint (km^2, without grid)
Belgium	3.9	855
Denmark	6.8	7043
Germany	20.8	4116
Ireland	1.5	338
The Netherlands	7.3	3606
United Kingdom	36.3	28154
TOTAL	**76.6**	**44111**

Table 7.2 - High Renewables Scenario: Breakdown of Grid Elements

High Renewables Scenario	Meshed Solution
Offshore Cable Length	8831
Number of hubs	42
Number of landing points	113
Number of offshore substations (HVAC and HVDC)	363

7.3 Format of the Appraisal

The appraisal has been laid out with reference in the first instance to the environmental topic headings already reflected in previous chapters of this Baseline Environmental Report and latterly with reference to the type and nature of the infrastructure proposed and their potential significant impacts.

It is considered that in practice certain impacts may not occur as it is reasonable to expect that certain receptors would be avoided in the first instance at the siting and routing stage (e.g. for cables and hubs) based on existing activity areas or exclusion/ priority areas already given over to other users of the sea.

The appraisal considers the broad elements associated with an offshore energy system as outlined in **Chapter 3** of this report.

7.4 Biodiversity, Flora and Fauna

The coasts and seas within the study area support a great diversity of habitats and wildlife and in recognition of this a large part of the coastline within the study area is protected under a range of national and European legislation. **Table 7.3** broadly outlines the key sensitivities identified under the topic of Biodiversity, Flora and Fauna.

Table 7.3 - Biodiversity, Flora and Fauna: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Biodiversity, Flora and Fauna	Protected Habitats	• Disturbance or displacement from or physical loss of benthic habitat. • Adverse impact to habitat from changes to hydrography, sedimentation or turbidity. • Changes to biotopes/ alteration of community structure. • Pollution of sediment.
	Protected Species (including marine birds, mammals, fish, reptiles, bats, benthos and ecological balance/ invasive species)	• Adverse physiological and/or behavioural reactions from: noise; sediment smothering/ sealing effects; release or remobilisation of contaminated material; release of antifoulants; produced or treated discharges; marine litter; use of explosives; from EMF emissions; geophysical survey techniques; changes to hydrology/ flow conditions; changes to thermal, salinity, redox or nutrient conditions. • Barrier effects/ displacement from loss of feeding, foraging and breeding grounds. • Induction of flight/scare response. • Collision risk from the physical presence of structures. • Physical loss of or disturbance to benthic habitats and species. • Changes to community structure (introduction of artificial substrate). • Introduction/spread of invasive alien species.

There are a number of protected habitats within the study area which could be impacted by the High Renewables Scenario. The key protected site types are listed in **Table 7.4**. Of note is that only a small proportion of the sites in question relate to the infrastructure footprint itself e.g. wind turbines, with the majority of protected sites being crossed by the grid.

Table 7.4 - International and European Protected Sites Intersected by High Renewables

Protected Habitats/ Sites	High Renewables Footprint[71]	Meshed Grid	Meshed Hub	Meshed Landfall
Ramsar Site	0	28	0	16
UNESCO World Heritage Site	0	0	0	0
UNESCO World Heritage Marine Site	0	1	0	5
UNESCO Biosphere Reserve	0	3	0	3
OSPAR Marine Protected Area	10	58	4	24
OSPAR List of Threatened or Declining Habitats	50	345	1	12
Natura 2000 - SAC	5	81	3	23
Natura 2000 - SPA	6	64	0	24

Wind energy source: Under the High Renewables Scenario, the footprint of existing and proposed wind farms and associated grid, intersect areas which are covered by significant natural heritage protections including SAC, SPA, Ramsar, Biosphere Reserve etc. (**Table 7.4**). These are further discussed in the following sections. It should be noted that several of the intersected sites are classed as 'Sites of Community Interest' (SCIs). For the purposes of this assessment, these SCIs have been included in the count as SACs and SPAs. These sites are: Sylter Außenriff (DE); Dogger Bank (UK); Margate and Long Sands (UK); Inner Dowsing, Race Bank and North Ridge (UK).

Direct physical loss of the seabed and benthic habitat

Wind turbines and windfarms have the potential for direct long-term and permanent negative impacts on seabed and benthic habitats. The significance of the potential impacts from energy systems depends on the element i.e. RES or grid, as well as the specific nature of the habitats and species encountered. Wind turbines may be set down into the seabed as monopiles (most common in the Irish and North Seas), utilise other types of foundation (e.g. gravity bases, jacket, tripod), or comprise floating monopiles which are moored/ tethered to the seafloor. Each of these footprints varies in terms of the scale of direct and indirect seafloor impacts.

Of the 5 SACs directly impacted by existing and proposed wind farm footprints under the High Renewables Scenario, each is designated for sandbanks as one of the qualifying features: Sylter Außenriff SAC (DE); Sydlige Nordsø SAC (DK); Dogger Bank SAC (UK); Margate and Long Sands SAC (UK); and Inner Dowsing, Race Bank and North Ridge SAC (UK). Reefs are an additional habitat in two of these SACs (Sylter Außenriff and Inner Dowsing, Race Bank and North Ridge).

Five SPAs are impacted by existing and proposed wind farms: Östliche Deutsche Bucht SPA (DE); Sydlige Nordsø SPA (DK); Outer Thames Estuary SPA (UK); Liverpool Bay/ Bae Lerpwl SPA (UK); and Northumberland Marine Potential SPA (UK). All are designated for various bird species.

It should be noted that several wind farms have already been built on European Sites e.g. the Teesside A and B Wind Farms were constructed on the United Kingdom's portion of the Dogger Bank SAC in 2014 (the Dogger Bank is a Site of Community Interest and SAC across the United Kingdom, Dutch and German EEZs, however the wind farms' footprints are only on the United Kingdom side). The Dogger Bank represents the largest sandbank designated as a European Site in the North Sea. An assessment of the impacts of Teesside A and B on the benthic and subtidal habitats of the Dogger Bank found that the majority of impacts were minor to minor-adverse.[72] The minor-adverse impacts related to permanent loss of benthic habitat under the footprint of the wind farm, sediment disturbance/ increased turbidity, and contaminant disturbance/ remobilisation. Two more wind farms are currently proposed on the Dogger Bank SAC to the west of Teesside: Creyke Beck A and B.[73]

Other wind farms under the High Renewables Scenario which are operational/ under construction and located on a European Site include: Butendiek in the Sylter Außenriff SAC/ Östliche Deutsche Bucht SPA (Germany); Gwynt y Môr and Burbo Bank Wind Farms in the Liverpool Bay/ Bae Lerpwl SPA (UK - Wales); Lincs, Lynn and Inner Dowsing, and Race Bank Wind Farms in the Inner Dowsing, Race Sands and North Ridge SAC (UK - England); Scroby Sands, Kentish Flats 1 & 2, and Gunfleet Sands in the Outer Thames Estuary SPA (UK - England); London Array 1 in the Margate and Long Sands SAC (UK - England).

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[72] Royal HaskoningDHV for Forewind (2013) Dogger Bank Teesside A & B, Draft Environmental Statement Chapter 12 - Marine and Intertidal Ecology.

[73] Royal HaskoningDHV for Forewind (2015) Dogger Bank Creyke Bank, Draft Environmental Statement, Non-Technical Summary.

The DanTysk 1, 2 and 3 Wind Farms are proposed developments under the High Renewables Scenario and will be located in the Sydlige Nordsø SAC/ SPA (Denmark).

It is evident from the examples provided, that the presence of a European Site has not precluded wind farm development, however appropriate mitigation, good siting and sensitive routing of cables is essential in order to avoid priority and ecologically important habitats and associated benthic species.

It is noted that a potential positive long-term impact from development of wind farms is the exclusion of other commercial activities in their vicinity i.e. the exclusion of destructive bottom-trawl fishing activities which can lead to improved fish stocks.[74,75]

Impacts to protected species

As outlined in **Table 7.3**, there are a suite of impacts which can directly and indirectly negatively impact marine species in the study area.

Under the High Renewables Scenario, of the 10 European Sites intersected by existing and proposed wind farms, two are designated for shad and European river lamprey (Sylter Außenriff SAC and Östliche Deutsche Bucht SPA); and four are designated for grey seal, harbour seal and the common (harbour) porpoise (Sylter Außenriff SAC, Östliche Deutsche Bucht SPA, Sydlige Nordsø SAC/ SPA). The four SPAs intersected by wind farms are designated for various seabird species e.g. various terns, gulls, kittiwakes, skua, scoters, divers etc.

In an attempt to quantify impacts, the OBIS-SEAMAP[76] data has been spatially queried and presented in **Table 7.5**.[77] The OBIS data represents grid cells (of dimension 0.1 degrees) containing counts of animal sightings. As the grid cells contain one or more species it has not been possible to split out the data by a particular species at this strategic level. However, the data provides a sense of the degree to which numbers of marine animal groups are intersected by the High Renewables Scenario.

Table 7.5 - Marine Animal Groups Intersected by the High Renewables Scenario

Animal Group	RES Footprint	Grid
Seabirds	191 681	381 620
Marine Mammals (Cetaceans and Pinnipeds)	1 710	5 469
Marine Reptiles (Turtles)	16	68
Cartilaginous Fish (Sharks, Skates, Rays)	0	0

The types of impact encountered by marine animals will depend on the type, scale and duration of offshore infrastructural related activities.

74 Byrne Ó Cléirigh Ltd., EcoServe and the School of Ocean and Earth Sciences, University of Southampton for the Irish Marine Institute (2000) Assessment of Impact of Offshore Wind Energy Structures on the Marine Environment.

75 Hammar L., Perry D. and Gullström M. (2016) Offshore Wind Power for Marine Conservation, Open Journal of marine Science, 6, pp. 66-78.

76 Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP). Retrieved: http://seamap.env.duke.edu/

77 OBIS-SEAMAP. Indicative counts of animals falling within 0.1 degree grid cells in the Irish and North Seas. Note that some grid cells contain counts of animal numbers from other species recorded during surveys. See Appendix E for all data citations.

Physiological and behavioural impacts from noise

One of the most significant issues encountered by marine species resident within the water column is the potential for indirect negative physiological and behavioural impacts as a result of the noise generated during the construction phase of wind farms, and particularly in relation to pile-driving activities to install turbine monopiles. Currently, the dominant anthropogenic source of noise in the marine environment comes from shipping traffic however Member States have reported that in addition to shipping, renewable energy extraction and hydrocarbon extraction are also major sources of noise.53

Research has been conducted on the impacts of underwater noise on marine animals and the main receptors affected are cetaceans, pinnipeds, turtles, fish and diving seabirds. Each of these groups generally represents highly mobile species which are capable of moving away from the source of sound. Whilst limited information is available on the behavioural influence of wind farms on turtles, trials with airguns indicated the induction of fast swimming responses and agitation.[78] As many turtles are capable of hearing low frequency sounds, they are likely to become disturbed or displaced by underwater noise.81 However, **Table 7.5** indicates that within the study area, there is a relatively low occurrence of turtles.

The noise generated from installation of offshore wind farms is temporary in nature however, depending on the techniques employed, installation activities can take several months or be spread out over several years. Turbine installation activities particularly pile-driving, can cause noise and vibration disturbance. The noise generated from piling is also dependent on the diameter of the pile and as wind farms scale up in capacity and size, there is potential for even greater levels of underwater noise.

There may be cumulative negative impacts therefore if several wind farms are being constructed in close proximity or in succession under the High Renewables Scenario. The operational phase of wind farm can also generate noise from the mechanical vibration in the gearbox and the generator inside the turbine nacelle, which transmit sound to the water column via the foundations. In addition the sound from the rotation of the turbine blades is generally reflected by the surface of the water.[79]

Marine mammals comprise one of the most widely studied groups of animals in relation to impacts from RES infrastructure with the majority of studies focusing on porpoises and seals and their interactions with wind farms. Monitoring studies of offshore wind farms indicate that the most commonly reported megafaunal response is avoidance of the wind farm during the construction phase. Monitoring of porpoises at Horns Rev in Denmark, an existing wind farm under the High Renewables Scenario, indicated they can suffer hearing damage as a result of wind farm construction.[80] Also the environmental study conducted at Horns Rev 2 noted that porpoises were found to react to noise levels up to 20km away from operations. The Environmental Impact Report for the Belgian Marine Spatial Plan notes that porpoises can suffer permanent hearing damage up to 2km away from pile-driving operations, whereas seals hear at lower frequencies and therefore could be affected up to 4km from driving operations.53

[78] Shields M. A. and Payne A. I. L. (2014) *Marine Renewable Energy Technology and Environmental Interactions*. Dordrecht: Springer Science & Business Media.

[79] Department of Energy and Climate Change (2016) United Kingdom Offshore Energy Strategic Environmental Assessment - OESEA3.

[80] Dong Energy, Danish Energy Authority and the Danish Forest and Nature Agency for Vattenfall (2006) Danish Offshore Wind - Key Environmental Issues.

Operational wind farms can potentially mask the bioacoustics of animals, i.e. the sounds they use to communicate with each other and find prey. For seals and porpoises, the sound emitted by operational turbines is not considered to affect these animals.84 The United Kingdom -based Sea Mammal Research Unit (SMRU) note that research on mammals in UK waters indicate that the impacts of operational wind turbine noise are likely to be negligible, however species with specialised low-frequency hearing (particularly minke whales) may detect operational wind farms up to 18km away and are the species most likely to be impacted during the operational phase (other whales and seals were considered unlikely to be impacted). The authors also note that more research is needed on the levels and extent to which hearing threshold shifts occur as well as hearing recovery rates.[81] There is less data available on the effects of wind farm noise on fish but research has indicated that operational noise causes no adverse physiological impacts but it can mask communication and orientation signals and consistently trigger a scare response, which has unknown implications for ecological fitness.[82]

As the marine megafauna represent a grouping of highly mobile species, they have the ability to move away from sources of noise. However there can be severe adverse physiological effects if noise is generated suddenly with no build-up to allow animals time to move away. Mitigating the effects of underwater noise, in particular for pile-driving, usually takes the form of soft-start procedures or other techniques to reduce the level or propagation of noise (e.g. bubble curtains, isolation casings). More turbines and thus more piling activities are expected under the High Renewables Scenario giving rise to temporary negative impacts with respect to underwater noise and potential effects for marine animals. **Appendix D** provides further information in relation to research undertaken on marine animals and underwater noise.

Techniques, employed during surveying and site preparation activities can use seismic reflection penetrating to a depth of about 50m. The energy output is generally less than what is used for hydrocarbon exploration however seismic survey noise has documented hearing and behavioural impacts on cetaceans, fish and seals.[83] The negative impacts relating to seismic reflection have similar characteristics to that discussed previously in relation to noise.

Collision risk

Collision of animals with wind farms can occur both within the water column (primarily affecting marine megafauna) and above the surface i.e. wind turbine. The majority of studies on collision incidence to date have focused on cetaceans. A review of recent research indicates that the most common response reported from monitoring studies is avoidance of the wind farm by marine mammals rather than direct collision. This impact is further discussed in the section dealing with barrier effects and displacement. The IUCN in 2010 considered that the collision risk to marine mammals from wind turbine piles to be small, however the level of certainty in this is low.[84]

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[81] Thompson D., Hall A. J., McConnell B. J., Northridge S. P. and Sparling C. (2015) Current state of knowledge of effects of offshore renewable energy generation devices on marine mammals and research requirements. Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, no. MR 1 & MR 2, St Andrews, 55 pp.

[82] Wahlberg M. and Westerberg H. (2005) Hearing in fish and their reactions to sound from offshore wind farms. Marine Ecology Progress Series, 288, pp. 295-309.

[83] AECOM Environment, METOC and the CMRC for the Sustainable Energy Authority of Ireland (2010) SEA of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland.

[84] Wilhelmsson D., Malm T., Thompson R., Tchou J., Sarantakos G., McCormick N., Luitjens S., Gullström M., Patterson Edwards J.K., Amir O. and Dubi A. (eds.) (2010) Greening Blue Energy: Identifying and managing the biodiversity risks and opportunities of offshore renewable energy. Gland, Switzerland: IUCN. 102 pp.

It is known that cetaceans can collide with all types of ships, including larger vessels where mammals often get caught on the bow of the ship, to smaller recreational and fishing vessels which dolphins and porpoises in particular often actively seek out in order to ride the bow waves. Collisions with ships occur worldwide in any location where shipping activity overlaps with cetacean habitat. The International Whaling Commission (IWC) states that currently the only proven and effective mitigation is to avoid high density areas where cetaceans are known to gather and to reduce speed while crossing those areas.[85] A summary of the most recent data in the IWC's collision database (published 2014) indicates at least 539 recorded collisions internationally, with one recorded in the Irish Sea in 2006 and 3 recorded in the North Sea between 1995 and 2006. These numbers are likely to be an underestimate as collisions may not be reported and/ or often go unnoticed, especially with larger vessels.[86] The realisation of the High Renewables Scenario increases the potential for conflict. The timing of deployment operations can be a significant factor in collision risk. For example, the harbour porpoise is abundant in the Irish and North Seas, with the greatest numbers seen in both seas in the summer months (peaking in July).[87] For other times of the year the porpoise is generally found closer to coastlines particularly in the Irish Sea, the east coast of England, north-west Scotland, and areas of the German Bight.87[,88]

This will be an important consideration at the project level to reduce collision potential although it is acknowledged that peak periods for mammals and birds (especially fledglings) may coincide with optimum deployment periods in terms of weather and other health and safety considerations in deployment.

In terms of bird collisions, it is noted from **Table 7.4** that the majority of the bird-related designations (Ramsar, SPA) in the study area are intersected by a grid rather than RES. In terms of impacts, birds (and bats) are more sensitive to the direct effects of above-surface component of wind farms i.e. the turbine and the spinning blades, than from below-surface structures. The higher risk issue therefore relates to the RES structure itself rather than the respective grid. Wind farms have represented the vast majority of RES infrastructure deployed to date in the Irish and North Seas. The response of birds to wind farms can be species-specific and also dependent on flight preferences and weather conditions. Monitoring of the effects of offshore wind farm collisions in Scottish waters noted that populations of some species (gulls, white-tailed eagle and gannets) are particularly sensitive to collision.[89] Monitoring of birds at the Horns Rev Wind Farm indicated displacement rather than recorded collisions. Other studies have estimated bird mortality to range from 0.01 to 23 per turbine per year and the IUCN in 2010 stated that most studies indicate a small impact from collisions with turbines on bird populations, although the effects can be long-term.84 Monitoring which took place at an unnamed offshore platform in the North Sea identified significant impacts for migrating passerines as it was estimated that mortality could reach the hundreds of thousands.

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[85] MEPC Session 69/10/3 (2016) Information on recent outcomes regarding minimizing ship strikes to cetaceans. Submitted by the International Whaling Commission to the Marine Environment Protection Committee of the International Maritime Agency.

[86] International Whaling Commission. Retrieved: https://iwc.int/index.php?cID=872&cType=document

[87] Reid J.B., Evans P.G.H. and Northridge S.P. (2003) Atlas of Cetacean distribution in north-west European waters, Joint Nature Conservation Committee.

[88] Harbour porpoise densities in the German EEZ. Retrieved as a web mapping service from the Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency):

https://www.geoseaportal.de/wss/service/BIO_HarbourPorpoise_Density_6x10/guest?request=GetCapabilities&service=WMS&

[89] Furness R.W., Wade H.M. and Masden E. A. (2013) Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management, 119, pp. 56-66.

This assumption was extrapolated from the mortality of 767 birds, mostly passerines, collected on 45 visits between 2003 and 2007.[90] The study also found that mass collision events were found to be associated with adverse weather conditions.

With increased development of offshore wind installations, there is potential for significant conflicts with bird populations. The scale and significance of impacts at the population level is still uncertain and requires more research data, particularly in relation to migratory birds and cumulative impacts from multiple encounters with offshore wind farms.[91]

Similarly for bats, it is known that some bats migrate across the North Sea however data on tracking of migration or movement patterns over the sea is limited owing to the difficulty in detection over long ranges. The lack of data and monitoring means the collision risk is hard to assess (see **Recommendation #6** in **Chapter 8**). It is highly likely that bats, like birds, are sensitive to offshore wind farm developments, and is further discussed in **Appendix D**.

Diurnal pelagic fish occupy the entire water column variously throughout the day and are therefore at risk of collision with all types of RES infrastructure. There is little research on the likelihood of collision with wind turbines and their foundations but the risk is considered to be short-term and negligible at the population level.84

Displacement and barrier effects

Post-construction monitoring at Horns Rev identified the effects of wind farm presence and operation on porpoise populations.[92] Results from a model simulation of porpoise populations indicate that wind farms had a small displacement effect, with the summer population averaging 10% lower than the model scenario without wind farms. Adding the cumulative effects of shipping to the model scenario with wind farms did not impact the populations any further however the addition of by-catch of porpoises by fisheries was found to decrease populations by a further 10%. The porpoise's relationship with the food resource in combination with the scare response to operational turbines was also found to be of importance. If the food source replenishes slowly from foraging/disturbance, populations must travel further afield but animals may return to the wind farm because they remember it as a foraging area. The scare response triggered by the turbines can cause the animals to forage for some time further away before returning to turbine sites again, which can result in lower energy levels and corresponding increased mortality, accounting for the 10% population decline. These findings identify the potential for cumulative negative impacts in the longer-term with other users of the sea, as well as impacts from foraging behaviour and flight responses.

The majority of studies investigating avoidance of structures by porpoises found that avoidance effects were short-term impacts and populations were only displaced for short periods of time before returning to the areas surrounding the turbines (see **Appendix D** for further details). Conclusions from the Danish study indicate that cumulative effects are not thought to have long-term effects on survival.92 While studies on the physiological effects of wind farms on mammals are extensive, studies on behavioural responses are lacking.

[90] Hüppop O., Hüppop K., Dierschke J. and Hill R. (2016) Bird collisions at an offshore platform in the North Sea, Bird Study, 63:1.

[91] AWEA 13th Meeting of the Technical Committee (March 2016) Identifying evidence needs to inform assessment of cumulative impacts from offshore renewable energy developments on migratory waterbird populations. Discussion paper prepared by O'Brien S. and Stroud D. (United Kingdom Observer to the Technical Committee) Joint Nature Conservation Committee.

[92] Vattenfall: Dong Energy for the Danish Energy Agency (2013) Danish Offshore Wind: Key Environmental Issues – a Follow-up.

For birds, displacement equates to habitat loss. Construction in favoured feeding areas can displace birds for years even if habitat and feeding resources remain intact, leading to long-term negative impacts at the population level. Undisturbed intertidal areas (e.g. Wadden Sea habitats) are crucial for migratory birds during spring and autumn.[93] The barrier effect can be significant if birds prefer to skirt around a wind farm rather than fly between the turbines, particularly in transit to and from foraging and/or breeding grounds. Monitoring at Horns Rev 2 indicated that the abundances of common scoter were similar in both the pre- and post-construction phases however the distribution was markedly different, with far less numbers in an area of approximately 100km^2 around the wind farm, to which the displacement is attributed. Wind farms can alter migration routes, another form of displacement, as illustrated by **Figure 7-2** which shows the distribution of common eiders at the Danish Nysted Wind Farm.[94,95]

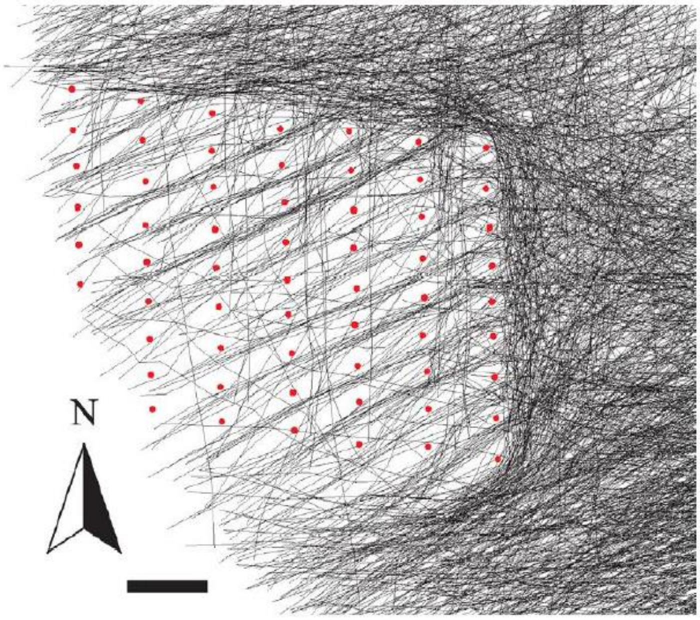

Figure 7-2 - Westerly-Orientated Flightpaths of Eider at Nysted Wind Farm

The southern North Sea is an important migratory passage for birds that then pass through the bottleneck of the English Channel. The alteration of flightpaths to avoid wind farms adds an energy burden to some birds e.g. they may have to avoid wind farms between the western isles and the continental mainland. Important resting sites for diver species in the eastern North Sea show avoidance areas of several kilometres around wind farms.93 The high-intensity of the High Renewables Scenario represents potentially significant impacts where a number of wind farms are being developed in close proximity. Recent research suggests that there is still a lot of uncertainty with how best to monitor the effects of wind farms on seabirds, as well as the degree to which seabird distributions overlap spatially with offshore wind farms.[96]

[93] BirdLife Europe Consultation II Response (October, 2016).

[94] Desholm M. and Kahlert J. (2005) Avian collision risk at an offshore windfarm, Biology Letters, 13, pp. 1-4.

[95] Desholm M. and Kahlert J. (2005). Reproduced from the United Kingdom's OESEA3 (2016) under Crown Copyright Open Licence. Red dots are turbines and black lines are flightpaths, scale bar represents 1000m.

[96] Lees K., Guerin A. and Masden E. (2016) Using kernel density estimation to explore habitat use by seabirds at a marine renewable wave energy test facility. Marine Policy, 63, pp. 35-44.

Figure 7-3 illustrates OBIS-SEAMAP data showing seabird density alongside areas for proposed wind farms off the north-east coast of Scotland (Beatrice Wind Farm and Moray Forth Eastern and Western Development Zones) which are included in the High Renewables Scenario. The Moray Firth area represents some of the highest densities of seabirds as recorded under the European Seabirds at Sea (ESAS) Programme.[97] The figure illustrates the potential conflicts from wind farms when they are proposed in areas of high-density for birds.

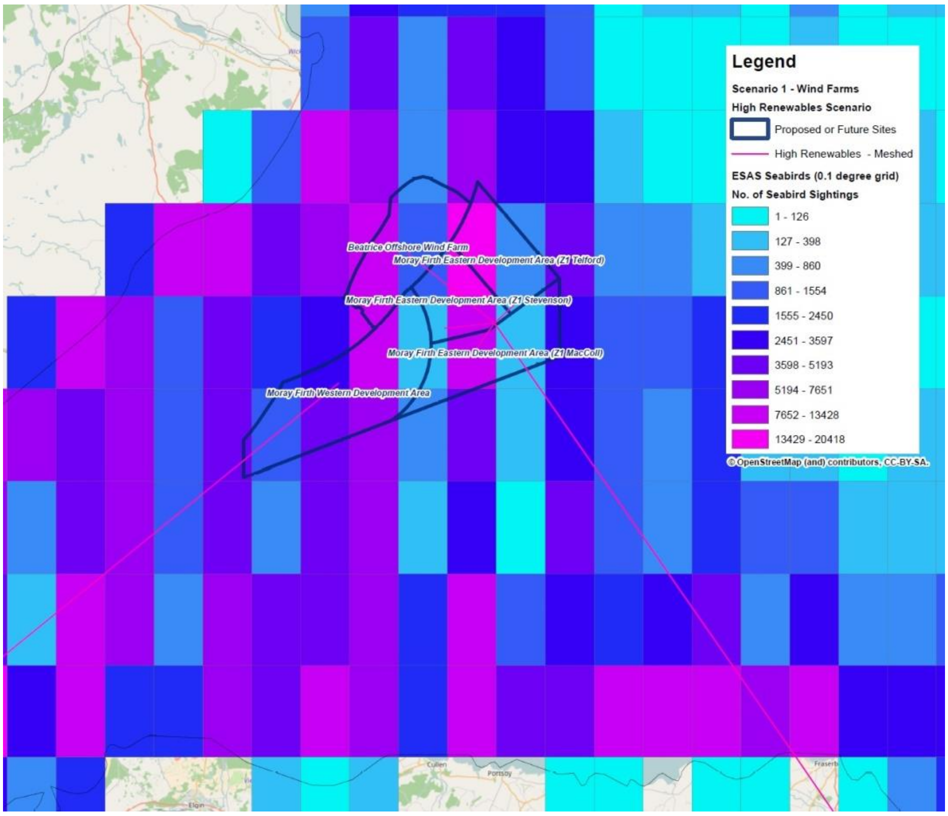

Figure 7-3 - High Seabird Density and Proposed Wind Farms off the North-East Coast of the UK

The IUCN in 2010 noted that there is a broad spatial impact to birds in the short-term construction phase, with a long-term broad spatial impact during the operational phase. The scale of the impact can be species-specific, for example sea ducks and divers are particularly sensitive to the barrier effect.84 The movements of ships can also disturb birds (particularly divers) by displacing them from feeding/ foraging areas, both onshore and offshore, as they tend to avoid ships. This effect is dependent on the timing of ship travel and also on the bird species, but would be increased during the construction phase of any development. Greater impacts to birds may therefore be triggered as a result of wind farms developing in areas where shipping was previously a low-disturbance activity.93 The effects of shipping can be mitigated through the timing of surveying and construction activities to avoid particular times of year.

The barrier effect for fish can include the loss or disruption to spawning grounds as well as the disturbance of migration routes. Seabed infrastructure and cabling can also cause fouling of spawning grounds or block access.

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[97] A standardised database managed by JNCC on behalf of the European Seabirds at Sea Database Coordinating Group.

The footprint of the wind farm may cause disturbance to or permanent loss of food resources and foraging grounds for some fish groups (e.g. keystone prey species such as sand eel and sprat). In addition, the disruption to these species can have indirect impacts on other species for which these fish are an important food source.[98]

Sediment smothering and sealing effects

The settling of disturbed sediment from both wind farm siting and cable preparation works can smother adjacent benthic habitats and can affect shellfish beds as well as fish spawning and nursery grounds, particularly for those fish species who favour clean gravel beds. Reefs are noted to be particularly sensitive to the effects of smothering.[99] The greatest amount of sediment dispersion would occur during construction and while the effect can be broad-scale spatially, construction works are temporary in nature however it is acknowledged that effects could be longer-term. Careful siting considerations should endeavour to avoid sensitive areas in the first instance. Sediment disturbance and resettling is further discussed in **Section 7.6: Soils, Geology and Sediment**.

Changes to biotopes and alteration of community structure

The placement of foundation structures, cabling and any associated rock armouring can introduce artificial hard substrate to areas which are normally soft-bottomed. This can allow colonisation of the area by hard-substrate species and alter community structure and predator-prey relationships. The 'artificial reef' effect created by the presence of offshore structures can also attract pelagic fish species to an area. For example, research conducted in the Belgian waters of the North Sea found that Atlantic cod and pouting were strongly attracted to wind farms (unnamed), with higher than average catch-rates. Further research on these species also indicated no discernible difference in the fitness to both species at the artificial reef of the wind farms compared to natural sandbank habitats[100] (see also **Appendix D**).

The artificial reef effect can also alter local nutrient conditions. For instance, turbine foundations can become colonised by a large number of sessile organisms, such as blue mussels. Their presence can cause a local reduction in plankton abundance and therefore cause a lowering of the biomass of other sessile filter feeders up to 20m from the turbine.84 These local impacts may be significant in protected habitats but impacts will be dependent on the scale of the development. Research conducted at wind farms in the Baltic Sea also examined the impacts of blue mussels which had colonised turbine foundations. Large numbers of blue mussels excrete ammonium which is in turn used up by other colonisers such as filamentous red algae. In addition, as a result of the shedding of additional organic matter (e.g. biodegradation, waste matter etc.) in the vicinity of the wind farm, this can increase oxygen demand and trigger localised pockets of anoxic conditions to form. Blue mussels can also be found further up the water column as they fix onto the turbine monopole.[101] The development of wind farms may have in-combination effects on community structures and nutrient conditions over a more widespread area, especially where multiple wind farms are in close proximity. As offshore structures typically have long lifespans (around 25 years), changes to community structure are likely to become permanent unless some form of decommissioning is undertaken.[102]

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[98] Inland Fisheries Ireland, Consultation II Response (October 2016).

[99] AECOM and ABP MER for the Department of Enterprise, Trade and Investment, Scottish Government (2015) ISLES II Sustainability Appraisal Sub-report: Strategic Environmental Assessment.

[100] Reubens J. (2013) The ecology of bentho-pelagic fish at offshore wind farms: Towards an integrated management approach. Ghent University, 237 pp.

[101] Maar M., Bolding K., Kjerulf Petersen J., Hansen J.L.S. and Timmermann K. (2009) Local effects of blue mussels around turbine foundations in an ecosystem model of Nysted offshore wind farm Denmark, Journal of Sea Research, 63, pp. 159-174.

[102] RenewableUK (2015) Wind Energy in the United Kingdom: State of the Industry Report 2015.

Introduction or spread of invasive alien species

Invasive alien species (IAS) have emerged as one of the key challenges facing EU biodiversity as well as presenting serious social and economic challenges. It is estimated that IAS have cost the EU over €12 billion per year for the last 20 years. At the EU level, the need to control and eradicate IAS has been incorporated into the EU Biodiversity Strategy through Target 5 which states that *"by 2020, IAS and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS."*

IAS negatively impacts biodiversity through competition, herbivory, predation, habitat alteration and introduction of parasites or pathogens and poses a risk to the genetic integrity of native species. The introduction or spread of IAS can include flora and faunal species, as well as various lifecycle components of organisms such as eggs, larvae and plant fragments. The potential spread of IAS can occur through a number of pathways related to renewable energy, for example: through ballast water discharges from ships and platforms; via the movement of workers/ equipment; via biofouled construction materials or vessels; from the movement and disposal of sediment or dredged materials which can transport invasive species significant distances; and during operations the physical presence of structures may influence water flow and local currents, potentially enabling invasive species to spread further afield.

A 'stepping stone' effect can occur where the introduction of artificial hard substrates in the offshore environment can allow IAS to spread via a network of artificial islands or structures. Similar to the artificial reef effect, the biodiversity on these artificial hard substrates can differ from natural hard substrate habitats. Monitoring of the Danish Horns Rev Wind Farm indicated rapid colonisation of the invasive American razor clam on offshore sandbanks.92 In addition, the data indicates that the razor clam has become an important supplementary food source for some diving bird populations, such as the common scoter.

The clam is well suited to areas which experience high seabed turnover and sediment deposition due to biological adaptations for living within and exploiting sediment depth for protection from predation.92 It can be noted from this example that not all introduced species to an area will necessarily have a negative impact on biodiversity overall, but their introduction could impact the local ecosystem balance and functioning.

There is an increased risk of spreading IAS across the study area due to the intensity of existing shipping traffic and the increasing presence of artificial substrates in the form of wind farms. The construction of wind farms and the deployment of a grid will create an additional shipping presence which may compound the spread. Potentially all benthic species and habitats are at risk of being affected by alterations to community structure as a result of the introduction IAS.99 However, as demonstrated by the Danish experience at Horns Rev, IAS can also have an indirect positive impact on other species.

Changes to hydrography, sedimentation and turbidity

The physical presence of wind farms in the marine environment can negatively impact the natural flow of water movements. Changing flow conditions can affect sediment budgets and cause a redistribution of material. This can affect faunal organisms which live on and in the benthic environment where changes to water flows can influence larval recruitment, sedimentation, the availability of food and oxygen and the removal of waste products. The effects of this are likely to be localised but can extend over the long-term, however there is uncertainty over the severity of the impact.84

Depending on local water movements, calmer areas will see increased deposition of sediments. Where the fraction of this settled material is comprised of organic wastes from fish and other sessile fauna settled around artificial substrate, this can provide a food source for surrounding benthic fauna up to 40m away and trigger local changes in community composition.84 These impacts are likely to be localised to the development area and could have significant impacts on protected habitats. The impacts will be dependent on the scale of the development with potential for in-combination effects over a more widespread area, especially where there are multiple wind farms in close proximity.

Such changing flow conditions as well as sediment erosion and scour at the base of turbines can affect the quantities of suspended sediment which can have knock-on effects on the level of light penetration, water column mixing and salinity. Changing these parameters can result in changes to oxygen levels, temperature and nutrient conditions.79 For example, levels of oxygen near the seafloor are important for flatfish i.e. less mobile species compared to pelagic fish which occupy the whole water column.[103] The IUCN reported in 2010, that whilst there was a low level of certainty the impacts of sediment dispersion on benthos are spatially broad but limited in the short-term to the construction phase.84 The artificial reef effect can also cause long-term alteration of organic matter transport but the effects are considered to be localised to the wind farm and within 100m of the water column.84

Physiological and or behavioural effects from use of explosives

Adverse physiological impacts or mortality may result from the use of explosives. Explosions can be set off either through the intended and controlled detonation of unexploded ordnance encountered during the survey or construction phase, or from the accidental disturbance of such material e.g. from anchoring and mooring. Underwater explosions have a significant adverse effect on marine organisms due to the sudden noise generated but also from the propagation of the shock wave. The magnitude is enough to cause significant impacts such as mortality or adverse physiological effects (e.g. deafness, damage to the swim bladder of fish). Explosives may potentially be used during the decommissioning of a wind farm e.g. on gravity bases and other foundation structures. To date, there is little information on the decommissioning process of wind farms in the Irish and North Seas; most wind farms have a life span of 25 years and all existing wind farms within the study area have been deployed within the past 20 years. Current practice in using explosives for decommissioning comes from the oil and gas industry, where cutting and explosives are commonly used to remove oil rig foundations.84

Wave and tidal source: Under the High Renewables Scenario, all existing and proposed wave and tidal devices are currently concentrated around north-east Scotland, off the coast of Wales and off the north-west coast of Denmark. As such, any potentials impacts associated with wave and tidal devices under this scenario are limited to these areas.

There is far less research on the environmental impacts from wave and tidal devices compared to the body of knowledge on wind farms. However, some monitoring has been undertaken in the study area. One such programme involved three year post-construction monitoring (beginning 2005) of a tidal stream device located in Strangford Lough in Northern Ireland. This SeaGen device was the world's first and largest commercial tidal stream device but it was decommissioned in 2016, and is therefore not part of this scenario. In terms of the footprint of the device, the benthic ecology was monitored using diver surveys.

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[103] Andersson M.H. (2011) Offshore wind farms - ecological effects of noise on habitat alteration and fish. Thesis, Stockholm University.

It was established that the changes observed to the benthic ecology as a result of the device's presence were considered to be gradual and in line with natural fluctuations. The device had become colonised by encrusting organisms since its installation and was noted to have replaced the benthic community lost by the device foundations during construction.[104] Other studies have found that wave and tidal devices can be rapidly and extensively colonised by epibenthic assemblages and fish, with species diversity increasing over time.[105]

In terms of barrier and displacement effects, the SeaGen monitoring identified that seals (harbour and grey) and porpoises regularly transited past the operating turbines, demonstrating the absence of a barrier effect. In terms of collision risk, the monitoring results also showed that while there was no change in the relative distributions of the seals and porpoises, the device caused a redistribution of populations during operation, rather than collisions occurring. The effect was observed within several hundred metres of the device and considered to be small. However the telemetry data was not at a fine enough scale to provide information on evasion or avoidance responses.104

Regarding seabirds, it was also considered that the local breeding bird populations were not adversely affected by the SeaGen device with monitoring indicating some minor displacement close to the turbine. However at the population level in the Strangford Narrows, the numbers remained stable.104 Under the High Renewables Scenario, there are 2 proposed tidal devices in northern Scotland (Inner Sound and Ness of Duncansby) which intersect with a European Site, the North Caithness Cliffs SPA. The site is designated for peregrine falcon, guillemot, razorbill, kittiwake, fulmar, puffin and breeding seabird assemblages. The birds nest on the cliffs within the SPA and feed at sea beyond its boundary. All but the peregrine falcon are seabirds which dive or swim beneath the surface to varying extents. The three proposed wave devices off the north-west coast of Denmark (DanWEC Test Site and two Demo Parks) presently do not intersect with any available spatial datasets of national, European or international designations.

In terms of assessing impacts, the RSPB notes that overall the level of risk presented by wave and tidal devices to birds is an area of uncertainty. This is largely due to the low level of commercial deployment and as such there is a major knowledge gap regarding the likelihood of potential impacts occurring as well the scale on which such impacts occur.[106] Further, there is a great deal of variability in the designs of such devices. For instance, tidal devices which do not have rotating blades may pose a lower risk than those utilising vertical or horizontal tidal blades.

To date, there have been no recorded instances of a collision with a wave or tidal device[107], however conflicts could arise where cabling is placed in the nearshore and high-energy tidal environments as these are important feeding areas for birds. Mooring lines represent a possible risk of entanglement as they have a small cross-section area and may prove harder to avoid.93 Wave and tidal devices could present a collision risk to diving seabirds, or limit the amount of space for manoeuvrability in the water column for birds to evade or avoid devices.

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[104] Royal HaskoningDHV and the Sea Mammal Research Unit for Marine Current Turbines Ltd. (2011) SeaGen Environmental Monitoring Programme Final Report.

[105] Langhamer O. and Wilhelmsson D. (2007) Wave Power Devices as Artificial Reefs, Proceedings of the 7th European Wave and Tidal Energy Conference, 11–13 September, Porto, Portugal.

[106] McCluskie A.E., Langston R.H.W. and Wilkinson N.I. (2012) Birds and wave & tidal stream energy: an ecological review. RSPB Research Report No. 42.

[107] Copping A., Sather, N., Hanna, L., Whiting, J., Zydlewsk, G., Staines, G., Gill, A., Hutchison, I., O'Hagan, A.M., Simas, T., Bald, J., Sparling C., Wood, J. and Masden, E. (2016) Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.

For mammals, there is little information available on rates of collision or mortality associated with wave and tidal devices. As previously noted, there have been no recorded instances of collision by mammals with wave or tidal devices.107 However given the lack of large-scale commercial deployment in this technology area, this conclusion does not preclude any significant impacts. Research reports by the SMRU for Marine Scotland indicate a lot of uncertainty with respect to wave and tidal devices. Tidal rapids are important habitats for both seals and porpoises and tests using seal carcasses indicated that not all tidal turbine collisions would prove fatal.81 An analysis of telemetry data indicated there could be 1 to 2 collisions per year with single turbines as part of an array of devices.81 However the report states that many knowledge gaps still need to be filled before the scale and significance of impacts can be properly characterised (see also **Appendix D**).

Data is also lacking with respect to the interactions of fish and wave/ tidal devices making the impact difficult to assess. The IUCN in 2010 considered that the risk of collision with turbines is small, but that there is a low level of certainty on this impact.84 More recent research suggests that the probability of fish surviving passage through turbines is upwards of 95%.[108]

Other studies indicate there are very likely to be interactions with turbines, including: avoidance being species-specific; larger fish may have more difficulty avoiding turbines; and the ability to evade depends on blade diameter and flow speeds. Uncertainties remain on what proportion of collisions proves fatal.107 Disturbance to or permanent loss of food resources/foraging grounds is possible for some fish groups (e.g. keystone prey species such as sand eel and sprat) due to the footprint associated with a wave or tidal device. The disruption to these species can have indirect impacts on other species for which these fish are an important food source.98 There is also the potential for disruption of migration routes (e.g. for eel, salmonids, lamprey and shad) where wave/tidal infrastructure is placed in the nearshore or inshore environment. This can disrupt access to hotspots for feeding in important estuary and coastal areas, or displace diadromous/migratory fish which rely on bays and inlets for access to freshwater streams and rivers.98

The physical presence of wave and tidal energy sources in the marine environment takes up physical space and these devices can affect the natural flow of water as they operate by extracting energy from the ocean and as such can cause local changes to hydrodynamics and flow conditions. This can then affect the amount of suspended sediment, the level of light penetration, water column mixing, salinity and loss of intertidal and estuary areas. Changing these parameters can result in knock-on effects to oxygen levels, temperature and nutrient conditions.79

Due to the lack of large-scale commercial deployment of such devices, the evidence base is lacking with respect to environmental impacts from changes to flows and sediment budgets, making an assessment of these impacts difficult to quantify. Life-cycle analyses are still lacking for a number of ocean energy devices.[109] Monitoring undertaken outside the study area, in the Shannon Estuary on the west coast of Ireland has indicated that the degree of impact from the alteration of hydrodynamic conditions will depend on the size of any array, as well as the spacing between devices.[110]

[108] Amaral S., Bevelhimer M., Čada G., Giza D., Jacobson P., McMahon B. and Pracheil B. (2015) Evaluation of behavior and survival of fish exposed to an axial-flow hydrokinetic turbine. North American Journal of Fisheries Management, 35(1), pp. 97–113.

[109] Uihlein, A. (2016) Wave and tidal current energy – A review of the current state of research beyond technology, Renewable and Sustainable Energy Reviews , 58, pp. 1070–1081.

[110] Fallon D., Hartnett M., Olbert A. and Nash S. (2014) The effects of array configuration on the hydro-environmental impacts of tidal turbines, Renewable Energy, 64, pp. 10–25.

As previously discussed changing flow conditions can affect sediment budgets and redistribute material causing smothering of benthic habitats and affect sessile filter feeders. These changes to the sediment can also affect habitat suitability for benthic organisms, which can be either positive or negative depending on the affected organisms.75 The impacts of the footprint of any wave or tidal device on the seafloor are similar to those discussed previously in relation to wind farms. The impacts associated with cabling are discussed in the following section which deals with the grid.

Grid: A significant issue for the delivery of the High Renewables Scenario (or indeed the other scenarios proposed through the regional concept) is the geographical extent of ecological designations, as shown in **Appendix D** (Figure 1-1). For example the Wadden Sea, an area of extensive intertidal flats, contains designations including: an SPA and SAC under the Birds and Habitats Directives; two Biosphere Reserve designations covering the German part of the sea (Waddensea and Hallig Islands of Schleswig-Holstein, Waddensea of Lower Saxony); and a Biosphere Reserve designation covering the Dutch part of the sea (Waddenzee Area). In total, the designations associated with the Wadden Sea extend to approximately 14000km^2.

To date, direct crossings of the Wadden Sea area in the German Bight have been avoided where possible. Examples include the export cables for the BARD Offshore 1 and Gode Wind 1 and 2 Wind Farms (operational wind farms) where the export cables made landfall first on the Frisian Islands and then traversed the Wadden Sea intertidal area via subterranean bores.[111]

While not itself comprising designated areas, the OSPAR List of Threatened or Declining Species and Habitats includes habitats which are used in the designation of SACs and Marine Protected Areas and is a good proxy for the sensitivity of offshore areas. Within the study area, the grid intersects 345 OSPAR sensitive habitats.

It is acknowledged that the refinement and routing of cables will be key to avoiding and reducing the significance of negative impacts on protected habitats. Cable routing could contribute to avoiding important habitats as a priority, such as benthic habitats which have higher ecological value and/ or are very slow-growing (e.g. seagrass/ eelgrass stands and maerl beds respectively). Other benthic habitats (e.g. soft-bottomed sediment with invertebrate communities, blue mussel beds) which are less sensitive need not be avoided if there are no other suitable options, as these benthic habitats have a high regeneration potential and concrete foundations may themselves become recolonised.93

Cable-laying disturbs the seabed causing an increase in suspended sediments with associated smothering effects. Reefs are noted to be particularly sensitive to the effects of smothering.99 As noted under the discussion of wind farm foundations, the greatest amount of sediment dispersion would occur during construction as well as the initial cable-laying activities although impacts would be expected to be into the medium to long-term given the sensitive nature of some of the habitats. Sediment dispersion from cables is discussed further under **Section 7.6: Soils, Geology and Sediment**.

Areas of very mobile sediments such as sandbanks may bury cable sections or alternatively re-expose previously buried cable sections. In such environments, achieving a sufficient buried depth for cables may not be possible due to the underlying geology and attempts to do so could adversely affect soft-sediment habitats. Surveys and routing considerations at the initial project stage may require such mobile sediment areas be avoided in the first instance.[112]

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[111] 4C Offshore: Transmission Export Cables. Retrieved: http://www.4coffshore.com/windfarms/transmission-export-cables.aspx

[112] BERR (Department for Business Enterprise & Regulatory Reform) in association with DEFRA (2008) Review of cabling techniques and environmental effects applicable to the offshore wind farm industry - Technical Report.

In addition to the direct impacts associated with disturbance to or removal of benthic habitat, the laying of cables can also lead to indirect negative impacts as a result of disturbance of other elements of the seabed such as historically contaminated sediment and dredge spoil piles, or contribute to water quality issues by generating suspended solids which can have a negative impact on benthos (see also **Section 7.7: Water**). For example, under the High Renewables Scenario, the grid intersects 34 dump sites. The remobilisation or resettling of contaminated material can be taken in by benthic organisms and bioaccumulate up the food chain. OSPAR considers that the risk of cable-laying disturbing contaminated sediment is only significant in areas which are heavily contaminated i.e. ports and dump sites, the majority of which are located in coastal areas.

As the majority of wind farms and their associated cables are located further offshore than coastal areas and away from ports, encounters with legacy sites and dumping grounds are likely to be limited and subject to appropriate siting considerations at project level (see also further discussion in **Section 7.6: Soils, Geology and Sediment**).

A significant ship presence would be required to deploy grid cabling and pollution from vessels is possible during all phases of development. Potential impacts to water quality are discussed in detail under **Section 7.7: Water**. The presence of ships and ship movements during cable-laying activities can induce scare or flight reactions and cause displacement. Birds can be displaced by ship movements and seals that are breeding or moulting spend more time out of water and could be disturbed by such activities (e.g. flight reaction and temporary abandoning of young). The type of vessel, distance from the noise/haul-out site and the approach angle of the vessel are factors in causing disturbance. Various studies have shown that seals can become disturbed at a range of distances (100m - 800m) depending on the species[113] and otters may also be disturbed by near-shore works and installations.93 The impacts of inducing a scare/ flight response are very similar to the barrier effect, discussed previously under wind energy source.

Similar to wind farm foundations, cables and any associated rock armouring/ mattressing can introduce artificial hard substrate to areas that were previously soft-bottomed, thus changing benthic communities. After the disruption of cable-laying activities, it is also known that benthic fauna can recolonise the area on and around a subsea cable however the longer term effects of this on community structure remains poorly understood.72 In the United States, it has been reported that where sections of a submarine acoustic hydrophone transmission cable had become exposed, it was recolonised by encrusting benthic fauna, with no apparent adverse impacts to the organisms.[114]

As offshore structures typically have long lifespans (around 25 years), changes to community structure are likely to become permanent unless some form of decommissioning is undertaken.102 In many cases offshore cables are not removed, particularly if rock mattresses are used. However this would be addressed on a case-by-case basis and RenewableUK notes that there is some uncertainly about the quantitative impact of cable removal on sediment suspension and seafloor disturbance.102 However, it is anticipated that more information may become available as the world's first offshore wind farm, near Lolland in the south east of Denmark is currently being decommissioned.[115]

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[113] Wilson S. The impact of human disturbance at seal haul-outs: a literature review for the Seal Conservation Society and Tara Seal Research.

[114] Kogan I., Paull C., Kuhnz L., Burton E.J., Von Thun S., Greene G.H. and Barry J.P. (2003) Environmental impact of the ATOC/Pioneer Seamount Submarine Cable, Monterey Bay Aquarium Research Institute, C.A. and the Monterey Bay National Marine Sanctuary, C.A.

[115] Retrieved: http://www.dongenergy.com/en/media/newsroom/news/articles/the-worlds-first-offshore-wind-farm-is-retiring

A potentially significant impact with respect to grid cabling relates to electromagnetic field (EMF) emissions. Much uncertainty persists as to the effects of EMF emissions from undersea cables on electrosensitive marine species.107 The Sustainable Energy Authority of Ireland (SEAI) concluded from a literature review conducted in 2010 that the amount of information and monitoring on the effects of EMF on marine mammals was very limited.[116] Electrosensitive species are known from laboratory studies to be attracted to sources of EMF and show avoidance. Some invertebrates are also reported to be sensitive to magnetic fields, generally related to the animal's ability to orient itself.112 The effects are thought to be small given that these invertebrates are mobile and can move away from the localised magnetic source of the cable.74
The UK's OESEA3 states that there is limited data on elasmobranch responses to EMF generated by cables.79 While some animals do exhibit sensitivity, the UK-based research organisation COWRIE (Collaborative Offshore Wind Research into the Environment) report that the effect is likely to be localised to the vicinity of the cable however the authors noted uncertainty about whether the behavioural responses were positive or negative.[117,118]

Limited research is available identifying the effects of EMF on turtles however analysis from the Oriel Wind Farm (not part of the High Renewables Scenario) in the northern Irish Sea concluded that EMF emissions would not significantly impact populations of leatherback turtles given their high mobility.[119] Some diadromous fish (e.g. Atlantic salmon, sea trout and European eel) use the Earth's DC magnetic field for orientation and migration however the results of a laboratory study showed that there was no observable behavioural response in the fish to EMF calibrated to emit at the standard UK mains transmission levels.[120] While the strength of the magnetic field decreases rapidly with distance from the cable72, there is potential for EMF to cause a barrier effect or disorientation, however this has not yet been observed to any significant level for any species.[121]

The barrier effect from EMF remains difficult to assess and Marine Scotland reports that as of 2015, there have been no new insights into the behavioural responses of fish to EMF.81

The recent 2015 NIRAS report on the effects of submarine cables reiterated these uncertainties.72 As of 2016, further areas needing research have been flagged by the Annex IV State of the Science Report with regards to EMF, noting that serious knowledge gaps remain and significant work needs to be done to fully characterise any potential impacts, particularly with the expansion of offshore renewables and the extensive cabling which will be deployed.107 Neither the scale of any adverse impact nor the long-term impacts of man-made sources of EMF in the marine environment are well known. In this respect, it remains difficult to assess the effects of EMF on marine animals. It is widely considered that burial of cables and rock armouring mitigates much of the emitted electric field by shielding it, but not the induced magnetic field or the secondary electric field induced from this magnetic field.

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[116] Vattenfall Power Consultant for the Sustainable Energy Authority of Ireland (2010) Impact of electric and magnetic fields from submarine cables on marine organisms: the current state of the knowledge.

[117] Gill A.B., Huang Y., Gloyne-Philips I., Metcalfe J., Quayle V., Spencer J. and Wearmouth V. (2009) COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Commissioned by COWRIE Ltd. (project reference COWRIE-EMF-1-06), 128 pp.

[118] Gill A.B., Gloyne-Philips I., Kimber J. and Sigray, P. (2014) Marine renewable energy, electromagnetic (EM) fields and EM-sensitive animals. Chapter in: Shields M.A. and Payne I.L. (Eds). Marine Renewable Energy Technology and Environmental Interactions: Humanity and the Sea series, Springer, pp. 61-79.

[119] Galway: AQUAFACT. For Oriel Windfarm Ltd. (2007) Environmental Impact Statement Non-Technical Summary for the Oriel Wind Farm.

[120] Armstrong J.D., Hunter D-C, Fryer R.J., Rycroft P. and Orwood J.E. (2015) Behavioural Responses of Atlantic Salmon to Mains Frequency Magnetic Fields, Scottish Marine and Freshwater Science, 6(9), Edinburgh: Scottish Government, 17 pp.

[121] OSPAR (2009) Assessment of the environmental impacts of cables.

Concerns therefore remain over the cumulative effects that may occur from the burial or bundling of numerous cables. This will occur with the expansion of the grid in the Irish and North Seas (circa 8000km of cable).

In addition to EMF, cables can also elicit thermal effects in sediment and cause warming of sediments (particularly exacerbated in the spring) which may impact on benthic fauna. Increased sediment temperature may also have implications for changes to chemistry parameters such as dissolved oxygen levels, redox conditions and nutrient profiles[122]; this has been discussed previously under the wind energy source. The UK's OESEA3 also surmises that the burying of cables and the resuspension of sediments into the water column can cause turbidity and elevate oxygen demand, however noting that the effects are likely to be similar to natural fluctuations owing to other pressures such as fishing activity and the influence of storms.79 This is further discussed in **Appendix D**.

Hubs and connectors: Under the High Renewables Scenario the grid would necessitate upwards of 42 hubs under a fully meshed solution. Of these, five hubs under the meshed solution intersect with four SACs and four MPAs. The SACs (and overlapping MPAs) are: Sydlige Nordsø SAC (DK); Sylter Außenriff SAC (DE); Dogger Bank SAC (UK); and Inner Dowsing, Race Bank and North Ridge SAC (UK). There is one operational hub located in the centre of the Sydlige Nordsø (DK) associated with the newly–constructed DanTysk DK1, DK2 and DK3 Wind Farms. There is one proposed hub on the very western edge of the Sylter Außenriff (DE), approximately 150m inside the boundary. The Dogger Bank (UK) has two hubs proposed in the centre of the site, associated with existing wind farms (Teesside) and the proposed Creyke Bank Wind Farms. There is one proposed hub in centre of the Inner Dowsing, Race Bank and North Ridge (UK) site associated with the proposed Race Bank Wind Farm.

The impacts in relation to hubs and connectors are similar to those previously discussed under the wind energy source and grid, with the scale of impact dependant on the duration of activities and the footprint of the hub. There is potential to cause direct visual and noise/vibration disturbances to species as a result of hub installation activities. There are also potential indirect negative impacts associated with pollution from installing hub infrastructure, such as from increased ship presence or disturbance of contaminated sites or dumping grounds. As identified for the wind energy source and the grid, while the presence of designated sites does not preclude hub development, sensitive siting should aim to avoid sensitive benthic sites.

Landfall: Under the High Renewables Scenario considered, 113 landfall points would be required. As there are extensive protected area designations in coastal and terrestrial areas, 52% of landfall sites intersect with protected areas and designated sites. Given the sensitive nature of many of the coastal areas within the study area for protected habitats and species, e.g. Wadden Sea, the potential for significant negative impact is high unless suitably mitigated through sensitive siting and routing procedures (see **Recommendation #5** in **Chapter 8**).

The physical presence of infrastructure at landfall can directly impact mammals found in terrestrial and coastal environments, e.g. otters can be affected by the barrier effect, causing displacement or inducing a scare/ flight response. Little research is available on the interactions of otters with energy systems[123] however conflicts may arise at landfall sites for cables linking offshore energy to the onshore substation/ terrestrial grid. Coastal development related to energy systems (e.g. pier construction, dredging, associated landfall infrastructure) and the increased presence of infrastructure in the nearshore environment can cause disturbance to seal haul-out sites as well as to shelters and habitat used by otters, causing displacement.

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[122] German Federal Office for Radiation Protection (2013) Environmental impacts of the cable connection of offshore wind energy parks to the interconnected power grid.

[123] TETHYS keyword search (2016). Retrieved: https://tethys.pnnl.gov/search/otter

Key Issues and Mitigation Measures for Biodiversity, Flora and Fauna

Key Issues	Mitigation Measures
• Sensitive siting and routing of energy generators and cable routing is required to minimise impacts on protected habitats. • The nature of protected areas and designations must be fully understood relative to the infrastructural element as not all aspects will pose risk for all protected habitats or species. • Considerable uncertainty remains in terms of potential for impacts as a result of wave and tidal devices. • Evasion or avoidance responses may be more prevalent than collision for mammals. • There is a lack of information on displacement effects as a result of impulsive sound and the associated impact at the population level. • There are large gaps in understanding of the response to EMF.	• Apply industry standard siting and routing guidelines. • Long-term studies into the effect of wave and tidal devices required. • More detailed telemetry data needed to provide information on evasion / avoidance responses. • More detailed studies on mammal hearing thresholds and hearing recovery rates needed. • Research and field studies needed on dose-response assessments for invertebrates, fish and commercially species, and exposure assessments for baleen whales where there is spatial overlap with RES and the occurrence of these taxa. • Targeted research needed into the effects and significance of EMF (e.g. dose-response and exposure assessments for various species).

7.5 Population and Human Health

Table 7.6 lists the key potential impacts that can arise from the development of an energy system with regard to population and human health. Populations, both resident and visiting, primarily utilise the terrestrial and nearshore space and it is in these locations that there is greatest potential for conflict. Offshore activities such as commercial fisheries and shipping are also relevant and have been discussed in **Section 7.9: Material Assets**.

Table 7.6 - Population and Human Health: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Population & Human Health	Tourism & Recreation	• Visual intrusion from physical presence. • Exclusion from zones of recreational activity. • Restrictions to port, harbour, marina or terrestrial approaches. • Increased risk of ship-ship or ship-RES collisions. • Changes to wave energy/tidal height of the water column.
	Settlements & Built-up Areas	• Adverse effects from emissions of noise and EMF, emissions of exhausts and impacts to air quality or impacted water quality.

Broadly speaking, the delivery of the High Renewables Scenario will have long-term indirect positive impacts for population and in particular human health as it will deliver up to 76.6 GW of energy from renewable sources rather than from the burning of fossil fuels. This offset of carbon will contribute to achieving EU and global GHG reduction targets which have been devised to tackle climate change, itself a significant risk for populations, especially coastal populations. Similarly, the installation of renewables will also offset other air emissions associated with the burning of fossil fuels, e.g. NO_x, SO_x, particulates etc., which have the potential for indirect positive impacts for human health in the medium and long-term.

Based on the EEA Tier 1 emission factors[124] it is calculated that for each gigajoule (GJ) of renewable energy produced from wind/wave or tidal, there is a consequent offsetting of 142g of NO_x and 25.2g of PM_{10} (using Heavy Fuel Oil as an example fossil fuel).

The High Renewable Scenario presents the greatest potential for conflict with coastal settlements and marine activities. A 2013 Eurostat report on coastal populations identified that for the target Member States within this Baseline Environmental Study, the percentage of the population within 5km of the coast spanned from a low of 6% in Belgium to a high of 50% in Denmark.[125] Population levels continue to increase, and there is significant pressure on coastal areas due to expansion of coastal settlements, especially given that they are desirable locations for living, adding to the cumulative pressures.

In addition, coastal communities often rely on the landscape, land and marine resources for employment through fisheries and mariculture industries, ports and shipping, tourism and recreation etc. This increases the potential for conflict with the types of RES and grid infrastructure proposed. There is also potential for conflict with terrestrial infrastructure to support population centres, e.g. roads, utilities, coastal defences etc., particularly close to landfall sites required to bring offshore energy to onshore connection points. The following sections provide a discussion on the impacts on population/ human health relative to the types of energy infrastructure proposed.

Wind energy source: This element of the infrastructure is located mainly in offshore locations and as such this limits the potential for negative impact on populations. There are however interactions with landscape and visual aspects (in particular seascape) which need to be considered. Visual intrusion may give rise to short to medium-term indirect negative impacts on tourism and on residential amenity where turbines and supporting infrastructure are visible on the horizon. The distance to the visible horizon at sea is dependent on the height from which it is observed, the curvature of the earth and by the observer's line of sight. This distance can range from around 5km when viewed from the shoreline at 1.8m above the ground, up to 50km when viewed at 200m height.[126] This is particularly relevant around the UK and Irish coastlines where high cliffs will offer a larger vantage point for visual intrusion. The highest cliffs in the study area are located around the UK e.g. the Cliffs of Dover, the Yorkshire coast and the East Caithness Cliffs in the north of Scotland. Potential impacts to the visual aspect of amenity and landscape are discussed further under **Section 7.11: Landscape and Seascape**.

In terms of recreation, as wind turbines are typically located offshore, the majority of recreational activities are generally not directly impacted by this type of energy infrastructure as surfing, swimming and other similar activities take place in the nearshore/inshore environment. Conflicts could arise however with recreational shipping and ferry routes, both local and intercontinental, as wind farms generally utilise an exclusion or operational safety zone within which certain activities or passage is forbidden (however exceptions may be made for some activities, fishing for instance).

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[124] EMEP/ EEA (30 Sep 2016) air pollutant emission inventory guidebook – 2016.

[125] Eurostat (2013) Coastal regions: people living along the coastline, integration of NUTS 2010 and latest population grid. Based on Nuts 2010 and Population Grid 2006.

[126] RPS Group (2012) Environmental Constraints Report for the Irish Scottish Links on Energy Study (ISLES).

The exact distance can vary but is usually between 50m and 500m. This may result in limiting the extent of the wind farm infrastructure possible at the project level or require rerouting of significant ferry routes to avoid any applicable exclusion zones, in turn leading to increased costs or travel times as a result of rerouting of ships. This could give rise to long-term direct and indirect negative impacts to the routes and those using/ relying on them.

There is also a potential increased collision risk, either from a ship-to-ship incident or from a ship-to- RES infrastructure incident. Estimates of collision risk are given in a number of Member State Plan SEAs however there is great variability in the estimations. The SEA of Dutch Coast noted for example that there were 20 recorded ship-to-ship collisions in wind farm zones in 2008. Extrapolated from that rate, it was considered that the potential rate of ship-to-turbine collision could occur at minimum once every 4.2 years, with a maximum collision rate of every 7 months.[127] Increasing competition for space is one of the most critical issues for the successful delivery of the High Renewables Scenario and sensitive siting and routing of infrastructure at the plan and project level will be critical. The cumulative impacts on population are likely to be significant in the context of the many other competing interests in the North Sea in particular, including nature and cultural heritage interests, fishing and shipping industry and recreation.

The roll out of maritime spatial planning by the target Member States will be indispensable in the delivery of the High Renewables Scenario and the necessary infrastructure beyond 2030 (see **Recommendation #1** in **Chapter 8**).

Wave and tidal energy source: There are a range of devices that can be suitably located in the nearshore and offshore environment. Wave energy devices typically comprise a sub-surface component (moorings, lines, anchors, foundation) and some have a surface or above-surface component). They may be installed as a single device or an array of devices depending on the technology. While there has been little deployment of wave energy devices to date in the study area, the future capacity scenario involves these devices particularly around the Orkney Islands off north-east Scotland and near the north-west coast of Denmark.

Wave energy devices are generally located in the nearshore/ inshore environment and therefore there are potential for direct and indirect negative impacts with recreational activities which are based closer to the coastline e.g. use of bathing waters, sailing, yachting, surfing etc. The significance of impacts may be greater at different times of the year in line with seasonal influxes of tourists and visitors to important recreational or tourist locations. Information on these types of recreational activities are not readily available as spatial datasets across all target Member States, however the presence of bathing waters and sandy beaches in an area gives a good indication of the likelihood of recreational amenities. The coastal morphology types around Orkney, characterised by mostly rocks and hard cliffs, interspersed with areas of soft sediment strands, are attractive coastal features for recreation and visual amenity value. The Brough Head proposed wave development is located immediately adjacent to the Orkney World Heritage Site, which is a cultural site designated for Neolithic settlements. The listing casts the surrounding landscape character as essential to the overall heritage value of the site.

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[127] RWS Water, Transport and Environment (2014) SEAs of the Rijksstructuurvisie Wind op Zee (WoZ) Netherlands.

The physical presence of such devices can have long-term permanent negative impacts as they can exclude recreational usage in high-energy nearshore areas and there are concerns that these devices can affect surfing, as these devices operate by extracting energy from the wave and tidal resource. Tidal structures can also include tidal barrages/tidal lagoons, which require the construction of an impoundment wall or dam structure in which turbines are accommodated to extract energy by the difference in water gradient. This can negatively impact on recreation through the physical loss of intertidal and estuary areas as well as from the visual intrusion of such structures.

Grid: This is taken to encompass the cables linking hubs as well as the export cables and interconnectors which link Member States. There is potential for negative impacts in the marine environment; principally this relates to shipping, as ships are required for the survey, enabling works (preparing the seafloor prior to cable-laying), construction (cable-laying) and decommissioning where an increased shipping presence can exclude other users of the sea. The physical presence of the cable also presents potential for indirect negative impacts as it can limit or exclude certain economic activities. This would be of particular concern in the inshore/ nearshore areas where communities and populations may rely on the marine environment for economic as well as recreational gain. Conversely it is acknowledged that the delivery of the High Renewables Scenario has the potential to bring significant positive impacts to local communities in the short and long term during the construction and ongoing operation of offshore energy systems. This includes tourist, food, drink and accommodation facilities in coastal locations where ships may be deployed for site preparation and / or in communities adjacent to landfall points.

The main potential effects from the placement of cables are temporary in nature and relate to the physical presence of shipping vessels in the maritime area. The temporary impact relates to the increased presence of shipping vessels which can cause disruption to, or rerouting of, commercial and recreational shipping and boating (e.g. ferry routes). Effects may also be felt at ports and port approaches where increased traffic may put pressure on port services and increase the risk of collisions. Under the High Renewables Scenario, there are approximately 1134 ports within 1km of the proposed infrastructure.

Hubs and connectors: The impacts regarding hubs and connectors are similar to the impacts related to offshore RES and the grid. Forty-two hubs are identified under the High Renewables Meshed Concept.

Landfall: One hundred and thirteen landfall points are identified under the High Renewables Meshed Concept. Negative impacts have been identified for population and human health as a result of landfall points and associated connections to the terrestrial grid in the various Member States.

Through the development of electricity networks there have been noted concerns relating to human health and the emission of EMF. The WHO reports that exposure to the low-frequency EMF generated by power lines is not considered to negatively affect health.[128] While the strength of an electric field drops rapidly with distance from the cable, the magnetic field can extend further. There remain concerns about the effects of long-term low-level exposure on health and general wellbeing; however no one epidemiological study has yet proven conclusive. Rock armouring or undergrounding mitigates much if not all of the EMF effect through shielding within the ground and the metal casing of the cable, so the health concerns relating to EMF generally apply to the overhead line solution and the substation/ converter station which would be required to connect the offshore grid to the terrestrial network. In general the population density is lower along the coast, although as noted earlier, coastal areas are desirable places to live and there is increasing pressure; there are 17 built-up areas[129] within 5km of the High Renewables Scenario presented.

[128] About electromagnetic fields. World Health Organisation. Retrieved: http://www.who.int/peh-emf/en/

[129] The Association of National Mapping Land Registry and Cadastral Agencies (2016) Built-up Area Clusters from EuroGeographics.

This potential negative impact can be addressed through sensitive siting and routing, taking into account stakeholder concerns from an early stage (see **Recommendation #5** in **Chapter 8**). It is acknowledged that despite a significant body of evidence in relation to EMF and its effects on human health this, there is still concern from the public, especially with regard to high voltage overhead lines and there remains a data gap in understanding both the link and the mechanism for causing any adverse impact (see **Appendix D** for further information).

Human health and wellbeing can also be negatively impacted by noise emissions which would primarily be related to the temporary construction phase. Increased shipping presence and other offshore activities which generate noise (e.g. seismic surveys) are not expected to negatively affect populations and health as these activities will take place some distance offshore during a temporary timeframe. On the terrestrial side, populations are generally exposed to the most noise from transport-related sources, particularly road traffic. The impacts of noise from RES will relate to the siting and construction of landfall-related infrastructure and grid routing and as such will be temporary and short-term in nature. The timing of construction is also an important consideration as many coastal settlements, aside from the resident population, can experience a seasonal influx of visitors either for short-term day activities (e.g. beach visits, use of walking and cycling trails) or for longer-term holidays (e.g. the East and West Frisian Islands are popular holiday home destinations overlooking the Wadden Sea).

The presence of structures can be detrimental for tourism so avoiding protected or designated viewpoints and features is essential. This provides an opportunity to develop cable and landfall routing guidance to standardise the approach (see **Recommendation #5** in **Chapter 8**).

Key Issues and Mitigation Measures for Population and Human Health

Key Issues	Mitigation Measures
• Offset of carbon through use of renewable energy and contribution to reduced greenhouse gas emissions. • Conflict with existing users of the sea (e.g. fishing, recreational boating) and potential exclusion from recreational areas. • Collision risk with other ships or RES. • Health concerns regarding EMF and proximity to overhead lines.	• Collation of recreation and amenity datasets needed at Member State level in order to better quantify the impacts to recreation and amenity users. • Develop good siting and routing guidelines for avoidance of built-up areas (e.g. undergrounding, minimum distances, cable shielding etc.).

7.6 Soils, Geology and Sediment

The Irish Sea is dominated by coarse seabed substrate and sandy deposits. Coarse substrate is also generally found in the English Channel and inshore areas around the UK. The central part of the North Sea is dominated by mud and sand, with mud found more in the deeper and flatter areas such as over the Fladen Ground and around the Skagerrak. Muddy sands are also found over the Oyster Grounds and just beyond the German Bight. Rocky boulders and outcrops are common around the west of Scotland in particular and parts of England's south coast.

The main conflicts with developing an offshore energy system and soils, geology and sediment processes relate to the disturbance and movement of sediment, changes to flow conditions, impacts to water quality and potential disturbance of geological heritage as outlined in **Table 7.7**.

Table 7.7 - Soils, Geology and Sediment: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Soils, Geology & Sediment	Soils	• Permanent loss of, or sealing, of soils.
	Geological Heritage	• Disturbance or physical loss of the seabed or terrestrial landscape.
	Coastal Processes & Sediment Movements	• Physical loss/ permanent modification of the seabed. • Changes to sediment distribution/ coastal sediment budgets. • Turbulence and sediment load changes. • Disturbance or remobilisation of contaminated sediment. • Contamination of sediment (vessel losses). • Changes to biotopes. • Introduction of light. • Heating of sediment. • Changes to erosion and accretion rates.
	Hydrodynamics & Flow	▪ Changes to hydrodynamics and flow, influencing: velocity; salinity; stratification and nutrient flushing; tidal and wave regimes. ▪ Changes to water levels and wave heights. ▪ Scouring. ▪ Wind shadow and wind drag effects. ▪ Induction of wake effects.

Wind energy source: The main impacts to coastal processes are primarily from the siting of renewable energy source infrastructure through site preparation and the setting of foundations and piles for turbines and other device structures. This can cause temporary to permanent disturbance of seafloor sediments and causes direct permanent alteration the bedrock in the case of piling, drilling and trenching. Localised erosion (scour) can occur around foundation bases or rock armouring when structures are placed in areas of soft sediment. Depending on the local conditions, the depth of scour can be extensive and up to several metres deep resulting in short to long-term impacts, dependent on the rock armouring used and how quickly it is installed. **Figure 7-4** illustrates an example of such scouring occurring around the base of an installed monopile as part of the Arklow Bank Wind Farm in the Irish Sea[130]. This part of the Irish Sea can experience strong currents and in the short interval prior to the setting of rock protection around the bases of the seven monopiles, deep scouring occurred up to 4m deep and 25m in diameter. CEFAS (2006) analysis indicates typical scour pit depths up to 5m and diameters which can extend up to 60m across.[131]

[130] HR Wallingford (2008), reproduced from the United Kingdom's OESEA3 (2016) under Crown Copyright Open Licence

[131] CEFAS (2006) Scroby Sands Offshore Wind Farm – coastal processes monitoring. CEFAS contract report no. AE0262, 51 pp.

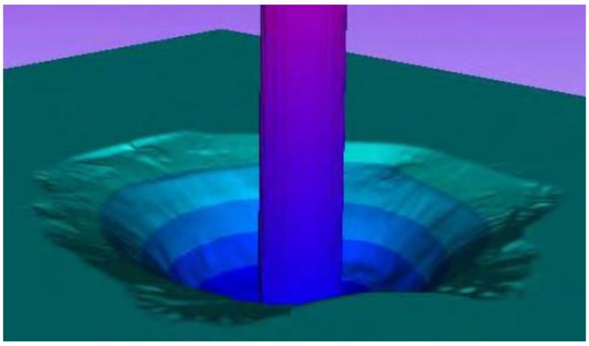

Figure 7-4 - Depth Contours at the Base of a Monopile from the Arklow Bank Offshore Wind Farm

Figure 7-5 gives another example from the Scroby Sands Wind Farm[132]. This Fledermaus 3D bathymetry image illustrates the development of temporary scour pits around the bases of the turbine monopiles, and also the development of other sediment forms such as small-scale scour tails between turbines. The physical presence of artificial structures can also potentially cause temporary to permanent impacts to sediment transport processes or act as a medium to long-term barrier to transport. From this there is the potential for knock-on indirect and cumulative impacts such as altered sediment deposition elsewhere affecting local bathymetry and smothering of benthic ecology/habitats. Ideally cable protection measures such as rock placement/concrete mattressing would be limited to areas where the cable cannot be sufficiently buried and this can lead to scouring of surrounding sediment through creating a localised morphological change on the seabed. The presence of RES infrastructure can also cause long-term permanent alterations to flow regimes in the vicinity of the development. For instance wind turbines cause localised alterations to wave height, as wave and tidal devices by their very nature cause changes to flow direction, velocity and wave height. Installation of such infrastructure in the nearshore and intertidal environment has the potential to have medium to long-term impacts on coastal processes, disrupt sediment supply and longshore sediment movement. The IUCN considers that the changed hydrodynamics that occur around wind farms are likely to be long-term but localised, and limited to the immediate area of the turbine.

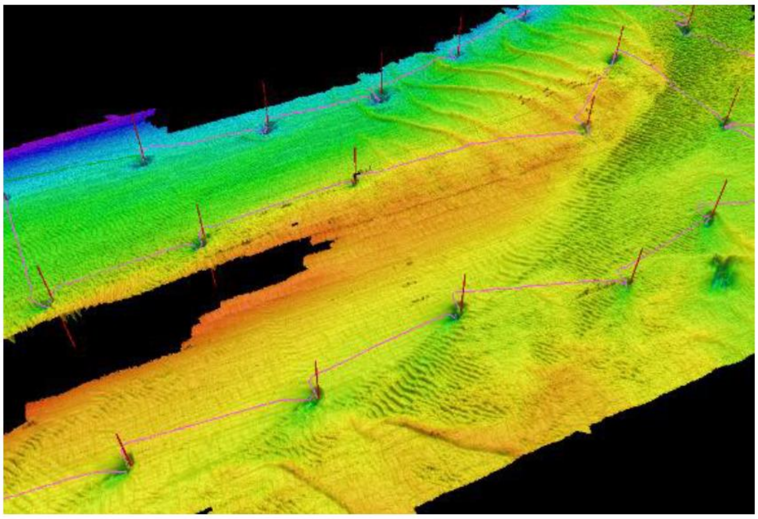

Figure 7-5 - Fledermaus Swathe Bathymetry at the Scroby Sands Offshore Wind Farm

[132] CEFAS (2006), reproduced from the United Kingdom’s OESEA3 (2016) under Crown Copyright Open Licence.

Site preparation can disturb sediments and cause them to be redistributed. The impact to the seabed is related to the footprint of the structure: gravity foundations would require direct permanent alteration of the seafloor through site preparation, dredging and removal of seafloor material, whereas moored floating structures and piles set directly into bedrock would have a smaller footprint on the seafloor and thus cause less disturbance to sediments. The introduction of artificial hard substrate via the siting of foundations or bases in areas dominated by soft sediment will also result in a medium to long-term permanent alteration of the seafloor. This could have positive indirect impacts in terms of the artificial reef effect which can attract pelagic fish to a wind farm.

Negative indirect impacts of this reef effect include alterations to the benthic assemblages to include hard-substrate benthos not normally found in soft substrate areas, as well as providing a stepping-stone to the possible spread of invasive species. Once established, invasive alien species can prove difficult if not impossible to remove and can therefore represent a permanent impact.

Techniques employed both during surveying and site preparation activities can use seismic reflection penetrating to a depth of about 50m. In addition to the potential for indirect negative biological impacts, such surveys or construction of marine infrastructure can cause landslip, the triggering of shallow geohazards or shallow gas causing physical disruption of the seabed, and secondary ship or infrastructure damage. Geohazards are more likely to occur at tectonic plate margins and in high-seismicity areas. In general, the Irish and North Sea areas are fairly tectonically inactive, however it is noted that significant earthquakes have occurred in the past around the UK and through Germany and Denmark.

It is noted also that detailed data on the location and distribution of offshore geohazards is sparse or is sometimes not made publically available. As such the scale and significance of this impact is difficult to assess at such a strategic level but should be gathered at the project level to fully characterise any potential impacts. Such data is usually obtained through detailed site and bathymetric surveys e.g. through seismic/ sonar surveys and core sampling.

Under the High Renewables Scenario, an interconnector linking Scotland and Norway would indicatively have to traverse a large expanse of mud volcanoes in the northern part of the North Sea. These areas can indicate active seismicity and mud flows, but in general monitoring of active sites is rare.[133] These areas could represent a significant potential geohazard to cabling or any associated seafloor infrastructure as areas with mud volcano can be unstable or impact on the stability or siting of infrastructure.

Wave and tidal energy source: The effects of wave and tidal devices on hydrodynamics are less well-understood than for wind energy, partly as the technology is constantly being developed. Such devices are usually located in high energy nearshore environments which are harder to model due to the dynamic nature of such environments. Assessing the impact of energy extraction from individual devices is currently considered to be too small to measure, but may be possible in the future at the array-scale and larger commercial deployment.[134]

The UK's OESEA3 notes that the majority of information on impacts of wave and tidal devices to hydrodynamics come from models and simulations, rather than actual site monitoring; studies to date flag that the impacts are often very site-specific and detailed surveys would need to be undertaken at the project level.

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[133] Mud volcanism: Processes and implications (2009) Editorial, Marine and Petroleum Geology, 26, pp. 1677–1680.

[134] Copping A., Sather N., Hanna L., Whiting J., Zydlewsk G., Staines G., Gil, A., Hutchison I., O'Hagan A.M., Simas T., Bald J., Sparling C., Wood J. and Masden E. (2016) Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Fact Sheet Chapter 5 - Physical Systems: Energy removal and changes in flow from wave and tidal devices.

Grid: Trenching of the seabed and the laying of cables in softer sediment layers can generate plumes of sediment causing indirect temporary through increases in the suspended solid content and increased turbidity of the water column. This may cause sediment to be redistributed and deposited elsewhere, for instance, from the installation of cables in the nearshore or intertidal areas which can temporarily affect coastal processes via changes to sediment supply in the area or by altering longshore drift. Finer sediments can disperse greater distances than coarser sediments.

Low energy areas (e.g. enclosed bays) may take longer to disperse sediment plumes than higher energy sites (e.g. exposed coastlines and areas with strong tides). In the United Kingdom, post-consent monitoring of wind farms sites determined that increases in suspended sediment loads as a result of cable-laying were short-term and localised to the cable route with loads occasionally similar to natural background fluctuations.[135] The UK's OESEA3 also surmises that the burying of cables and the resuspension of sediments into the water column can cause turbidity and elevate oxygen demand, however noting that the effects are short-term temporary and likely to be similar to natural fluctuations owing to other pressures such as fishing activity and the influence of storms.79

The UK's Marine Monitoring and Assessment Strategy136 also concluded that whole the amount of cabling required to meet the needs of expanding offshore renewable energy source development, the effects are localised, temporary and within background levels. For example, suspended sediment loads in the southern North Sea in summer range from 0-4mg/l, rising to over 300mg/l in high energy areas such as estuaries; winter suspended sediment loads are noted to be higher (typically double the summer loads).[136] Sediment modelling undertaken for the UK's Dogger Bank Teesside A and B Wind Farm export cables indicated that generated sediment loads would be highest at two points, nearest the shore and approximately 50km offshore, falling with increasing distance from the cable. Modelling also estimated that sediment re-deposition was estimated to be under 5mm along the cable, dropping to 0.5mm about 35km from the cable.[137]

Exposed bedrock is less desirable for cable-laying as the cable would have to lie on the surface and may need to be armoured with rock from other sources. The biology associated with rocky seafloor features (epifauna) would therefore subject to greater direct and permanent impacts than sediments. The High Renewables Scenario has the most potential for conflict with sediment transport and coastal processes, based on it having a larger development footprint.

Cable-laying can also disturb contaminated sites; for instance oils and heavy metals are usually found more in the nearshore environment and bound up in finer sediment. The remobilisation or resettling of contaminated material can be taken in by benthic organisms and cause temporary to permanent impacts to organisms through bioaccumulation up the food chain, depending on the concentrations level of the pollutants.

OSPAR considers that the risk of cable-laying disturbing contaminated sediment is only significant in areas which are heavily contaminated i.e. ports and dump sites, the majority of which are located in coastal areas. Impacts are further limited if cables are not removed during decommissioning or damaged during operation e.g. damage to cables which carry dielectric fluids.121 As the majority of wind farms are located further offshore than coastal areas and away from ports, encounters with legacy sites and dumping grounds are likely to be limited.

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[135] Marine Management Organisation (2014) Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms. MMO Project No: 1031, 208 pp.

[136] Frost M. and Hawkridge J. (Eds.) Charting Progress 2: Healthy and Biological Diverse Seas Feeder Report (2010) Published by Department for Environment Food and Rural Affairs on behalf of the United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS). 672 pp.

[137] Forewind (2014) Dogger Bank Teesside A and B Environmental Statement.

Sediment quality is generally assessed at the project-level prior to cable-laying operations and routing at the site selection stage, which also allows known or unknown contaminated or legacy sites to be avoided.

The Geological Events and Probabilities Work Package data, currently being compiled as part of the EU's EMODnet Geology Project, gives an indication of the types of geohazards that are likely to occur in the Irish and North Seas. As the project is still ongoing, the absence of data in an area does not preclude the absence of any geohazards. Much of the data in the study area so far is for the UK's EEZ. The grid would have to cross some offshore fault lines, and there are areas, particularly around north-east England and Scotland where there have been recorded tsunami events (e.g. in the Firth of Forth and Moray Firth).

The presence of grid cables can also elicit a heating response in the surrounding sediment in which it is buried. However, the impact on the benthic environment are poorly understood. In the US, elevated sediment temperatures have been measured as low as 0.000006°C in the vicinity of a power cable[138], with modelled temperatures varying between 5 and 15 Kelvin in the surrounding sediment in German waters.[139] Monitoring of cable heating at the Dutch Nysted Wind Farm indicated that 132kV cables display a greater heating effect than 33kV cables. In this instance, the maximum temperature increase was measured as 2.5K at a sediment depth of 20cm from the cable. **Appendix D** provides more information on findings from current available research studies and the studies indicate that the impacts are likely to be negligible, but acknowledging that there is potential for localised impacts.

Hubs and connectors: There will be a permanent and direct impact to the seabed from the footprint associated with the placement of hubs with similar impacts to those of turbine bases, foundations and the grid. The strategic environmental assessment of the ISLES II concept considered that given the exposed nature of offshore areas, that the level of deposition from dispersed sediments is not likely to be detectable beyond background levels and natural fluctuations. Negative impacts can be addressed through sensitive siting and placement, taking into account the potential opportunities for phased and coordinated rollout of key infrastructure, for example hubs (see **Recommendation #2** in **Chapter 8**).

Landfall: The siting of terrestrial infrastructure such as converter stations or substations will result in direct permanent loss of, or sealing of, soils. Inland and coastal areas often contain geological heritage features such as cliff faces, beaches and river mouths. In addition, these areas often contain geological features of interest which have become exposed due to the action of weather and erosion. Siting of structure at landfall means there are potential conflicts with disturbance to or preservation of such features of geological heritage or geomorphological interest.

The effects can be mitigated through sensitive siting and routing by avoiding sensitive coastal landscapes and landfall sites, taking into account stakeholder concerns from an early stage (see **Recommendation #5** in **Chapter 8**).

[138] Department for Business Enterprise & Regulatory Reform (BERR) in association with DEFRA (2008) *Review of cabling techniques and environmental effects applicable to the offshore wind farm industry* - Technical Report.

[139] Pophof B. and Geschwetner D. (2013) Environmental impact of the cable connection of offshore wind energy parks to the grid network: Effects of operating electrical and magnetic fields as well as thermal energy entries in the sea bottom. Report produced for the German Federal Office for Radiation Protection.

The operational EMEC Wave Test Site on the west coast of the Orkney Islands is located in proximity to Stromness Heaths and Coasts, a Site of Special Scientific Interest, which are an excellent example of Devonian Old Red Sandstone bedrock, as well as including interesting coastal features such as cliffs, caves and sea stacks. The environmental statement[140] for EMEC Wave Site states that seascape is not a key sensitivity and illustrates that with good siting, wave energy devices can be located in nearshore areas that are considered sensitive environments from a geological and landscape perspective.

Key Issues and Mitigation Measures for Soils, Geology and Sediment

Key Issues	Mitigation Measures
• Permanent alteration of the seafloor. • Potential for loss of or sealing of soils. • Localised scouring around foundations, also affecting sediment transport. • Effects from wave and tidal devices less well understood.	• Undertaking of appropriate bathymetric, geophysical and oceanographic surveys. • Good siting principles to avoid sensitive benthic habitats, polluted sites, dredge spoil, munitions dumps or dangerous shipwrecks. • Project level requires detailed seabed modelling of seabed, sediment processes and local bathymetry.

7.7 Water

Offshore water quality is in general poorly-characterised and there is a general lack of water quality monitoring data for the Irish and North Seas, and especially in relation to offshore developments as evidenced in the collection of baseline data presented in **Chapter 5** and **Appendix D** of this report. In terms of chemical impacts, there are a suite of chemicals i.e. ship paints, biocides and antifoulants, which can leach from vessel hulls and certain energy devices. However, these chemicals are subject to strict regulation in Europe and as such their interaction with the marine environment is understood. As such, this facet of water quality is considered to be of low priority risk in terms of impact on the environment.134 **Table 7.8** lists the key potential impacts that can arise from the development of an offshore energy system with regard to the main water receptors.

Table 7.8 - Water: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Water	Water Quality	• Suspension of sediment/ turbidity. • Resuspension/ remobilisation of contaminated materials. • Leaching of chemical pollutants to water. • Disposal of litter to sea. • Loss of ship fluids at sea. • Changes to retention times. • Introduction of microbial pathogens.
	Flood Risk	• Impacts to wave height/ altered flow regimes and exacerbation of flood risk in other areas.
	Coastal Defences	• Impacts or modifications to coastal defence structures. • Potential conflict with landfall and future-proofing for climate change.

[140] EMEC (2004) Billia Croo Environmental Description (Aurora). REP096-04-03 20090625.

Wind energy source: There is the potential that the increased presence of vessels needed for installation of renewables infrastructure would lead to temporary impacts to water quality from accidental losses of fuels or other contaminants. The OSPAR Quality Status Report outlines that in general, the trends in contamination levels across the regional seas are falling but there are still exceedances being reported for the Irish/Celtic Seas as well as the North Sea.42 Legacy contaminated marine sites continue to be a long-term source of contaminants, and marine sediments are also an important sink for heavy metals. In general, the most contaminated sites are found closer to shore and are associated with ports, harbours, marine outfalls and industrialised sites. Monitoring data is variable across Member States but Denmark, Germany and Ireland have reported elevated levels of heavy metals in many marine samples (MSFD/ OSPAR reporting) and the United Kingdom reports some increasing trends with respect to PCBs. The inconsistency of reporting across countries with regards to marine water quality means the impact risk is difficult to assess (see **Recommendation #6** in **Chapter 8**). Installation of RES and grid infrastructure will potentially result in the resuspension of contaminated material causing a temporary increase in suspended solids and turbidity in the water column. There is greater potential impact from the High Renewables Scenario as it represents an intense deployment of wind farms.

Wave and tidal energy source: Some wave devices can contain a lot of oil and as such any collisions or damage to such devices (e.g. deployment of anchors or mooring) could result in direct losses of oil to the water column. Depending on the level of damage, impacts to water quality are likely to be temporary in nature but leaks may persist for some time. Wave and tidal devices operate by extracting energy from wave motion and the action of the tides. Therefore these devices, by their very nature, cause direct medium to long-term alteration of local hydrodynamics, wave heights and tidal amplitudes. This can directly impact biodiversity as discussed under **Section 7.4: Biodiversity, Flora and Fauna**.

Grid: There is the potential that the increased presence of vessels needed for cable installation could lead to impacts to water quality from accidental losses of fuels or other contaminants. Vessels should strive to be compliant with the International Convention on the Prevention of Pollution from Ships (MARPOL) as well as follow the best practice guidance for working over water.

The presence of litter in the marine environment also impacts on water quality and is included as a descriptor under the MSFD. In the OSPAR North East Atlantic region both land-based activities and offshore activities, such as shipping, resource extraction, fishing etc., are noted as being equally significant sources of litter.81 As marine litter remains a significant issue for the Irish and North Seas, it can reasonably be expected that the increased shipping presence required under the High Renewables Scenario to deploy cabling could be reasonably expected to contribute to this issue. The impacts of litter to water quality would potentially have short to medium-term impacts, related to the duration and intensity of ship presence.

This would be highest during the construction phase, with a less intense presence related to other activities, such as RES or grid maintenance. Marine litter is a particular concern as marine animals often ingest litter particles which can lead to negative impacts to health and fitness. For example, 95% of beached fulmars from the southern North area were found to have plastics in their stomachs.42 The release of contaminants from disturbed sediment can impact on benthic ecology by altering the oxygen demand or chemical levels in the habitat. Dispersion is more likely in areas with finer sediment substrate (e.g. muds) than in areas of coarser sediment or high energy areas which can disperse sediment plumes more quickly.

The installation of cables will cause a temporary impact through increasing suspended solids and turbidity in the water column, with the High Renewables Scenario having the potential to have the largest impact. Disturbance of military munitions or unexploded ordnance can represent a significant risk to ship and platform personnel as well as wildlife. Disturbed munitions can also release contaminants to the water column (e.g. fuel and oil from wrecked or sunken vessels) and there is a high risk as there was extensive dumping of munitions in the years immediately following the end of World War II. Trends indicate the majority of conventional munitions dumping occurred in German coastal waters within the 12nm limit. The two major dumping grounds for chemical munitions occurred in the Skagerrak Sea and in the Bornholm Basin (Baltic Sea)[141], both of which are outside the study area. There are thirty-nine recorded munitions within a 1km corridor of the cables based on available datasets. Careful siting, (**Recommendation #5** in **Chapter 8**) should aim to avoid known munitions grounds in the first instance, along with undertaking appropriate detailed site investigations.

Hubs and connectors: As noted previously for the wind/ wave/ tidal sources and grid, the impacts to water quality from hub and connector elements are considered to be broadly similar. The impacts are mainly indirect and relate to: disturbance of sediments, contaminated sites and munitions resulting in remobilised contaminants or an increase in suspended solids; and contribution of litter to the marine environment or fluid losses from ship presence/accidents.

Landfall: Coastal defences are found all across Europe and each of the Member States in this Baseline Environmental Study have some form of coastal defence structures. Conflicts between energy system development and coastal defences can arise where the installation of platforms and cables has the potential to impact on the integrity of flood defence infrastructure or coastal protection.
Appropriate siting guidance should be considered as per **Recommendation #5** in **Chapter 8**. In terms of the grid, there are forty-nine encounters with coastal defences within the study area.

Key Issues and Mitigation Measures for Water

Key Issues	Mitigation Measures
• The impacts to water quality as a result of renewable energy development are not fully understood. Lack of quantified studies and monitoring data on water quality, in particular quantification of long-term impacts. • Potential for accidental losses of contaminants (from ships and RES/ grid). • Legacy contaminated sites and potential for disturbance.	• Compliance with MARPOL and follow industry best practice guidance for working over water. • Use of appropriate ship management systems including Health and Safety Plans and reduce the effects of contamination or incidents occurring through for instance implementation of Shipboard Oil Pollution Emergency Plan (SOPEP). • Long-term studies into the effects of wave and tidal devices on hydrography.

[141] Marencic H. and Nehring S. (eds). Wadden Sea Ecosystem No. 25: Quality Status Report (2009) Thematic Report No. 3.5. Common Wadden Sea Secretariat Trilateral Monitoring and Assessment Group.

7.8 Air Quality and Climatic Factors

Table 7.9 outlines the key sensitivities were identified under the topics of Air Quality and Climatic Factors.

Table 7.9 - Air Quality and Climatic Factors: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Air Quality	Air Quality	• Emission of exhausts from both land-based traffic and shipping during construction. • Reduction on emissions from electricity generation through displacement of fossil fuel based power generation.
Climatic Factors	Climate	• Emission of exhausts from both land-based traffic and shipping during construction. • Reduction on emissions from electricity generation through displacement of fossil fuel based power generation.

As shown in the baseline assessment, the two sectors that are currently the greatest pressures on local and regional air quality in the six Member States are from the electricity generation sector and the transport sector. The pressures from these sectors are predominately caused by the combustion of fossil fuels and the resultant emissions of combustion gases and particulates. Any development that facilitates the reduction in the combustion of fossil fuels is likely to have a positive air quality impact in the long term.

However, as with any development project, the construction stage of the High Renewables Scenario will require fuel use for transport of materials and laying of cables and in this regard there will be likely short-term emissions to air as a consequence. These emissions will depend on the types of vessels, the fuels employed and the distance travelled in laying the cables.

The EMEP/ EEA air pollutant emission inventory guidebook 2016[142] references typical emissions from water-borne navigation across the EU. The EMEP/EEA Tier 1 default emission factors for all vessels using marine diesel oil/ marine gas oil for the various pollutants are listed as follows:

- Oxides of Nitrogen (NO_x): 78.5 kg/tonne fuel consumed
- Carbon Monoxide (CO): 7.4 kg/tonne fuel consumed
- Non-Methane Volatile Organic Compounds (NMVOC): 2.8 kg/tonne fuel consumed
- Particulate Matter (PM_{10}): 1.5 kg/tonne fuel consumed

Actual emissions will depend on the fuel type, vessel power output, fuel efficiency, speed of operation, etc. but the default parameters are presented for illustration of the extent of emissions from this scenario.

[142] EMEP/EEA (September 2016) Air pollutant emission inventory guidebook – 2016.

In terms of laying cables for the High Renewables Scenario, an estimated distance that the vessels will have to travel is 8831km for offshore cable length. It is acknowledged that ongoing maintenance and monitoring using vessels and associated equipment will be required over the lifetime of any projects arising from the High Renewable Scenario. It is important to note that the local impact of any emissions on human health will be limited given that the majority of emissions (i.e. those beyond the construction of landfall connections) will be in the marine environment and will not be located close to any sensitive human receptors. However, at a regional/international scale the potential for impact for transboundary emissions may be more significant. The construction impacts (including ongoing maintenance and monitoring) are predicted to be principally short-term temporary and a slight negative for air quality.

Post construction, the deployment of up to 76.6 GW of renewable energy in the Irish and North Seas will have a long term significant positive air quality impact in the event that clean renewables such as wind, wave and tidal are used to offset the combustion of fossil fuels and solid biomass for electricity generation. The use of combustion-based electricity generation (through fossil fuels or biomass) generates levels of combustion gases and particulates with potential impacts at the local level close to the generation source (human health) and at the regional level (transboundary). Renewable sources (e.g. wind, wave and tidal) have no direct impacts to air quality post construction (as noted above) and represent a significant positive impact.

The EMEP/EEA Tier 1 default emission factors142 for various combustion fuels are shown in **Table 7.10** along with the estimated emissions from various fuels based on a 1-hour operation of the full 76.6 GW capacity of the High Renewables Scenario. This illustrates that in the event that the deployment of the renewable grid could potentially offset 22.3 - 57.6 tonnes of NO_x per hour, and 0.2 – 42.7 tonnes of PM_{10} per hour, depending on the combustion fuel displaced by renewables. While this analysis is based on a theoretical full renewables utilisation of the grid capacity and an equivalent GJ reduction in fossil fuel/biomass only, the analysis does illustrate the extent of the potential positive air quality impacts that may be achieved.

Table 7.10 - Potential Emissions Reductions

Parameter	Pollutant	Hard Coal	Natural Gas	Heavy Fuel Oil	Biomass
Tier 1 default emission factors (g/GJ)	NO_x	209	89	142	81
	PM_{10}	7.7	0.89	25.2	155
Emissions per hour (tonnes)	NO_x	57.6	24.5	39.1	22.3
	PM_{10}	2.1	0.2	6.9	42.7

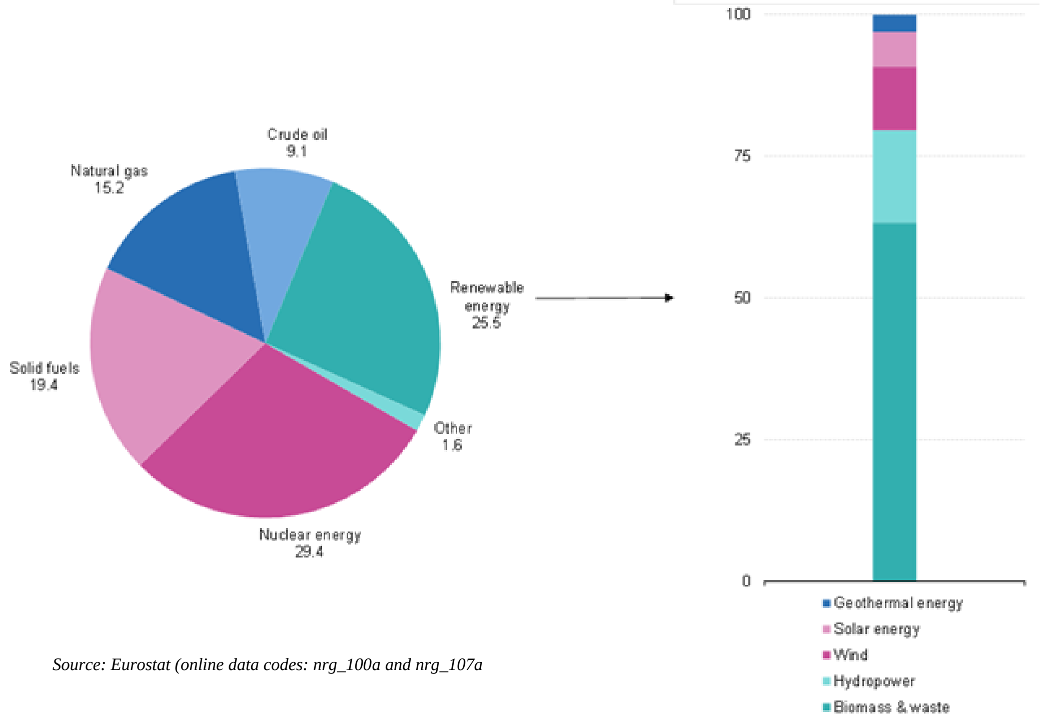
In addition, the development of the grid infrastructure will facilitate the development of non-combustible renewable sources which will offer significant positive air quality impacts over combustible renewable sources (such as biomass) as well as fossil fuel combustion. Biomass combustion for power generation can have air quality impacts similar or worse to fossil fuel combustion and the facilitation of offshore, wind and wave energy development offers long term positive benefits. The positive air quality impacts associated with the decarbonisation of the electricity generation sector offered by concepts such as the High Renewables Scenario and the subsequent facilitation of alternative technologies for road transport (electric vehicles) offers a further indirect positive impact. Directive 2014/94/EU on Alternative Fuels introduces binding targets on Member States for a minimum level of infrastructure for clean fuels such as electricity along with common EU wide standards for the equipment needed. The successful deployment of this infrastructure coupled with the decarbonisation of the electricity generation sector will offer further positive impacts for local and transboundary air quality.

The construction and maintenance elements of the development of the High Renewables Scenario will cause short-term slight negative impacts to air quality primarily from vessel emissions. These impacts are minor but will offer long term positive impacts to air quality through the facilitation of the decarbonisation of the electricity generation sector and the shift towards alternative fuels for transport (e.g. electric vehicles). Overall, the High Renewables Scenario will have a strong net positive impact for air quality. Similar to air quality, there are two conflicting potential impacts for climate change associated with the development of the High Renewables Scenario, including:

- Short-term direct GHG emissions from the construction phase. These emissions include both embodied emissions in the grid materials as well as combustion emissions from plant operation and material transport; and
- Long term indirect reductions in GHG emissions from fossil fuel combustion through the deployment of up to 76.6 GW of renewable energy in the Irish and North Seas. These indirect impacts will first be related to the decarbonisation of the electricity generation sector and subsequently for other sectors such as transport, where a decarbonised electricity network will have further positive indirect impacts.

The net impact for climate will be significantly positive in the long term from the deployment of large scale renewable infrastructure allowing Member States to reduce the reliance on carbon based fuels and facilitate the transition to a low carbon economy.

Production of primary energy in the EU-28 totalled 771 million tonnes of oil equivalent (Mtoe) in 2014[143] and 25.5% of this total was through renewables (refer to **Figure 7-6**). A further 15.2% is through natural gas, 9.1% through crude oil and 19.4% through solid fuels. Data from the EEA[144] shows that GHG emissions from Public Electricity and Heat Production (Category 1.A.1) from the combustion of fossil fuels in the EU-28 equates to 1066 million tonnes of CO_2, approximately 26% of the EU-28 inventory for 2014. The energy sector is one of the largest GHG emission sources in the EU-28 and there are several policy documents and directives that have set targets for Member States to move away from fossil fuel combustion to more sustainable renewables.



Source: Eurostat (online data codes: nrg_100a and nrg_107a

Figure 7-6 - Production of Primary Energy (% of Total, Based on Tonnes of Oil Equivalent)

[143] Eurostat (2014) Energy balance sheets.

[144] EEA (2016) Annual European Union greenhouse gas inventory 1990–2014 and inventory report.

The planned deployment of up to 76.6 GW of renewable energy under the High Renewables Scenario for the six Member States will facilitate the shift from fossil fuels to renewables in line with international and EU policies and targets. A wind farm typically operates for circa 4000FLH (full load hours) per year therefore produces 306400 GWh. The International Energy Agency (IEA) has published average GHG emission factors for various fuels[145] that have been utilised in this assessment to estimate the extent of GHG that may be offset by the development. Based on the potential renewable input associated with this study (306400 GWh) and the pro-rata share of the fossil fuels as published by Eurostat, an estimated maximum CO_2 saving from the offsetting of fossil fuels from the development of the renewables grid is presented in **Table 7.10**. It is noted that this is a simplified assessment that assumes typical utilisation of the grid and a maximum reduction on fossil fuels contribution only from the energy mix and is provided for illustration.

Table 7.11 - Estimation of Maximum Potential Carbon Savings from the Grid

Fuel	Fraction of EU-28 Energy Mix	Total Energy Input (GWh)	IEA Emission Factor (gCO_2/kWh)	Total Emissions (million tonnes CO_2)
Natural Gas	0.152	46573	400	19
Crude Oil	0.091	27882	645	18
Solid Fuel	0.194	59442	925	55
Total Potential GHG Reduction				92

The results of the simplified analysis indicate that the development of the grid infrastructure coupled with the subsequent reduction in fossil fuel combustion for energy use, has the potential for a maximum reduction of circa 200 million tonnes of CO_2 per annum or 8000 million tonnes over a 40 year lifetime. Any actual emissions reduction will depend on the degree to which fossil fuel use is reduced, the state-specific emission factors and the utilisation of the grid infrastructure. However, the data illustrate the potential for long term reductions in GHG emissions from the development of the infrastructure.

As outlined for air quality, the decarbonisation of the electricity generation sector also offers potential for reduced GHG emissions from other sectors such as transport. The High Renewables Scenario will offer further indirect positive impacts for transport related GHGs on the successful development of RES.

All construction projects will generate a degree of GHG emissions and this is also true for renewable projects. Construction materials such as steel, concrete, glass, plastic, etc. have embodied carbon emissions associated with their manufacture at source and in this project this includes the cables, devices, hubs connectors, etc. In addition, the laying of the cables, construction at landfall etc. require the use of vessels, cranes and other plant as well as transport of materials to the work area all of which generate combustion emissions. Finally, the routine inspection and maintenance of the cables will also require vessel transport and energy use on an ongoing basis.

A 2011 study carried out by the Norwegian University of Science and Technology (NTNU)[146] looked at the full life cycle analysis of offshore infrastructure in the North Sea. Projects such as the 450kV NorNed cable between the Netherlands and Norway have been used a reference as they are directly relevant. The findings of the Norwegian study have been used as an illustration of the carbon impact from the development of grid infrastructure under the High Renewables Scenario.

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[145] International Energy Agency (2015) CO_2 Emissions from Fuel Combustion - Highlights (2015 Edition).

[146] Christine Birkeland NTNU (2011) Assessing the Life Cycle Environmental Impacts of Offshore Wind Power Generation and Power Transmission in the North Sea.

The Norwegian study identifies that a 450kV HVDC power transmission cable used for long distance has a total carbon footprint of 215kg of CO_{2eq} for each 1MW/km. This covers circa 40% of emissions for the manufacture of the cable, circa 46% for the manufacture of other components, circa 12% for the construction stage (road transport and cable laying) and finally circa 2% for ongoing inspection over 40 years. The results illustrate that the bulk of the footprint relates to the manufacture of the components with only a fraction required for actual cable laying.

As the footprint is based on a MW per km basis, these actual impacts will be dependent on the length of cable laid, i.e. longer cable distance will require a greater volume of cable and hence materials and construction impact.

Key Issues and Mitigation Measures for Air Quality and Climate

Key Issues	Mitigation Measures
• Localised impacts to air quality with an associated carbon footprint associated with the manufacturing, transport and installation of RES and grid.	• Aim to ensure that the carbon footprint associated with RES and grid development is 'carbon neutral' and preferably 'carbon positive'.

7.9 Material Assets

The main impacts from RES and grid development on material assets across the different maritime uses essentially relates to direct physical impacts such as reduced access, displacement effects and exclusion from opportunity areas. There are also a suite of indirect impacts to material assets which also share interrelationships with other SEA topics and reference is made to other relevant assessment sections as appropriate.

Under all scenarios, the footprint of the existing and proposed wind farms, wave and tidal devices, hubs, and associated infrastructure create a physical constraint to activities. The High Renewables Scenario represents the greatest potential for conflict with existing material assets, given the higher deployment of wind farms and the associated cabling. The Irish and North Seas are heavily constrained from the perspective of the existing physical assets, licensed activity and shipping movements.

In compiling the Impact Dictionary, key sensitivities were identified under the topic of Material Assets; a summary of these are listed in **Table 7.12**.

Table 7.12 - Material Assets: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Material Assets	Cables & Pipelines	• Damage or disturbance to existing cables and pipelines. • Exposure of cables from changing sediment dynamics or disturbance. • Restriction of siting options for other cables and pipelines.
	Fisheries	• Adverse physiological damage from: survey techniques; smothering; changes to sediment types. • Disturbance/ remobilisation of contaminated sediment (aquaculture safety). • Physical loss of shellfish beds. • Induction of scare/ flight response in fish. • Barrier effect to migration routes or to commercially targeted species. • Collision risk/ snagging of fishing gear.

Topic	Environmental Receptor	Key Potential Impacts
		• Exclusion from fishing grounds.
	Shipping	• Changes to/ intensification of traffic flows. • Exclusion from sea lanes/rerouting. • Collision risk and resulting potential for loss of fuel/ oil/ hydraulic fluid etc. • Obstruction from other vessels/ platforms/ rigs etc. • Reduced access to ports/adequate water depths. • Impacts of EMF on positional bearings. • Impacts to navigation channels from sediment redistribution.
	Military Activities & Aviation	• Exclusion from military areas/ rerouting. • Interference of EMF on civil/defence radar (shore and ship-based). • Interference from physical presence on radio systems. • Physical obstacle to aircraft.
	Hydrocarbon Extraction	• Exclusion from resource/ opportunity areas. • Restriction of access to subsea wells.
	Dredging & Aggregate Extraction	• Exclusion from resource/ opportunity areas.
	Marine Disposal	• Restriction of access to disposal sites. • Disturbance to contaminated, hazardous material or munitions sites.
	Carbon Storage	• Exclusion from storage opportunity areas.
	Emergency Services	• Impacts to marine emergency response times from exclusion zones. • Restriction of take-off and landing safety zones. • Physical obstacle to aircraft (e.g. helicopters).

Wind energy source: For wind farms and other renewable resources, surface infrastructure creates a physical barrier to maritime industries, including ship movements. The Irish Sea and the North Sea in particular are some of the most highly trafficked maritime areas in the world. **Figure 7-7** from MarineTraffic gives an indication of this by displaying the shipping density for all types of traffic in these seas for 2016.[147]

[147] MarineTraffic and OpenStreetmap (December 2016)

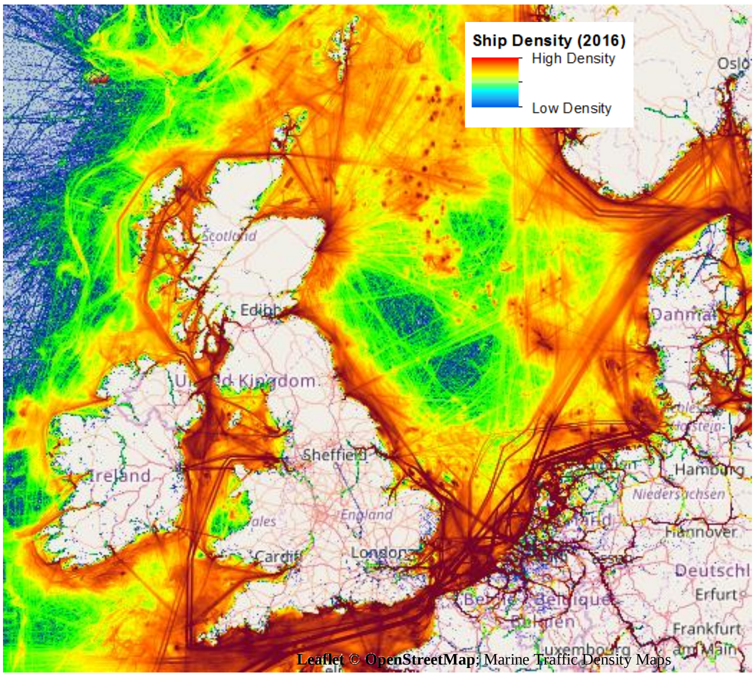

Figure 7-7 - Shipping Density of All Vessels in the Irish and North Seas (2016)

Many wind farms apply a safety exclusion zone within which other users of the sea are restricted or prohibited from entering. As the physical presence of offshore renewables continues to expand, this leads to the need for rerouting of traffic and results in intensified use of existing navigation routes. **Figure 7-8** shows the separation zones which are in effect within the Southern Bight, a particularly busy part of the North Sea. Spatial data on shipping density was only available for the UK and Germany however this figure illustrates the intense shipping activity which is occurring. Under the High Renewables Scenario, **Figure 7-8** shows that existing and proposed wind farms can be accommodated between the major shipping lanes in this area.

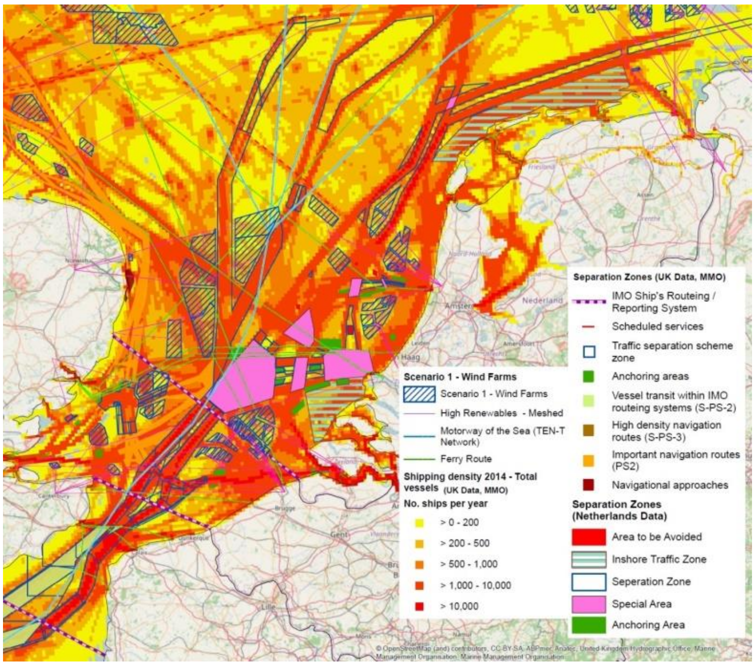

Figure 7-8 - High Renewables Scenario and Separation Zones in the Southern Bight Area

The competition for physical space is one of the most critical issues for the successful delivery of the High Renewables Scenario. Sensitive siting and routing of infrastructure at the plan and project level will be critical. The cumulative impacts on existing and future material assets are likely to be significant when other competing interests are considered, in the North Sea in particular. This includes intensification of shipping lanes, space for recreational areas and commercial fishing. In this regard, consideration of maritime spatial planning for such a physically-constrained area by the target Member States will be key in the delivery of the High Renewables Scenario and associated infrastructure beyond 2030 (see **Recommendation #1** in **Chapter 8**).

As noted in **Section 7.5: Population and Human Health**, estimates of collision risk with RES vary considerably between the various maritime plans from Member States. The SEA of Dutch Coast noted that there were 20 recorded ship-to-ship collisions within wind farm zones in 2008. Collision risk with RES structures themselves is generally based on extrapolations from ship-to-ship collisions.[148]

Across Europe, a total of 9180 marine accidents or incidents were reported over the period 2011-2014 to the European Maritime Safety Agency (EMSA).[149] The majority of these incidents were classified as 'less serious' (59%), while a small proportion was classified as 'very serious' (4%). The number of 'very serious' incidents rose from 81 in 2013 to 99 in 2014, with similar numbers expected for 2015; the total number of ships involved in all incidents was 10440. There is potential for direct impacts to other maritime users from increased collision risk, due to an increased shipping presence in the Irish and North Seas as a result of the need to build offshore RES and install the cabling. The issue of collision risk may be exacerbated if shipping routes are rerouted or intensification occurs in existing sea lanes. For instance between 2011 and 2014 alone there were 164 accidents in the Irish Sea, 240 in the German Bight, 532 in the Southern Bight area and 751 accidents within the English Channel.149

There is also the potential risk of a ship-to-RES collision occurring. Unless there is sufficient clearance for smaller vessels, navigation through wind farms is often prohibited due to the risk of collision with the blades. This risk should be considered given the continued expansion of offshore renewables development and the intensification of shipping or necessary rerouting. At worst, a RES device would damage a ship's hull (potentially leading to losses such as oil or fuel) or a wind turbine rotor and generator weighing several hundred tonnes could dislodge from its foundations and land on the ship. Some types of shipping activity may however be permitted within wind farms. For instance, smaller recreational craft is permitted within the UK's Teesside Wind Farm on the Dogger Bank, where the turbine and row spacing allows leisure craft and fishing boats to pass within.[150]

Environmental risk evaluations which take the impacts of different types of foundations on ship hulls into consideration, have ranked collisions with jacket and tripod constructions as the most severe, while a collision with a monopile may cause less damage to the environment.84 Currently, monopile foundations are the most commonly-used type in the offshore area due to their relative ease of installation in shallow to moderate water depths.[151] In all cases, whilst the risk of hull breach or fuel or cargo loss will impact water quality, physical collision will cause damage to both vessels and RES infrastructure.

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148 RWS Water, Transport and Environment (2014) SEAs of the Rijksstructuurvisie Wind op Zee (WoZ) Netherlands.

149 European Maritime Safety Agency (2015) Annual Overview of Marine Casualties and Incidents 2015.

150 EDF Energy Renewables. Teesside Wind Farm Brochure.

Retrieved: http://www.edf-er.com/Portals/edfrenewables/Documents/OurProjects/Teesside%20Completion%20brochure%20LR.pdf

151 4C Offshore (2016) Monopile Support Structure. Retrieved: http://www.4coffshore.com/windfarms/monopiles-support-structures-aid4.html

Physical presence may not only directly impact fishing and shipping industries, but also cause disruption to, exclusion from or restriction of access to aggregate industries. Shallow water areas and sandbanks may be desirable locations for wind farms but they also represent target areas for material extraction.79 Under the EMODnet Geology Project, offshore areas have been mapped for potential aggregate deposits (sands, gravels etc.) and it is noted that much of the southern North Sea area has significant aggregate potential. It has been identified that aggregate extraction in the UK is concentrated around the southern part of England which is of strategic importance.79

The proposed High Renewables Scenario (including the cable grid) will cross areas of high aggregate potential e.g. the proposed East Anglia Wind Farms. However this scenario does not intersect with existing licenced, optioned or application areas. In addition, the export cables for the Galloper Wind Farm currently under construction avoid the licensed aggregate area. The EIA for the Greater Gabbard Wind Farm notes that impacts to aggregate extraction can arise as a result of the wind farm's presence due to restriction of access to opportunity areas.

However the impact for this wind farm was considered to be small and indirectly positive due to the placement of stabilising foundations and scour protection on the sandbank, potentially protecting extraction areas.[152] Wind farms are unlikely to be built in areas where active materials extraction is taking place, or where there are licensed future exploration option areas.79,[153]

Physical presence can also cause direct medium to long-term impacts as a result of exclusion from or restriction of access to areas for hydrocarbon exploration and exploitation. Taking the Dutch Coast proposed wind farms as an example, the Hollandse Kust H and Kust Noord B Wind Farm zones overlap with active hydrocarbon exploitation lease blocks, which also have active rig/ platform installations and associated pipeline network.

For safety reasons, platforms generally apply a 5 nautical mile (nm) exclusion zone which accommodates helicopter take-off and landing and also allows sufficient space for abort procedures and drop-height in case of aircraft malfunction. These factors can affect the siting of turbines and further, the exclusion zones for existing cables and pipelines needs to be considered. Within the 5nm rig safety zone, flight safety might be compromised, with take-off and landing restricted in certain directions.[154] The SEA of the Dutch Coast considers that as hydrocarbons represent a finite resource, rigs and platforms are likely to be decommissioned in the future and this will facilitate available space for offshore renewables.127

Potential radar interference is only likely to be generated by offshore wind farm developments, as wave and tidal devices generally do not protrude more than a few meters above the water surface. The long vertical profiles of turbine monopoles as well as the blades cause a direct physical barrier to radar and microwave transmissions that can have negative impacts on both civil and military communications. As radio signals require a clear line-of-sight, wind farms can cause masking effects, produce undesirable or false signal returns, and cause scattering of signals (e.g. reflections from turbine blades). In this sense, the physical presence of the wind farm is more relevant in terms of any impact, whereas grid has negligible impact.

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[152] PMSS (2005) Greater Gabbard Offshore Wind Farm Non-Technical Summary.

[153] AECOM Environment, METOC and the CMRC for the Sustainable Energy Authority of Ireland (2010) SEA of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland.

[154] PONDERA Consult for the Ministries of Economy Business and Infrastructure and the Environment (2016) Appendices Hollandse Kust (zuid) Wind Farm Sites I & II. Appendix B: Summary Environmental Impact Assessment Part of Project and Site Description.

In the Belgian part of the North Sea, the EIA for the Northwester 2 Wind Park examined the barrier effects to radar and radio direction finding (RDF).[155] The results outlined that ship-to-ship communication would not be adversely affected by the full deployment of all wind farms within the Belgian part of the North Sea. The report asserts that ship operators are aware of erroneous information appearing on radar as they tend to represent other large objects such as ships. It was noted however that 'dead zones' can occur behind wind turbines but that there is sufficient transparency to not cause an adverse effect. This report also notes that ship-to-ship communication between wind farms is impossible, but considers that the full deployment of wind farms within the Belgian part of the North Sea should not adversely impact very high frequency (VHF) ship communications systems, such as RDF and automatic identification system (AIS). This is due to the presence of secondary shipping routes around wind farms and the attention to ship safety procedures. However it is noted that wind farms located closer to shore can form long-term semi-permanent barriers to communication; examples include the Norther, C-Power and Thornton Bank Wind Farms.

These fall within the active zone of both the Flemish and Dutch radar stations and operating VHF radio stations. Suggested mitigation in the EIA includes monitoring of ship traffic around the seaward side of the wind farm concession areas, and possibly the establishment of an additional radar installation to create better coverage. There are potential cumulative and transboundary impacts to ship and coast-based communications where a series of wind farms are being developed in close proximity or in adjacent EEZs.

As noted previously, the rollout of coordinated maritime spatial planning across the target member States is critical to reduce impacts resulting from barrier effects (see **Recommendation #1** in **Chapter 8**).

For commercial shellfish and fin fisheries, the indirect impacts of increased sedimentation or remobilisation/ disturbance to contaminated sites from setting wind farm foundations/ turbines also becomes relevant in terms of smothering effects (particularly with respect to spawning and nursery grounds) and indirect impacts with population and human health e.g. tainted shellfish or bioaccumulated contaminants in fish/shellfish meant for human consumption. The remobilisation or resettling of contaminated material can be taken in by benthic organisms and bioaccumulate up the food chain. This is discussed in detail in **Section 7.6: Soils, Geology and Sediment**. In addition to the contamination and biological effects, such events can damage fisheries by contaminating fish stocks either making catch unsalable due to low levels of contamination. While the contamination may be below detection levels, it could result in indirect impacts by altering the flavour and reducing market price e.g. shellfish products.

Noise impacts from survey and construction activities (e.g. pile driving, shipping, geotechnical surveys) can cause indirect impacts to biodiversity and fisheries stocks via the displacement of fish species or by causing indirect negative physiological damage to fish, larva and eggs. This is discussed in detail in **Section 7.4: Biodiversity, Flora and Fauna**. The result of such changes on commercial stocks can cause displacement or a reduction in fecundity in the short term affecting fish stocks and catches for fisheries.

The placement of RES foundations and grid cabling with associated rock armouring, results in long-term permanent alteration of the seabed from the introduction of artificial hard substrate to areas which are normally soft-bottomed. This can have indirect negative impacts by allowing colonisation of the area by hard-substrate species and alteration of community structure and predator-prey relationships. The 'artificial reef' effect created by the presence of offshore structures can also attract pelagic fish species to an area.

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[155] IMDC (2014) Environmental Impact Assessment Non-technical Summary of the NV Northwester 2 Wind Park.

For example, Atlantic cod and pouting were found to be strongly attracted to wind farms in the Belgian waters. Studies have also been conducted investigating the possible impacts of RES on fish communities and many have noted increases in species diversity near turbine foundations i.e. the artificial reef effect (see **Appendix D**). This has been previously discussed in detail in **Section 7.4: Biodiversity, Flora and Fauna**. The result can be an indirect positive impact for commercial fisheries by increasing recruitment and stock recovery for commercial fish stocks.

The introduction or spread of invasive or alien species can include flora and faunal species. Some species such as *Didemnum vexillum* (carpet sea squirt) have an indirect negative and potentially long-term impact to infrastructure by causing damage to material assets particularly mariculture, ports and intakes. Other species may out-compete commercial species thus have indirect negative impacts on fisheries by reducing or removing fisheries.

RES infrastructure can directly impact local hydrodynamics; this can indirectly impact both positively and negatively faunal organisms which live on and in the benthic environment as changes to water flows can influence larval recruitment, sedimentation, the availability of food and oxygen, and the removal of waste products. The impacts of this are likely to be localised however impacts to these hydrodynamic parameters can alter the presence or success of shellfish beds in an areas and therefore commercial catches. The impacts of sedimentation are discussed in **Section 7.4: Biodiversity, Flora and Fauna** and in **Section 7.6: Soils, Geology and Sediments**.

The physical presence of RES in the coastal and marine environment can have a long-term localised impact on the natural flow of water movements. Changing flow conditions can affect sediment budgets and redistribute material elsewhere, dependent on grain size and flow velocity. This can cause smothering of benthic habitats and affect sessile filter feeders. These changes to the sediment can also affect habitat suitability for benthic organisms, which can impact on fishing industry (e.g. spawning/nursery grounds, shellfish).

Whilst the climate change impacts of renewables are predominately positive, locally the presence of RES arrays may alter shipping traffic, add to traffic by construction and maintenance or have coastal industry or energy storage emissions. As a result, there may be negative short-term impacts from degradation of air quality in localised areas, or negative impacts from increases in GHG emissions associated with shipping redeployment and intensification of shipping in some routes. **Air Quality and Climatic Factors** are assessed in detail in **Section 7.8**.

Wave and tidal energy source: The impacts to material assets from wave and tidal devices are similar to the wind energy source. The addition of physical infrastructure to the marine environment can have direct negative long-term impacts, which can reduce access, cause displacement effects or exclude other maritime activities. The United Kingdom's Royal Yachting Association (RYA) notes that wave and tidal devices placed within the 12nm limit may negatively impact areas used by leisure craft and recreational boating.[156]

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[156] Royal Yachting Association (September 2015) The RYA's Position On Offshore Renewable Energy Developments: Paper 3 (Of 4) – Tidal Energy.

There is potential for direct negative impacts from collision with wave and tidal devices, however less information is available on the risk of vessel collision. As these devices generally have low profiles on top of or within the water column, there is potential for conflict here. The RYA also states that collision risk with wave and tidal devices can be minimised through appropriate charting and lighting as well as device operators specifying the safety clearance over submerged structures and any associated infrastructure,156 as determined by the Maritime and Coastal Agency's Under Keel Clearance Policy Paper.[157]

Potential interference effects to radar systems are likely to be restricted to wind farms, as wave and tidal devices generally do not protrude more than a few meters above the water surface. However during maintenance activities, tidal stream devices may protrude several metres above water level. Impacts to radar from tidal devices are likely to be localised and temporary in nature. As noted previously, coordinated maritime spatial planning is key to identifying, reducing and mitigating negative impacts from barrier and displacement effects.

Hubs and connectors: The impacts to material assets from hubs and connectors are similar to those for the wind energy source. The impacts will be dependent on the scale of infrastructural development, the footprint and siting considerations with respect to other existing material assets.

Grid: Existing cables physically constrain the placement of other power cables, telecommunication cables and pipelines. Due to the effects of power cables on other infrastructure, there are specific design tolerances placed on the distances between cables laid in parallel to prevent electromagnetic interference. Cables are restricted to crossing other cables at a 90 degree angle and there are restrictions to cables adjacent to pipelines.

As well as the safety issues around interference, cables are also closely regulated to ensure that they can be isolated for any future maintenance without potential damage or interference with other cables which have equal legal precedent under the United Nations Convention on the Law of the Sea (UNCLOS). It is noted that as there is a greater need for more cables to be deployed to connect RES, this increases pressures on other sectors due to the physical footprint required for new cabling, applying appropriate exclusion zones and competition for space with other maritime users of the sea.112 Currently, there is no one commonly-accepted approach to the siting of cables and reducing the negative potential long-term impacts to existing cables i.e. the avoidance of interference or causing transmission losses.

The laying and burial of cables on the seafloor can have indirect impacts by disturbing historically contaminated sediment, or dredge spoil piles. However the meshed High Renewables Scenario has the ability to intersect fewer sites, 34 in total, due to its reduced footprint. As noted previously, the remobilisation or resettling of contaminated material can result in indirect negative impacts to benthic organisms through bioaccumulation up the food chain. This is discussed in detail in **Section 7.6: Soils, Geology and Sediment**.

Figure 7-9 illustrates the existing density of cabling within the southern North Sea, and the future cabling which would be required under the High Renewables Scenario. Due to the structure of the meshed scenario there is less cabling required and as such a reduced opportunity to conflict with existing cables. The High Renewables meshed scenario demonstrates that 174 existing cables would be intersected. In addition, the meshed scenario will be required to traverse major shipping lanes and there is potential for direct negative, short-term temporary impacts to existing ship movements and the requirements for ships to install/maintain future cabling.

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[157] Maritime and Coastguard Agency (May 2014) Under Keel Clearance – Policy Paper Guidance To Developers in Assessing Minimum Water Depth over Tidal Devices.

Due to the reduced length of cable required under the meshed scenario there would be a lower level of disruption in this regard.

Electromagnetic (EMF) effects arising from cabling may affect the distribution of elasmobranch species. These may cause negative behavioural impacts by causing displacement or attraction effects which have the potential to affect predator-prey relationships and the distribution of fish species, causing potential impacts to related commercial and sport fish industries. The uncertainties surrounding the biological effects of EMF on marine animals are discussed in **Section 7.4: Biodiversity, Flora and Fauna**. Much of the literature focuses on the environmental impacts of subsea cables but there is less information on good siting or proximity guidance on the impacts to existing cables as a material asset.

Some guidance does exist in relation to siting of cables and proximity to wind farms, e.g. the United Kingdom Crown Estate's guidance document on 'Submarine cables and offshore renewable energy installations'[158] and the Subsea Cables UK guidelines on proximity of offshore installations and subsea cables.[159]

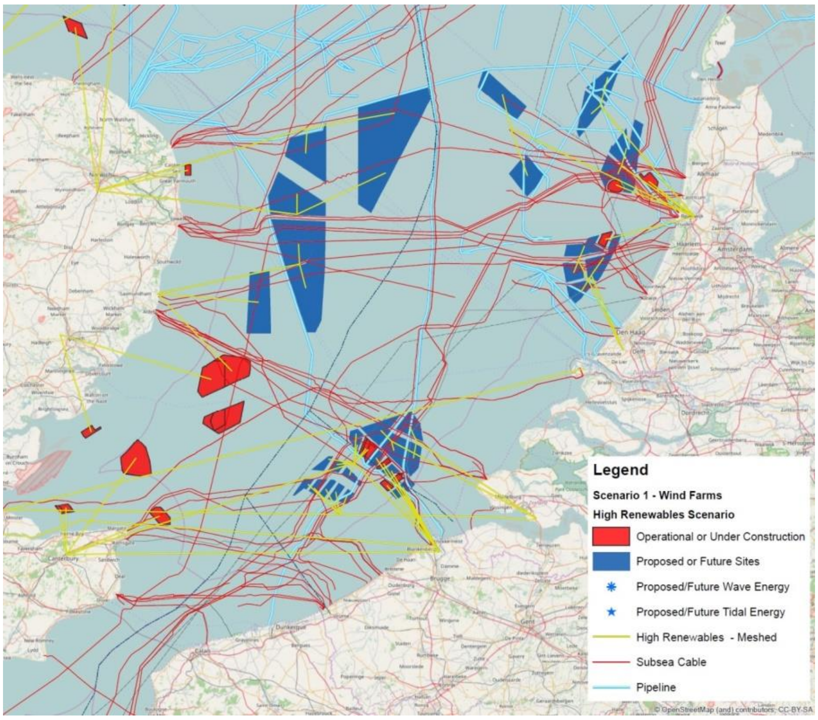

Figure 7-9 - Meshed Solution Intersecting Existing Cables and Pipelines

The International Cable Protection Committee (ICPC) has general guidance regarding cable routing, proximity and crossing of existing infrastructure. With respect to offshore wind energy development (also applying to nearshore wave and tidal devices), the ICPC recommends that existing cables in shallower waters (up to a depth of 75m) be given a default 500m exclusion zone on either side, to allow for cable fault location.[160] The actual distance will vary between Member States.

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[158] Red Penguin Associates Ltd. for the Crown Estate, United Kingdom Government (2012) Submarine Cables and Offshore Renewable Energy Installations - Proximity Study Report.

[159] Renewables Sub-Group of Subsea Cables United Kingdom (Subsea Cables UK, Renewable Energy Association, RenewableUK and the Crown Estate) (2012) Subsea Cables United Kingdom Guideline No 6: The Proximity of Offshore Renewable Energy Installations & Submarine Cable Infrastructure in United Kingdom Waters.

[160] Working Group 8 Submarine Cable Routing and Landing for the Communications Security, Reliability and Interoperability Council IV (December 2014) Protection of Submarine Cables Through Spatial Separation - Final Report.

For instance in the UK, the Marine Management Organisation recommends a 250m exclusion zone either side of existing cables[161], and in Denmark 200m either side is recommended[162], with activities such as dredging and anchoring forbidden.

The interactions of existing cables and pipelines with the need for increased deployment of cabling under the High Renewables Scenario, means siting and crossing considerations are important in terms of cumulative negative EMF impacts and avoiding disturbance to existing linear infrastructure. For instance, multiple sources of EMF in proximity can cause interference to the transmitted signal in a cable.

The level and significance of this impact depends on a number of factors including the distance to other cables and the design specification of the cable(s), such as the level of shielding. With circa of 8000km of cabling required for a High Renewables meshed grid, this represents considerable competition for seafloor space but does present a better option when compared to a radial approach with would require 12000km of cabling.

Subsea infrastructure is also a constraint to other activities and cables in particular interact with the fishing and aggregates industry. Fisheries guidance charts exclude fishing, anchoring and other activities in the vicinity of cables due to the potential for negative impacts due to cable snagging from anchors or bottom-trawl gear, or damage from coastal vessel traffic.112 As such cables form a linear barrier to these activities. Cables may be buried within sediment, armoured to provide additional protection or laid directly on the seabed. Maritime activities, such as fishing that interacts with the benthic environment, are generally constrained where cables occur.

Figure 7-10 displays the ICES bottom trawl survey data for 2015 which gives an indication of fishing activity across the North Sea (recent data for the Irish Sea not yet fully available). It can be seen that commercial fishing takes place throughout the study area. The footprints of wind farms zones under the High Renewables Scenario intersect some high intensity areas for fishing in terms of number of hauls, e.g. around the Southern Bight area and the Firth of Forth, representing potential for adverse impacts. The dark dots represent the spawning and nursery ground for various fish species. The concentration of spawning and nursery grounds are highest in the northern part of the Irish Sea and around the western parts of Scotland, but the data indicates all parts of the study area are important grounds for the lifecycle of a number of fish species.

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[161] United Kingdom Marine Management Organization (August 2013) Strategic Scoping Report for Marine Planning in England.

[162] Order on Protection of Submarine Cables and Pipelines (The Order on Cables), No. 939, arts. 1-4 (November 27, 1992).

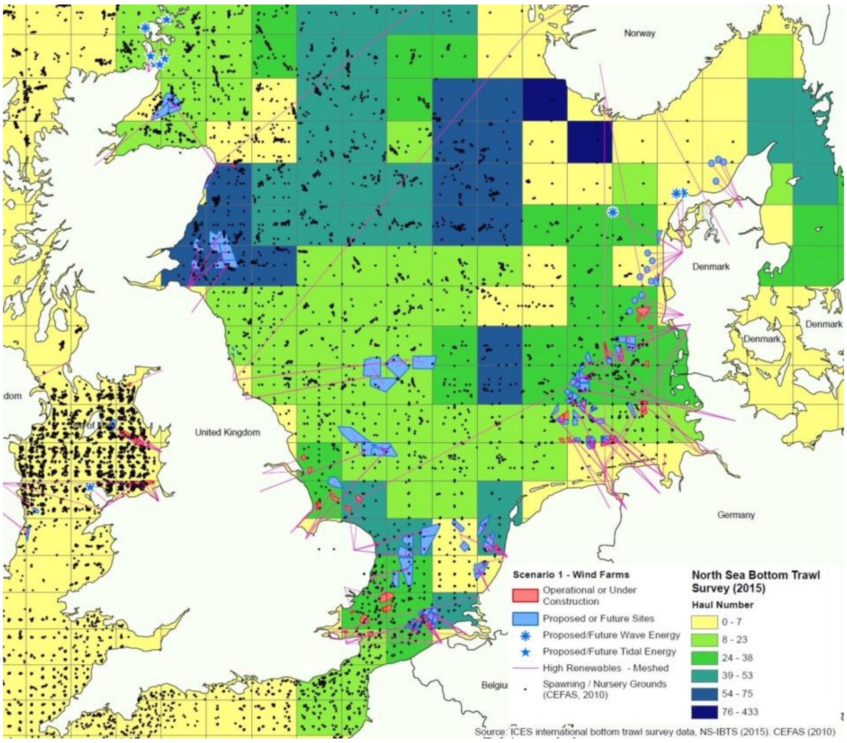

Figure 7-10 - North Sea Bottom Trawl Survey (2015) and Spawning/Nursey Grounds (2010)

Landfall: Impacts are only likely to occur at landfall where grid cables come onshore to connect to the terrestrial system. Site selection assessment for any infrastructure (converter stations etc.) would be appropriately applied at the project stage (see **Recommendation #5** in **Chapter 8**).

Key Issues and Mitigation Measures for Material Assets

Table 7.13 - Summary of Key Issues for Material Assets

Key Issues	Mitigation Measures
• Potential for exclusion from opportunity or resource areas.	• The presence of RES and/or grid may not necessarily preclude usage of an area, and will depend on best practice in different jurisdictions, the extent of safety/ exclusion zones and what types of activity are permitted in certain circumstances etc.

7.10 Cultural Heritage

Coastal areas and maritime regions have, over thousands of years been important for human habitation and they have developed a rich and diverse history based on their role as: a source of natural resources such as water, food, transport links; commercial centres, social outlets, a religious focus and a venue for recreational opportunities. Examples of coastal and maritime heritage includes settlements, submerged landscapes, shipwrecks and underwater artefacts, harbours, dams, light houses, industrial heritage associated with the fishing and marine industry, boat builders, etc.

While coastal heritage is well documented, underwater heritage is less well characterised. **Table 7.14** lists the key potential impacts from an offshore RES and grid with regard to Cultural Heritage.

Table 7.14 - Cultural Heritage: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Cultural Heritage	Coastal & Submerged Heritage Features	• Disturbance, damage or destruction of submerged landscapes/ features. • Visual impact to perceived historical setting. • Disturbance, damage or destruction of coastal heritage features.

The main impacts to cultural heritage involve disturbance to, or the physical destruction of, known or previously unknown underwater archaeological features during construction of new structures, infrastructure upgrades or the laying of cables. Impacts may also arise in the terrestrial space where as a result of landfall and connection to the terrestrial grid. The High Renewables Scenario therefore represents the greatest conflict as this scenario has the largest footprint and thus has the potential to affect a larger proportion of submerged heritage features. Detection and avoidance of submerged heritage is related to the age of the feature, e.g. more recent metal structures are more easily detected, more likely to have remained intact and therefore less likely to be damaged compared to older structures made of less durable material (e.g. wood, canvas).

Submerged prehistoric settlements are likely to consist of scattered artefacts or structures buried under sediment. Buried structures are harder to identify and as such there is greater potential for disturbance or destruction of these features. The presence of vessels during survey, installation, maintenance and decommissioning would only have temporary and localised effects on a cultural heritage setting.

Wind energy source: This element of the infrastructure is located mainly in offshore locations and as such there is potential for direct and indirect negative impacts with underwater heritage features such as shipwrecks, aircraft losses, submarines losses or remains of ancient settlements from submerged land bridges. These impacts are related to sediment disturbance from construction and also placement of wind turbine footprints on heritage features or material. Many of the proposed wind farm footprints under the High Renewables Scenario cover recorded wreck sites and as such have potential for direct negative impacts through loss or damage to the features. **Figure 7-11** illustrates that there are 38 known wrecks which occur within the footprints of four proposed wind farms under the High Renewables Scenario, referred to as Hollandse Kust Zuid I, II, III and IV. These wrecks are also located within 60km of the Dutch coast.

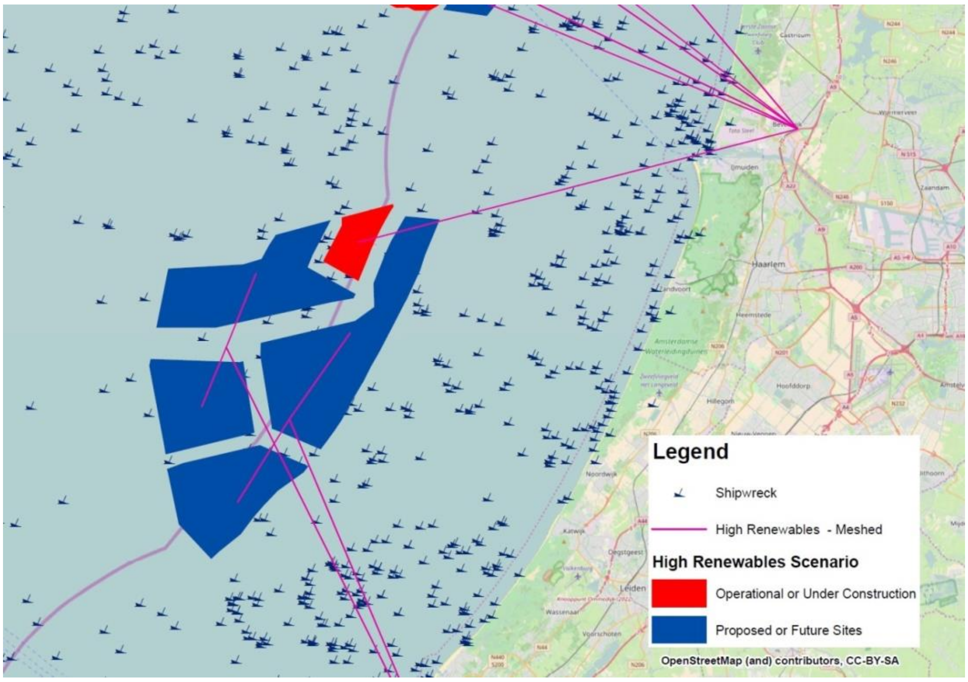

Figure 7-11 - Known Shipwrecks within the Proposed Dutch Hollandse Kust Zuid Wind Farms

In comparison to the Dutch example, the UK's Hornsea Project One, Two and Three wind farms are located much further offshore, approximately 138km from the English coast and have no recorded shipwrecks within their footprints. However, the absence of spatial data for an area however does not necessarily preclude any features from being present, as the nearshore environment by its nature is better understood than deep water sites. For example, the HMS Sealion wreck is located on the Dogger Bank, approximately 330km from the English coast, with the proposed Teesside B Wind Farm located 7km to the south of the site (see **Figure 7-12**).

Geophysical or geotechnical surveys may be undertaken prior to the siting of foundations for wind turbines. This may involve the use of passive geosurveying techniques only or may require the collection of sediment samples or rock cores in areas where the seafloor is not well-characterised or poorly-understood. There is likely to be a short-term negligible impact during the survey phase if only passive techniques are used however potential impacts may arise if archaeological features are damaged during the collection of grab samples. Alternatively, this process may have indirect positive impacts if sampling results in the discovery of previously unknown archaeological features and thus adds to the understanding of the site. As best practice, during survey operations any core or grab samples should be inspected for archaeological material.

The presence of wrecks and other archaeological features does not necessarily preclude the development of offshore wind energy. For known archaeological sites, avoidance should obviously be the first consideration but where this is not possible or where unknown features are encountered, the issue can be resolved through the application of mitigation such as use of exclusion zones and/ or recording of features.

As discussed in the soils, geology and sediment section, long-term changes to sediments can lead to scouring of the sea floor and changes in sedimentation. This has the potential for long-term negative impacts even in instances where features have been avoided in the first instance. A buffer zone is therefore an important consideration for heritage features and should be developed on a site by site basis by a suitably qualified specialist.

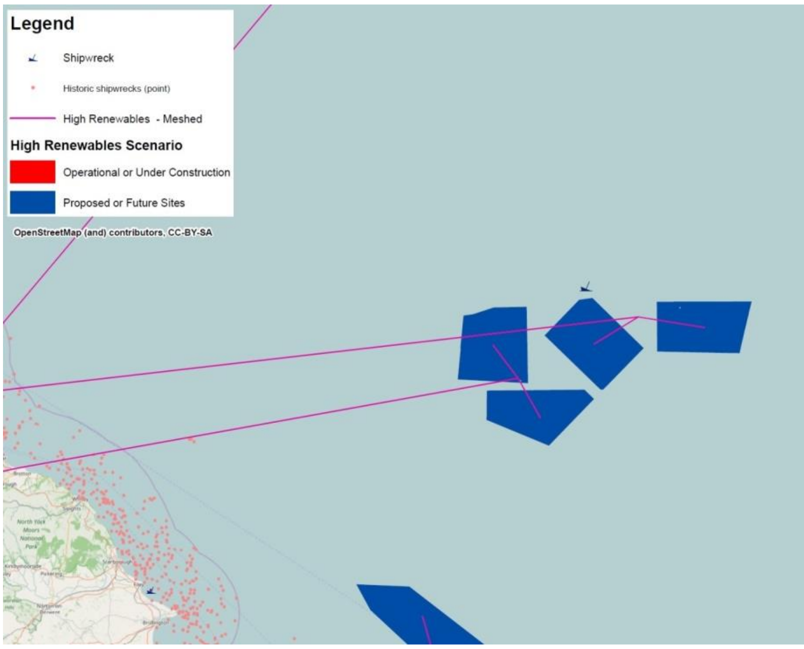

Figure 7-12 - Known Shipwrecks Near the Proposed UK Dogger Bank Wind Farms

The cumulative impact of multiple windfarms and other marine activities is also an important consideration. An obvious example is the Doggerbank Teeside A and B and the Doggerbank Creyke Beck A and B windfarms. These windfarms are all located in the shallower waters of the Dogger Bank. All have been the subject of a planning process in the United Kingdom and as part of this process consideration has been given to the archaeological resource through all phases of development and appropriate mitigation such as, the use of Archaeological Exclusion Zones has been applied. It is noted in the Creyke Beck Environmental Statement that cumulative impact assessment has also been carried out with reference to such texts as Guidance for Assessment of Cumulative Impacts on the Historic Environment.[163]

Wave and tidal energy source: Wave energy devices are generally located in the nearshore/ inshore environment and therefore there is potential for direct and indirect negative impacts with heritage features that are situated closer to the coastline. Under the High Renewables Scenario, wave and tidal devices are predicted in a cluster off the northeast coast of Scotland and individual or smaller localised groupings including off the Danish coast. The majority of recorded wrecks around Ireland and Scotland are in the nearshore environment in water depths of less than 50m. There are a significant number of features associated with wartime activity in the North Sea, particularly World War II.

Historic England, UK has reported that during World War II hundreds of aircraft were abandoned or crash-landed on or near coastlines along the English Channel and the North Sea and this is likely to be the case for the other Member States within the study area.

Wave energy devices may also alter local hydrodynamics which has implications for deeper burial from altered sedimentation rates or via disturbance from altered wave and tidal heights. Tidal barrages require the construction of an impoundment wall which can cause significant changes to coastal sediment budgets and sedimentation rates. This would have implications for coastal heritage features, and indirect negative impacts could include the burial of features, or conversely changes to sedimentation and deposition may help to uncover previously buried sites.

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[163] COWRIE (2008). Guidance for Assessment of Cumulative Impacts on the Historic Environment from Offshore Renewable Energy.

The Irish Offshore Renewable Energy Development Plan surmises that most disturbed sediments are unlikely to cause damage to all but the most fragile materials but damage can occur when larger fragments are shifted.

The Orkney World Heritage Site off the coast of north-east Scotland is a cultural site designated for Neolithic settlements. This UNESCO listed site also casts the surrounding landscape character as essential to the overall heritage value of this site. The proposed Brough Head wave device is located immediately adjacent to this site (see **Section 7.5: Population and Human Health**). This sensitivity of the site includes surrounding landscape character, submerged landscapes in the vicinity of the Bay of Skaill and a number of wrecks including the HMS Hampshire which is a designated war grave. The planning process for the wave farm has included scoping of such issues in order to ensure early resolution through macro/ micro siting and application of appropriate mitigation. As with windfarms, cumulative assessment is essential at the project level and it is noted that the Scottish Government has developed supporting information for developers, identifying key projects which should be taken into account for the Pentland Firth and Orkney Waters.

Grid: As the seafloor needs to be prepared for the laying of cables, seabed preparation can have a direct negative impact on cultural heritage via damage or destruction of features during trenching of the seafloor. However, impacts are likely to be localised given the relatively small cross-sectional area of cabling compared to its overall length. The pre-historic submarine archaeology of the Irish and North Sea is largely unknown and there are likely to be areas which have potential for submerged and partially submerged landscapes which were historically dry land as a result of relative sea-level changes.

Hubs and connectors: As for offshore wind and grid development, the impacts from hubs to cultural heritage are similar and are related primarily to disturbance or destruction of heritage feature from site preparation and the footprint of the hub on the seafloor. Hubs, like offshore wind farms, are generally located a considerable distance offshore and therefore should have more limited effect on cultural heritage.

Landfall: The heritage resource along coastlines is varied and often includes military, religious and settlement related features. Examples in the study area for the High Renewables Scenario include promontory forts and defensive structures, tombs, burial grounds, pilgrimage routes and lighthouses. The main impacts to consider at landfall relate to: direct negative impacts from physical disturbance of the heritage resource both known and unknown; and indirect negative impacts from visual intrusion on the historical setting. Underground cables in particular have potential to impact on physical features, while overhead lines have greater potential to impact on the visual setting. These impacts can be addressed through sensitive siting at the project stage however it is acknowledged that a meshed grid would result in fewer landfall points compared to a radial grid solution.

The undertaking of appropriate site investigations and surveys in sufficient time prior to planning and or site preparation and cable-laying activities will avoid and reduce the risk of disturbance in the first instance. Engagement with heritage regulators is essential to the proper resolution of these features.

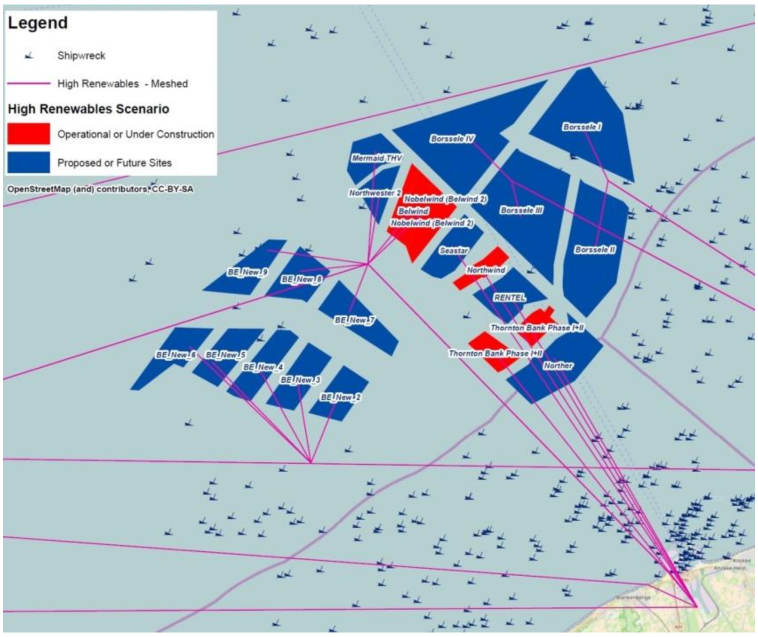

Figure 7-13 - Meshed Solution for Belgian Wind Farms

Key Issues and Mitigation Measures for Cultural Heritage

Table 7.15 - Summary of Key Issues for Cultural Heritage

Key Issues	Mitigation Measures
• Impacts on cultural heritage features which have yet to be discovered. • The positional accuracy of subsea heritage can vary depending on the survey date (e.g. older GPS coordinates are less reliable).	• Avoid known heritage features by a suitable distance. • Allow sufficient time to resolve conflicts with cultural heritage, either through avoidance or proper investigation and recording of features for the historical record. • Report new heritage features as discovered during RES and grid development.

7.11 Landscape and Seascape

Landscape and seascape are strongly inter-related with population settlement natural and cultural heritage. The quality of the coastal environment is a key draw for visitors and is often a factor in selecting an area in which to live and work. There are a number of recreational and tourism activities which could be considered important from a population perspective including: walking, hiking and cycling; sea and shoreline angling; sailing; kayaking and canoeing; diving; bird watching and wildlife tours. Many tourists also visit areas which are designated for protection as a result of their natural heritage characteristics. The variations in the rugged coastline and the numerous sandy beaches throughout the study area provide opportunities for numerous recreation activities and general enjoyment. **Table 7.16** lists the potential impacts from RES and grid infrastructure with regard to Landscape and Seascape.

Table 7.16 - Landscape and Seascape: Impact Dictionary Key Sensitivities

Topic	Environmental Receptor	Key Potential Impacts
Landscape & Seascape	Landfall	• Physical disturbance to or loss of terrestrial landscape. • Visual intrusion from physical presence.
	Landscape & Seascape Character	• Negative perception of character. • Physical loss, fragmentation or modification of landscape character/ coastal features. • Visual intrusion from: safety/lighting features; silhouetting/flicker; obstructed views.

Wind energy source: Wind turbines and wind farms have the potential for direct negative long term impacts on the landscape. In the context of the High Renewables Scenario, this type of development is predominantly located far offshore, therefore the significance of the visual impacts in terms of visual intrusion are limited.

Conflicts with landscape and seascape character generally occur when the infrastructure is located closer to the coast or where it falls within the viewshed, or where the geographic area which is visible from any given location. Wind turbines have a long vertical profile in addition to the length of the turbine blade which can be visually intrusive. Other factors are also of relevance in determining the impact to landscape and seascape including the vantage point and height from which an installation is observed, as well as the colour, number and height of any installation. When viewed from the shoreline at an average head height of 1.8m above ground, the horizon appears approximately 5km away, and therefore any installations situated further than this distance from the coast are potentially less visible.126 However, seascapes of high amenity value are often associated with geological features such as sea cliffs or mountains and it must be acknowledged that at a 200m height the horizon can appear to be over 50km away. Overall, the visual impacts decrease the further offshore infrastructure is sited.

Other visual effects can include silhouetting, where the structure appears dark against a pale background, or flicker effects where light reflects off the structure and can be perceived as a nuisance. These are intermittent day-time effects but depending on the location of the turbines and the requirements of site-specific guidance, lighting may be required on the turbine nacelles for safety purposes, which can also prove to be a permanent long-term visual intrusion particularly at night. Depending on the size of the wind farm, an array of turbines can also cause obstructed views of other aspects of the landscape leading to indirect long-term negative impacts in the wider environment. Under the High Renewables Scenario, the majority of the existing and proposed wind farms are in general located beyond 16km from the coastline. Within the Belgian EEZ the scenario identifies zones for wind farms approximately 25km from the coast; and in the German EEZ, the zones are located at a minimum of between approximately 40km and 60km from the coastline. This reduces the potential direct impacts on communities and other stakeholders using the inshore and coastal areas.

Wave and tidal energy source: The nature of wave and tidal devices delivered under the High Renewables Scenario is a significant factor in reducing the potential for negative impacts which include visual intrusion and obstruction. There is an evidence base from existing sites such as the Strangford Lough SeaGen Tidal Demonstration sites which demonstrate how this technology can be positioned in a sensitive area.

In the SeaGen example, devices are located within the Strangford and Lecale Area of Outstanding Natural Beauty, as well as being located in close proximity to internationally-designated IUCN Category V Protected Marine Landscapes (designated nature reserves) along the Strangford strait; see **Figure 7-14**. As the tidal demonstration devices are completely submerged, there is no visual impact to the surrounding landscape and seascape setting. There will however be temporary short-term visual impacts associated with surfacing the devices for periodic repair and maintenance.

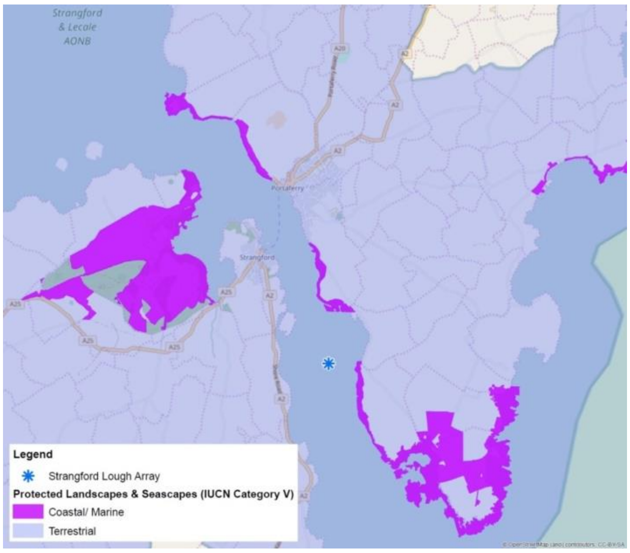

Figure 7-14 - Strangford Lough Wave Energy Devices within Designated Landscapes

Grid: Subsea cables do not represent visible features and have a low to negligible impact on landscape and seascape character. There are short-term temporary negative impacts associated with the presence of vessels during installation and as such a meshed scenario would facilitate a reduced impact due to the requirement for a lower quantity of cabling.

Hubs and connectors: The impacts regarding hubs and connectors are similar to the impacts related to the offshore wind and grid. As hubs are generally located far offshore in deeper water and close to the sources of energy generation, the impacts on landscape and seascape as a result of installing and removal of any infrastructure are considered likely to be limited owing to the temporary short-term duration of activities, the smaller scale of the infrastructure and greater distance from more sensitive coastal receptors.

The Wadden Sea, which stretches from the Netherlands up the Danish coast, is covered by multiple nature and landscape designations including National Park status (e.g. Schleswig-Holstein Wattenmeer, Germany), biosphere reserves (Netherlands) and as UNESCO World Heritage Site. As a result of the density of designations, alternative methods have been used to reduce the need for direct crossing of this sensitive area. For example, the export cables for the BARD Offshore 1 and Gode Wind 1 and 2 Wind Farms first make landfall on the Frisian Islands and then traverse the Wadden Sea via subterranean bores.

Landfall: The landfall of grid infrastructure can result in direct long-term negative impacts on visual receptors and on the wider landscape depending on the nature of the onshore grid infrastructure e.g. overhead line or underground cable, converter stations connections to existing transmission/distribution powerlines. Impacts include direct loss of landscape character features e.g. hedgerows, and visual intrusion on residential and other properties.

Where offshore cables make landfall, there will be localised and temporary effects to receptors (principally populations) during the construction/installation phase from the presence of construction machinery on the terrestrial side and from installation ships in the nearshore area associated with cofferdams or directional-drilling operations. Sensitive landscapes and areas of high amenity value should be avoided in the first instance through appropriate routing and siting considerations. Where this is not possible or where proposed landfall occurs within designated sites, consideration should be given to reducing the impacts as much as possible, particularly avoiding those aspects of the landscape for which it is designated.

Cumulative impacts on landscape are particularly important in the context of the High Renewable Scenario. The 76.6 GW of renewable power will significantly change the seascape of the North Sea in particular and further development is likely in this renewables sector in order to fulfil 2050 targets and beyond.

Key Issues and Mitigation Measures for Landscape and Seascape

Table 7.17 - Summary of Key Issues for Landscape and Seascape

Key Issues	Mitigation Measures
• None / limited impact to landscape if wind farms are situated beyond the visible horizon. • The visual impact from turbine nacelle lighting or other safety/navigational features are uncertain.	• Avoid highly sensitive landscape and seascape designations in the first instance. • Apply sensitive siting principles such that infrastructure does not fragment the landscape, fills a bay/ lough/ narrow, or otherwise provides an unreasonable obstruction to views.

7.12 Conclusion

This chapter has provided an assessment of the potential environmental effects arising from the deployment of the High Renewables Scenario, under a meshed grid solution.

There are obvious benefits to the delivery of the High Renewables Scenario, not least the reduced reliance on fossil fuels and improved air quality as discussed in **Section 7.8**. However there is no doubt that a high level of offshore renewables deployment, combining multiple sources, as envisaged under the High Renewables Scenario has the potential to impact on the wider environment across a range of receptors.

Much of the impact from the offshore elements relate to biodiversity through direct conflict (e.g. collisions, loss of habitat, smothering etc.) or indirect impacts (increased effort required for feeding, avoidance behaviour etc.). Closer to shore, the biodiversity impacts are compounded by impacts to people as they occupy the inshore and coastal areas to a much greater extent be it as resident or visitors.

The impact assessment has identified as far as possible the key issues of concern, and where appropriate has included mitigation measures. It should be noted that the Regional Concept is inherently flexible in nature and much of the potential impact associated with the High Renewables Scenario can be mitigated by sensitive siting and better understanding of the complexities of the receiving environment.

The grid solution in particular is open to sensitive routing to avoid many of the sub-sea issues such as shipwrecks and sensitive biodiversity, and a meshed approach offers greater opportunities to limit impacts across the wider area. Its use as a localised solution offers a definite mitigation to avoid destruction and/ or disturbance to many of the environmental receptors identified in this chapter.

8 RECOMMENDATIONS

8.1 Introduction

In developing the Baseline Environmental Study a number of key issues were identified by the study team and also through stakeholder consultation. These issues relate to both practical issues of implementation of a Regional Concept such as coordination and governance, and strategic considerations of a regional scale such as overall data management and guidelines. The recommendations presented are intended to be building blocks toward creating a backdrop where coordination is facilitated across Member States through a common context for renewable energy sources (RES) and its grid.

The recommendations are also intended to inspire policymakers and other stakeholders to drive and influence policy where protection of the environment is a fundamental starting point. It is anticipated that, in the first instance, the recommendations presented in this report will assist the Support Groups which have been established as part of the implementation of the political declaration on energy cooperation between the North Seas Countries, signed in 2016.

The recommendations provided in this chapter reflect progress towards an integrated meshed grid scenario, in line with the impact assessment findings in **Chapter 7**.

8.2 Recommendations

Recommendation #1: Planning Framework

In order to provide comfort to developers and regulators on how the infrastructure is to be managed, a planning framework is required. This ensures that greater certainty can be applied to resources, programmes etc. in a clear phased approach which emphasises local opportunities as well as regional opportunities for cooperation and coordination. The development of a planning structure or framework will facilitate the identification of ownership and responsibility issues within the Irish and North Sea thus laying a pathway to future infrastructural implementation.

Therefore it is recommended that phased Regional Implementation Plans be developed, which have regard to a Regional Concept and the findings of this Baseline Environmental Study. The plans will outline policies and objectives for the implementation of offshore RES, grid cabling and associated equipment including hubs. Such plans will take a clear step toward identifying a realistic, phased delivery of key projects where coordination can and should be applied, based on agreement among the relevant Member States. This includes having regard to the objectives of the Maritime Spatial Planning Directive (MSPD) and the benefits marine planning can bring, including: reduced conflict; encouragement of investment; increased cross-border cooperation and protection of the environment.

The plans should focus in the initial phase on key projects with greater certainty (some may already be underway) and those with specific strategic effect i.e. key hubs. Future phases within the plans, should be rolled out as the level of certainty on delivery increases over time. The Directive 2001/42/EC puts responsibility for performing SEAs with the Member State. The directive gives indications for how international impacts can be handled via information and consultation. In order to facilitate orderly planning, and come to a Regional Plan, it is recommended that Member States agree on an additional process to coordinate and integrate their SEAs. Consideration should be given to identifying a lead Member State for each phase to initiate a formal SEA procedure under Directive 2001/42/EC, which includes at the initial stage, SEA Screening in accordance with Articles 2 and 3(2) of the directive. This lead Member State ensures all national SEAs remain coordinated in methodology and process.

As there is no formal system for the identification of a lead Member State, this step will require discussions between the relevant countries in order to establish leads for each of the plans. This additional process layer is a voluntary process not yet addressed in the directive. It is however a voluntary action which would meet the goals as taken up in the North Sea Political Declaration of June 2016 for WG1, which includes "*coordinating the planning and development of offshore wind and grid projects beyond national borders including area mapping; and developing a common environmental assessment framework*". The WG1 could as such be the forum to guide this Regional Plan preparation and development.

Recommendation #2: Coordinated Infrastructure Roll-Out

The North Sea is an intensively used area with many competing interests and as such there is limited space available to deliver on RES, particularly in the context of the High Renewables scenario presented in the Regional Concept. Improved spatial planning, including better coordination, is required in order to optimise resources and minimise conflict between users.

To adequately support the existing coordination initiatives, both EU and Member State regulatory approaches must encourage opportunities for synergies in connecting renewable energy infrastructure and grid infrastructure. Given that the full capacity of a hub may not be realised for many years and inhibits higher costs and risks, private developers will not take the initiative for such significant investment and continue to try to deliver individual radial solutions. Consideration should therefore be given to support or possibly mandate a developer (TSO or based on competitive bids) to put in place key hub points up front so that any investor would only be required to invest in the connection to the hub. Such a hub approach is already implemented in the Netherlands, Germany and Belgium, though still from a national perspective with the hubs being directly connected to shore. No hubs are planned yet based on Regional Planning with wind farms for different countries tying in, nor are these hubs planned from the perspective of linking to interconnectors where it would lower societal costs. A regional view could find the appropriate phased solutions of hubs. Combined with national and regional commitments for an offshore roll-out, investor confidence can be given for financing this infrastructure to avoid stranded costs. It remains a political discussion with need for more economic analysis on how such infrastructure funding should be leveraged via public support, and who would be the most appropriate party to develop this connection infrastructure. Key strategic hubs could be developed within the first phase of one of the Regional Implementation Plans as previously recommended.

It must be acknowledged that coordination has to include detailed discussions with Transmission System Operators (TSOs), government and industry in order to reduce the risk of stranded assets into the future. TSOs and governments have to align with regard to site preparation, support/ auctioning systems and any planning timeline.

Recommendation #3: Management Framework to Minimise Environmental Impacts

It has been identified through the consultation for this Baseline Environmental Report and existing studies on offshore renewables and grid development that there is potential for significant effects (both positive and negative) on the wider environment. In order to continue to protect the environment, compliance with existing frameworks or the development of new frameworks is required.

It is recognised in Recommendation #1, that formal SEA under Directive 2001/42/EC should be considered for multi-phased roll out of Regional Implementation Plans. A lead Member State should be identified for each of the plans phases, to advocate for the plan and coordinate the regional actions in implementing 2001/42/EC, including transboundary consultation and stakeholder engagement. This model already exists with projects such as ISLES II, which saw a joint SEA carried out between Ireland, Northern Ireland and Scotland. In this case, the government of Scotland acted as the lead authority.

It is recommended that following SEA, an Environmental Management System (EMS) type approach should be considered for projects arising from the plans. An EMS will facilitate the development of processes and practices which allow the coordinating Member States to reduce environmental impacts. Key elements of such an EMS would be to develop agreed templates for Environmental Management Plans, Environmental Impact Assessments, Monitoring and Mitigation Plans and Stakeholder Engagement Plans which identify the agreed acceptable standards (note this should not necessarily be a minimum acceptable standard but rather an agreed acceptable standard for participating Member States). It is acknowledged and accepted that Member States may have specific local requirements reflecting their specific environmental sensitivities and these can and should be accommodated beyond any agreed standard template.

Recommendation #4: Data Management and Storage

One of the most significant challenges for the development of the Baseline Environmental Study has been the identification and compilation of data across Member States. This is of particular concern in relation to opportunities for coordination or cooperation of an energy system as developers and regulators may have to work across more than one jurisdiction. From experiences associated with this study, data is fragmented across multiple organisations within each Member State with limited support systems to assist developers or regulators in accessing the appropriate data. This diffusion of information has significant repercussions for the delivery of joint projects in the Irish and North Seas. Networks such as EMODnet have recognised data limitations in the marine environment and have taken steps to address the issue at an EU level through the development of a web portal to make available to public and private users '*quality assured, standardised and harmonised marine data'*.

A further issue in relation to data management is that data is often held in a number of formats and not all are available to public and private users to inform project or plan level assessment. There are ongoing activities which will alleviate this to a certain extent, namely the practical implementation across Member States of, the Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD) and the requirements of the INSPIRE Directive. It is recognised that the current and future activities from the MSFD and MSPD are more related to a data repository while INSPIRE acts to create an EU spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment and as such their focus is somewhat different[164].
However these parallel frameworks can nonetheless contribute to the alignment of data held at regional level.

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[164] http://inspire.ec.europa.eu/about-inspire

To address the data management issues in the short to medium term, before the abovementioned frameworks are fully in place, the BEAGINS study has developed a searchable Data Catalogue which identifies both the scope and source of spatial datasets under defined environmental topic headings. The intention is that this tool will assist Member States in the planning and rollout of coordinated RES as they move through planning. In order to maximise the access to this tool and make it as user-friendly as possible, it is intended that this Data Catalogue will be made available through an online web portal. Discussions are currently ongoing with a number of host sites.

In order to be a practical tool going forward, the metadata files associated with the Data Catalogue must be maintained at the Member State level. This dynamic maintenance requires a fully resourced and robust maintenance programme (recurring) to ensure that the spatial datasets are kept up to date and the catalogue remains current. As such, it is recommended that a resource from each Member State should be identified to periodically update links and other necessary attributes to support the dedicated web portal.

Alongside the future maintenance of the Data Catalogue, it is anticipated that new data will become available over time and this should be added as appropriate by each Member State representative. To be of most use and to integrate with the existing data, all new data should align to the following criteria:

- For consistency in the language across Member States, it is recommended that in addition to the language of the Member State, the metadata files are also provided in English to facilitate easier access to the datasets.
- To ensure homogeneous spatial referencing, it is recommended that the coordinate reference system recommended by the Coordinate Reference Systems for Europe be utilised. (http://www.crs-geo.eu). Note, the pan-European CRS are based on and redirect to the definition in the EPSG Geodetic Parameter Registry (http/www.epsg-registry.org/).
- It is recommended that metadata files should be developed in line with the INSPIRE Directive 2007/2/EC to facilitate data interpretation. However, as the directive does not outline standards for metadata files, these will be required to be developed and applied across Member States. To ensure exchangeability of data, it is recommended that shapefiles, web mapping services and web feature services are utilised.

Recommendation #5: Best Practice Guidance

Consultation feedback as part of this Baseline Environmental Study highlighted the need for focussed guidance in relation to marine assessments and monitoring. Whilst it is recognised that there are a number of guidance documents from OSPAR[165], the EU[166] and organisations such as the JNCC,[167] already in existence in relation to offshore wind energy developments and marine seismic surveys, it has been identified that this is still not sufficient. Therefore there is a need for a coordinated approach to undertaking surveys and data gathering exercises.

Specific topics identified as needing further consideration included: consistent standardised methodologies; standardised limit values for various environmental parameters; and siting guidance for landfall points.

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[165] OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development (Ref. 2008-3)

[166] Wind Energy Developments and Natura 2000: EU Guidance on wind energy development in accordance with the EU nature legislation (Ecosystems Ltd., 2011)

[167] JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys (Joint nature Conservation Committee, August 2010)

It is therefore recommended that a cross-jurisdictional group (such as the existing North Sea Support Group on Maritime Spatial Planning or newly established group if necessary) be identified to develop, in the first instance, an overarching methodology for marine assessments and marine monitoring. The group should also oversee long-term monitoring and coordinate the dissemination of relevant information to the target Member States.

Recommendation #6: Monitoring and Data Requirements

One of the recurring issues for planners and regulators of projects such as those likely to arise from a Regional Concept is the lack of evidence base on which to make sound judgements and determinations. This is in part due to poor sharing of data from operational projects and a legacy of confidentiality issues associated with the disclosure of monitoring data. Until such issues are resolved, progress on understanding impacts and impact interactions may be hampered. A structure is required across the Member States to facilitate the storage, collation and public accessibility of monitoring data and to also provide advice on proposed large scale monitoring programmes. Consideration should be given to establishing a centralised data centre for offshore energy projects. As a minimum, those receiving EU funding or support should be required to submit monitoring data and monitoring programmes for general access.

It is also in part due to a lack of coherent post-construction long-term monitoring of environmental parameters which would allow an evidence base to develop to the benefit of all players in the energy market. Consultation feedback has reiterated this through calls for funding of such post-construction monitoring to address data gaps. It is therefore recommended that a programme of evidence base studies is funded and developed to specifically address uncertainties in relation to the delivery of an offshore energy system.

With the implementation of the MSFD and the MSPD there is potential to further develop national monitoring programmes. The MSPD is still in its infancy regarding development but it is recognised that for the MSFD there will be several cycles of assessment of the status and monitoring of the marine environment. These activities will provide, on a country by country basis, monitoring data and an assessment under 11 descriptors of the status of the marine environment. This high level information is useful and will be beneficial to marine users and all sectors however it will be reliant on the sectors contributing to the monitoring programme. In compilation of the baseline data for this study, the following key data gaps should be addressed as a priority through these evidence base studies:

- Studies into the effects of RES and grid infrastructure at different ecosystem scales e.g. effects of individual collision events on bird / bat populations as well as assessing the impacts at the population level where barrier/displacement effects may become more significant. The scale and significance of impacts at the population level is still uncertain and requires more data, particularly in relation to migratory birds and cumulative impacts from multiple encounters with offshore wind farms.
- Studies into the effects of multiple sources of electromagnetic fields (EMF) on marine organisms from the deployment of grid cables. Such a study would have to be designed to ensure that there is recognition for a large scale significant length (km) of grid cables potentially to be laid in the Irish and North Sea.
- Studies into the effects of the construction, operation and decommissioning of RES and grid infrastructure on marine water quality.
- Opportunities to share existing published and unpublished studies by each Member State should be identified in the short-term (see **Chapter 5** for a list of data gap issues). Opportunities to undertake jointly funded studies to sole these gap issues should also be explored by the Member States through a forum such as the Support Groups established for the implementation of the political declaration on energy cooperation.

- Long-term monitoring beyond the typical post-construction monitoring period, where appropriate, to provide better understanding of trends and impacts.

Multiple stakeholders have flagged the need for long-term detailed environmental monitoring. It is recognised however that long-term surveys are often costly, and that monitoring of highly mobile species and within high-energy environments (e.g. tidal areas) can often be difficult. Recognising this, an adaptive monitoring strategy, the Survey Deploy Monitor (SDM) approach, was developed by Marine Scotland for post-consent and post-deployment monitoring of marine renewable devices, with a focus on wave and tidal technologies. Under the SDM approach, in deciding the level of monitoring to be undertaken it is recommended that this is informed by the scale of the development, the risks associated with the technologies being utilised and the environmental sensitivity of the area in which it is being deployed. This approach acknowledges that undertaking environmental surveys and monitoring are often costly and time-consuming.

Further to the SDM approach, the RiCORE Project (Risk-based Consenting for Offshore Renewables)[168] from the Offshore Renewables Institute ran from January 2016 to June 2016. The main aim of this project was to further develop the Scottish SDM approach by expanding it to include all marine renewable resources and to establish a risk-based and best-practice approach for post-consenting and post-deployment strategies, having regard to the issue of time and costs associated with environmental monitoring of offshore renewables. It is therefore recommended that this approach form the basis discussions going forward with a view to adapting the model to the broader North Sea Region and encouraging synergies among the target Member States. This could form an action as part of the Support Groups which have been established as part of the implementation of the political declaration on energy cooperation between the North Seas Countries.

[168] http://ricore-project.eu/

ABBREVIATIONS

AA	Appropriate Assessment
AC	Alternating current
AIS	Automatic identification system
BACI	Before-After-Control-Impact
BEAGINS	Baseline Environmental Assessment for the Grid in the Irish and North Seas
CapEx	Capital expenditure
CO_2	Carbon dioxide
COP21	Conference of the Parties in Paris
CRS	Coordinate reference system
DC	Direct current
EC	European Commission
EEA	European Environment Agency
EEAP	European Environmental Action Programme
EEC	European Economic Community
EEZ	European Economic Zone
EIA	Environmental Impact Assessment
EMF	Electromagnetic field
EMODnet	European Marine Observation and Data Network
EMS	Environmental Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
EUNIS	European Nature Information System
EWEA	European Wind Energy Association
FiT	Feed-in-Tariff
GES	Good environmental status
GHG	Greenhouse gas
GIS	Geographic Information System
GW	Gigawatt
GWh	Gigawatt-hour
HELCOM	Helsinki Commission
HCAC	High voltage alternating current
HCDC	High voltage direct current
IAS	Invasive or alien species
ICES	International Council for Exploration of the Sea
ICPC	International Cable Protection Committee
INSPIRE	Infrastructure for Spatial Information in Europe
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
LCoE	Levelised Cost of Energy
MESH	Mapping of European Seabed Habitats
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSPD	Maritime Spatial Planning Directive
MW	Megawatt
MWh	Megawatt-hour
NO_x	Nitrogen oxides
NSCOGI	North Seas Countries’ Offshore Grid Initiative
OBIS-SEAMAP	Ocean Biogeographic Information System - Spatial Ecological Analysis of Mega vertebrate Populations
OPSAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PCI	Projects of Community Interest
PM	Particulate matter

AA	Appropriate Assessment
PRIMES	Price-Induced Market Equilibrium System
RES	Renewable energy source(s)
RiCORE	Risk-based Consenting for Offshore Renewables
SAC	Special Area of Conservation
SCI	Site of Community Interest
SDM	Survey Deploy Monitor
SEA	Strategic Environmental Assessment
SO_2	Sulphur dioxide
SPA	Special Protection Area
TEN-E	Trans-European Energy Network
TEN-T	Trans-European Transport Network
TSO	Transmission System Operator
TW	Terawatt
TWh	Terawatt-hour
TY	Target year
UNESCO	United Nations Educational, Scientific and Cultural Organization
WDPA	World Database of Protected Areas
WFD	Water Framework Directive
WG	Working Group
WP	Work Package

GLOSSARY OF TERMS

Term	Description
Appropriate Assessment (AA)	AA is required for any plan or project likely to have an adverse effect on the integrity of a European Site, designated pursuant to Directive 92/43/EEC (the Habitats Directive) or 2009/147/EC (Birds Directive). The ultimate objective is to ensure that the species and habitats reach "*favourable conservation status*" and that the plan or project does not result in any adverse effects on the integrity of any European Sites in view of its conservation objectives. Where a plan or project will have a likely significant effect on a Natura 2000 site, an AA (required under Article 6(3) of the Habitats Directive) which requires decision makers to establish *beyond reasonable scientific doubt* that adverse effects on site integrity in light of the conservation objectives of the site, will not result.
European Atlas of the Seas	An interactive web mapping portal hosted by the European Commission which allows data visualisation through a range of datasets relating to Europe's coastlines, seas, environmental data and maritime activities.
European Marine Observation and Data Network (EMODnet)	A network and data initiative comprising over 160 contributing organisations and a series on online data portals hosted by the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE).
Energy System	For this study, an energy system comprises renewable energy sources (RES), the grid and all associated infrastructure such hubs, connectors, platforms and converter stations.
Environmental Impact Assessment (EIA)	The Environmental Impact Assessment process identifies the potential environmental effects of the development and examines how these impacts can be avoided or reduced during the design process, construction and operational stages of the development. The EIA process is governed by 'The EIA Directive' (EU Directive 85/337/EEC as amended by Directive 97/11/EC, 2003/35/EC and 2009/31/EC). The initial Directive of 1985 and its three amendments were codified by Directive 2011/92/EU and this has now been amended by Directive 2014/52/EU. The latter must be transposed in to national Member State legislation by May 2017.
ENTSO-E	The European Network of Transmission System Operators for Electricity (ENTSO-E) is an association of 42 transmission system operators (TSO) from 35 countries across Europe. ENTSO-E has legal mandates given by the European Union's Third Energy Package which aims to open up the gas and electricity markets in the EU.
EU-28	Since July 2013 there are 28 Member States in the European Union, referred to interchangeably as the EU or EU-28.
Geographic Information System (GIS)	GIS is used to view, collate, analyse and display spatial data and maps.
Greater North Sea	The wider North Sea also including the English Channel, the Skagerrak Sea and the Kattegat Sea.
Grid Concept	A grid in this study refers to the cable infrastructure linking an energy system to various countries. The configuration of the grid depends on the level of coordination between counties i.e. a meshed versus radial solution or combination of the two.
High Renewables Scenario	This scenario refers to a high level of offshore renewables deployment, combining multiple energy sources. The offshore wind capacity development (2015) is based on the European Wind Energy Association (now known as WindEurope) 'High' wind energy scenario for 2030. The wave and tidal capacity (2011) is based on the

Term	Description
	European Commission (EC) Energy Roadmap 2050 'High Renewable Energy Source' scenario combined with the country-specific offshore energy roadmaps of Ocean Energy Services (OES) and an IEA Technology Initiative.
Maritime Spatial Planning	Maritime spatial planning contributes to the management of maritime sectors and their associated activities to enable effective coordination that reduces potential conflict and helps meet environmental, economic and social objectives. Maritime spatial planning is a practical way of managing maritime resources and space in combination with environmental requirements and sector-specific policy goals. In July 2014, the European Council adopted legislation to establish a framework for the implementation of maritime spatial planning in EU waters (Directive 2014/89/EU) with the objective to promote the sustainable growth of maritime activities. The Maritime Spatial Planning Directive (MSPD) supports on-going implementation of sea-related policies in Member States through more efficient coordination and increased transparency.
Marine Strategy Framework Directive (MSFD)	The Marine Strategy Framework Directive 2008/56/EC, forms an integral component of maritime planning within the EU and requires Member States to develop a strategy to achieve or maintain Good Environmental Status (GES) in their marine waters by 2020.
Meshed grid	A meshed grid corresponds to coordinated development that leads to selective clustering of offshore projects, where cost reductions compared to individual radial connections are observed. The meshed case therefore consists of some sites being connected radially to onshore substations, while others are connected to offshore hubs. These hubs are connected to onshore substations and/or to other hubs via hub-to-hub interconnectors.
NSCOGI Scenario	This reference scenario was developed in 2011 by the North Seas Countries' Offshore Grid Initiative (NSCOGI) in collaboration with TSOs, governments and regulators. In this scenario, the year 2020 is based on ENTSO-E EU2020 scenario, following the national renewable energy source targets defined. The 2030 scenario is based on the PRIMES model, and was adjusted to take into account the views of national authorities.
North Sea Grid Project	The North Sea Grid Project, funded by the Intelligent Energy Europe (IEE) program, was the follow-up project of Offshore Grid. THINK was an FP7-financed project that advised the European Commission (DG Energy) on a diverse set of energy policy topics. In total, 12 reports were produced over this period including "Offshore Grids: Towards a Least Regret EU Policy".
Offshore Grid Project	The Offshore Grid Project was the first in-depth analysis of how to build a cost-efficient grid in the North and Baltic Seas. As such, it is a compelling milestone in the development of a secure, interconnected European power system, able to integrate increasing amounts of renewable energy. The Offshore Grid project results are a practical blueprint for policymakers, developers and transmission grid operators, to plan and design a meshed offshore grid.
PRIMES Reference Scenario	PRIMES (Price-Induced Market Equilibrium System) is an energy system model developed by the Energy-Economy Environment Modelling Laboratory at the National Technical University of Athens for the European Commission. In the Regional Concept Report, the PRIMES Scenario is similar to the NSCOGI scenario but represents a stronger deployment of offshore wind energy development.
Radial grid	The design basis for a radial grid is that all offshore sites are developed independently and are connected individually (radially) to an onshore substation.

Term	Description
Regional Concept Report	The objective of the Regional Concept Report is to develop a detailed plan of the combined energy infrastructure in the Irish and North Seas. The approach taken is consistent with current targets related to renewable energy and current network developments in the study area. The level of detail is at single power plant resolution (e.g. offshore wind farms or wave devices) and to a high level of detail for the grid infrastructure (e.g. number of cables in each corridor, technology specifications and ancillary equipment).
Regional Capacity Scenarios	Based on the information on energy policy action plans in the study area, three technology-specific target scenarios for the development of renewable energy sources and energy storage in the territorial waters of each country for the target year 2030 have been developed for the Regional Concept Report. These are: High Renewables Scenario, PRIMES Reference Scenario and NSCOGI Scenario.
Renewable energy source (RES)	For this study, RES includes wind turbines/ wind farms, wave energy devices and tidal energy devices.
Strategic Environmental Assessment (SEA)	The SEA Directive 2001/42/EC requires that certain Plans and Programmes, which are likely to have a significant impact on the environment, be subject to the SEA process.
Target Member States	The Member States included in this study: Belgium, Denmark, Germany, Ireland, the Netherlands and the United Kingdom.
Transmission System Operator (TSO)	A term defined by the European Commission, a TSO is national entity with responsibility for transporting gas or electricity via a network at the regional or national level.
Water Framework Directive (WFD)	The Water Framework Directive 2000/60/EC, established a framework for the protection/ enhancement of all waters (surface, ground and coastal waters). It sets a goal of achieving Good Ecological Status for all EU ground and surface waters including intertidal, transitional and coastal waters.

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