Subsea Cable Interactions with the Marine Environment

Expert review and Recommendations Report

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1. Executive summary

Grid development is vital in order to achieve European energy objectives for a competitive and integrated energy market. Power transmission via subsea cables is required to interconnect terrestrial grids, to supply offshore facilities and to connect renewable energy sources such as offshore wind, wave and tidal power with the grid.

This report provides an overview of the top-priority challenges that need to be tackled in Northern European Seas with respect to subsea cable development and associated environmental impacts in the marine environment. It outlines a set of nine options and actions for the subsea cable industry to take forward (section 9), including improved procedures at the outset of project planning and knowledge sharing; improved guidance on environmental impact assessment (EIA), including EIA scoping and cumulative effect assessment (CEA); and focus on research areas that would lead to a better understanding of different consenting requirements across countries; and addressing knowledge gaps identified by current literature, the industry and relevant stakeholders.

These recommendations have been informed through a literature review (section 5), as well as primary stakeholder data collection. In December 2015, a total of 140 individuals participated in a targeted online survey that sought opinions on key environmental impacts and knowledge gaps associated with the subsea cable industry. A total of 26 interviews were then conducted by NIRAS personnel, targeting industry representatives and relevant stakeholders, as well as marine environment specialists, providing an insight into specific issues encountered in practice, how these translate into consenting constrains and how these issues should be explored.

Overall, there was a common perception that knowledge gaps in relation to potential environmental impacts of subsea cables are associated with uncertainties around how electro-magnetic fields (EMF) and, to a lesser extent, heat emissions produced by subsea cables affect marine receptors' behaviour. There were contrasting opinions on whether these emissions were a realistic issue. Uncertainty around the quantitative impact of cable installation and decommissioning phases, in relation to seabed disturbance and sediment suspension, was also highlighted by both the interviewees and current literature, indicating a need to better understand these impacts to inform future use of specific installation / decommissioning techniques.

Environmental assessments of subsea cable deployments were generally considered to be effective and fit-for-purpose, although participants indicated that further guidance should be produced, specifically in order to inform the scoping process and to focus environmental assessments. Cumulative effect assessment was also identified as a process requiring further guidance in terms of approach and scope.

Among potential impacts of subsea cables identified, conflict with other marine stakeholders was considered as a key issue that subsea cable developers currently face. There was a general consensus that the improvement of tools for stakeholder engagement and information sharing would be welcomed by both the industry and other marine users.

Finally, in relation to consenting facilitation, it was considered that a better understanding of consenting regimes and requirements across countries would help to reduce consenting risks and potential delays, particularly in relation to shared offshore grids and interconnector deployment.

2. Introduction

2.1. The Renewables Grid Initiative (RGI) is a Berlin-based collaboration of Transmission System Operators (TSOs) and non-governmental organisations (NGOs) from across Europe. RGI members work together to ensure the grid modernisation, which is needed to integrate large shares of renewables and achieve simultaneously social and environmental protection.

2.2. The EU has established ambitious targets for the decarbonisation of its economy through the development of renewable energy sources (RES), efficient use of energy sources, and the introduction of carbon emissions trading applicable to different sectors of the European economy (EC, 2014). In 2009, the Renewables Directive[1] set binding targets for all EU Member States in order for the EU to reach an energy target of 20% from RES by 2020.

2.3. Grid development is vital in order to achieve European energy objectives of a competitive and integrated energy market. Power transmission via subsea cables is required to interconnect terrestrial grids, to supply offshore facilities and to connect RES such as offshore wind, wave and tidal power with the grid.

2.4. In relation to offshore RES, there is a total of 2,488 offshore wind turbines installed and grid connected in Europe, with a further 98GW of planned offshore wind farms in the pipeline (EWEA, 2015). In addition, the European Ocean Energy Association considers that there is potential for the EU to reach 100 GW of combined wave and tidal installed capacity by 2050 (European Ocean Energy, 2013).

2.5. Increased generation of renewable energy is therefore a major driver in grid development. With a total of 11 offshore grids currently operating and 21 offshore grids being considered by grid operators in the Baltic and North Seas, Europe's offshore grid will be developed to integrate the expected 40GW of offshore wind power by 2020 and 150GW by 2030 (EWEA, 2010). Careful strategic and participatory planning is needed to realise new grid infrastructure so electrical needs of the coming years can be met.

2.6. In addition, there is a general consensus that a European transnational offshore interconnector grid will provide access to the up-coming RES, smoothing the variability of their output on the markets and contributing to the development of a single European electricity market, which will ensure Europe's energy security.

2.7. As the amount of RES in the electricity grid increases and new interconnector projects are added to the pipeline, new challenges emerge, including the potential for subsea cable deployments to cause environmental impacts to the marine environment.

2.8. The potential environmental effects of subsea cables may occur during the installation, operation and decommissioning of a project. There are strong uncertainties regarding specific impacts to the marine environment, mainly in relation to electro-magnetic fields (EMFs) and thermal radiation, for which a number of knowledge gaps exist, with both authorities and project developers recognising the risk of permits not being granted if information is insufficient or impacts not effectively assessed.

3. Objective of this report

3.1. This report reviews key environmental issues associated with subsea cable deployment identified through a literature overview and through both questionnaires and interviews undertaken with key representatives from the industry, relevant stakeholders and marine environment specialists. This

[1] Renewable Energy Directive 2009/28/EC:
http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028

review has identified key knowledge gaps and has informed a set of options and actions for the subsea cable industry to take forward.

4. Methodology

Literature review

4.1. The literature review incorporates relevant existing material relating to the potential marine environmental effects of subsea power cables. The review includes a legislative and policy overview, describes the strategic planning and assessment of offshore electricity networks and provides an overview of cable types and activities involved in their life-cycle, from installation to decommissioning.

4.2. The literature review also provides a systematic review of the potential impacts of subsea cables in the marine environment with any knowledge gaps highlighted; an overview of how cumulative effects should be considered and an initial look into data collection opportunities are also provided.

4.3. In order to collate the necessary research materials to inform this overview document, a key word search was carried out on a variety of search engines. Environmental Impact Statements from relevant projects were also included to provide project specific information. Additional information has been sourced from technical notes, installation method statements, NGO guidance and regulatory authority reports.

Online survey

4.4. An online survey was developed to gather an initial insight into a wide constituency of stakeholder views on the environmental effects of subsea cables. The contents of the survey were based on the Project objectives, acceptability for participants and ability for their subsequent analysis and interpretation. The survey was available from the 11 November 2015 to 21 December 2015.

4.5. The survey included four multiple choice questions:

- Opinion on the top three marine environmental impacts affecting the development of subsea cables
- Opinion on the top three marine environmental receptors most sensitive to impacts
- Opinion on the key knowledge gaps in subsea cable environmental effects
- Opinion on the top three environmental receptors where further understanding of the impact of subsea cables is needed

4.6. The survey was circulated through RGI and NIRAS industry contacts and selected relevant industry mailing lists. Participants were requested to include their employment position, stakeholder category and country of employment, allowing the results to be manipulated by these categories in order to help identify any themes / trends. The use of statistics was solely descriptive, providing accumulated data summaries in tables and graphs.

4.7. A total of 140 individuals participated in the online survey, of which 41 provided additional comments.

Telephone interviews

4.8. Interviews were selected as the second means of primary data collection. Identification of interviewees was facilitated by targeting key experts in the subsea cable industry combined with questionnaire participants who had expressed an interest in participating in the interviews, of which there were 54.

4.9. A total of 26 interviews were carried out between 26 November and 17 December 2015, with stakeholders ranging from transmission system operators, regulators, consultancies, developers and operators, academics, NGOs and cable installation and manufacturing companies. Each interview was planned and moderated to run for 30 minutes, occasionally extending to 40 minutes.

4.10. Semi-structured telephone interviews were employed in order to guide discussion, using ten open questions to collect a greater insight into the participants' opinions and expertise. The ten questions focused around the following topics:

- Involvement in environmental assessments or similar exercises;
- Current knowledge and knowledge gaps surrounding the environmental impacts of subsea cables;
- Specific species of concern;
- Subsea cables and the monitoring of the marine environment;
- Reducing environmental and permitting difficulties; and
- Future priorities.

5. Literature overview

Regulatory framework

5.1. This section provides an overview of relevant regulatory frameworks that support the development of offshore grids, including the legislation at an international and EU level that needs to be considered regarding the planning and environmental assessment of subsea cables.

National support schemes and permitting

5.2. Energy markets alone cannot deliver the desired share of renewable energy in the EU and require national support schemes to support the market and promote investment in the renewable energy sector (CEER, 2015). Most countries use feed-in-tariffs (FiT), but certificate and bonus systems, as well as combined systems are also implemented, responding to specific national needs.

5.3. The permitting process for offshore renewable sources and their connections to onshore landing points differ widely across countries, especially in relation to level of detail of associated studies required by authorities, permitting process duration and costs.

5.4. In most countries, the grid connection responsibility lies with the national TSO, who are responsible for the bulk transmission of electric power on main high voltage electric networks. TSOs provide grid access to electricity market players, including offshore energy developers. In many countries, TSOs are in charge of the development of the grid infrastructure too. The European Network of Transmission System Operators for Electricity (ENTSO-E[2]) promotes cooperation across Europe's TSOs to achieve the integration of RES into the power system and to develop and operate the European power grid, including interconnectors (ENTSO-E, 2014a).

[2] https://www.entsoe.eu

5.5. The Ten-E regulation (Regulation No 347/2013[3]) lays down rules for the timely development of energy networks in the European Union and the European Economic Area. This includes guidelines for establishing streamlined processes for consenting Projects of Community Interest.

5.6. In addition, there are a number of legislative requirements at the international and European level that subsea cables developments must adhere to. These are summarised in section 11 (Appendix A).

Strategic planning and assessment

Strategic planning

5.7. While the electricity markets are required to contribute for the development of an integrated European market, national TSOs are responsible for the development of grid infrastructure (Jacques, et al. 2011).

5.8. Cross-border flows have increasingly been considered due to market coupling as well as RES deployment (Jacques, et al. 2011), becoming one of the infrastructure priorities for the EU (EC, 2008; EC, 2011). To date a number of studies have been undertaken to look into potential opportunities and challenges in cross-border grid integration (Dena grid study (Dena, 2005); TradeWind[4] 2006 – 2009; or the European Wind Integration Study[5], 2010; TWENTIES[6], 2013 among others).

5.9. The Regulation 714/2009[7] brought international grid planning to a new stage, it provided for increased cooperation and coordination amongst TSOs in order to ensure effective and transparent access to the transmission networks across borders. According to the Article 7, TSOs are required to set up regional structures within the overall cooperation structure, ensuring that these are compatible to ten-year network development plans (TYNDP) at a Community level. Article 8.10 stipulates that the planning should be based not only on national grid analyses but also on integrated community-wide modelling.

5.10. The ENTSO-E is the legally mandated body of electricity TSOs at the European level, its 2014 TYNDP (ENTSO-E, 2014b) investigates the development of the European transmission grid to 2030, including the analysis of different scenarios, investment needs and projects' portfolio. According to the TEN-E regulations, the TYNDP is also mandated as the sole instrument for the selection of Projects of Common Interest (PCIs), energy infrastructure projects with the greatest added value. According to the TYNDP, the European transmission network presently consists of ca. 300,000 km of routes, both onshore and offshore. Completing the projects of pan-European significance would lead to about 4,000 km of existing assets being refurbished and 43,000 km of new assets being built by 2030, of which more than one third are subsea. It is estimated that 4,000 km of the new subsea cables will connect offshore wind farms (half with AC and half with DC technology), and about 12,000 km of DC subsea cables will increase the interconnection capacities, especially In the North Sea (approx. 10,000 km).

5.11. Although the TYNDP is considered a "framework for planning the European grid and supplying a long-term vision" (ENTSO-E, 2014b, p. 19), the TYNDP does not propose a specific offshore design, which has,

[3] 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: http://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A32013R0347

[4] http://www.ewea.org/eu-funded-projects/completed-projects/tradewind/

[5] The European Wind Integration Study: http://www.wind-integration.eu/

[6] http://www.twenties-project.eu/node/1

[7] Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003: https://www.energy-community.org/pls/portal/docs/1164178.PDF

however, been considered at a regional level (e.g. OffshoreGrid programme[8] in Northern Europe or OffshoreDC in the Baltic Sea region[9]).

Maritime Spatial Planning (MSP)

5.12. Growth in the subsea cable industry and other marine sectors increases the risk of potential damage to cables and further interactions with other users, including competition for space with oil and gas pipelines, fishing and shipping. Maritime Spatial Planning (MSP) emerges as a tool to facilitate marine energy development and associated energy storages, power cables deployment and grid connection, as well as interconnection between countries. In a context of intensifying economic activity and increasing marine spatial demands and growing competition, MSP is conceived to manage human sea uses, supporting a sustainable use of marine resources by providing means to effectively control human use of the marine space. It provides long-term stability, predictability and transparency for investors, and has the potential of bringing down the costs of renewable energy generation through an optimal integration of generation assets into the marine environment (Jacques et al. 2011; EWEA, 2012).

5.13. Although individual Member States have started to consider MSP within their national plans, including in the context of marine energy development (BSH, 2013; The Danish Government, 2010; DETI, 2012; HFE, 2014), there is currently no integrated perspective of MSP at the regional level.

5.14. The European Commission intends to support the development of MSP processes throughout the European Union[10], and, in 2013, a new Directive on MSP[11] was proposed in order to promote the sustainable growth of maritime activities, establishing a framework for the implementation of MSP throughout the EU. At an early stage maritime spatial plans can reduce conflicts between economic objectives (i.e. different marine users) and environmental legislation. Member states will have to transpose the Directive into national legislation by 2016 and nominate the Competent Authority in charge of the implementation of MSP. Member States must draw up their national maritime spatial plans by 2021.

Strategic Environmental Assessment (SEA)

5.15. Plans associated with the integration of cross-country / individual countries offshore grids are subject to the Strategic Environmental Assessment (SEA) Directive (section 11, Appendix A).

5.16. SEA is a political instrument, which has the objective of providing for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development. The public must also be consulted on draft plans or programmes and on the environmental assessment and their views taken into account (EC, 2003).

5.17. The SEA Directive does not indicate how the assessment should be carried out but best practice guidance (Partidário, 2012) indicates that there are nine structural elements in the strategic thinking model for SEA:

[8] OffshoreGrid (Intelligent Energy Europe programme): http://www.offshoregrid.eu/
[9] Offshore DC: http://www.offshoredc.dtu. http://www.offshoredc.dtu.dk/Project-descriptiondk
[10] Commission communication on marine spatial planning in the EU (2010): http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52010DC0771
[11] Until its entry into force the Draft Directive adopted by the European Parliament can found here: http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2014-0449

- Object of assessment;
- Driving forces;
- Environmental sustainability issues;
- Strategic Reference Framework;
- Critical Decision Factors;
- Governance Framework;
- Strategic Options;
- Opportunities and Risks; and,
- Follow-up.

5.18. SEA can inform locational guidance for the development of offshore electricity networks, establishing routeing and siting strategies and supporting principles such as integrated consideration of environmental and social impacts, the importance of working with stakeholders or consideration of engineering and commercial issues. In addition it is considered that SEA can provide early warning of cumulative effects and propose preventive measures in terms of identified environmental objectives.

5.19. While SEA applies to policies, plans and programmes and focus on assessing development conditions (institutional, policy, economic, social issues, etc.) towards the creation of better environmental and sustainability decision contexts and outcomes, Environmental Impact Assessment (EIA) (see below) applies to projects and focus on the effects that a development may have on the environment. Further differences between both SEA and EIA are outlined in Table 5.1

Table 5.1: Fundamental differences between SEA and EIA. Source: Partidário (2012).

SEA	EIA
The perspective is strategic and long-term	The perspective is of execution in the short and medium-term
The process is cyclical and continuous	The process is discrete, motivated by concrete intervention proposals
The purpose is to help build a desirable future, it is not an attempt to know the future	The purpose is to know what the future will be, forecast potential impacts, based on predictions of past events.
The definition of what is intended is vague, there is a large amount of uncertainty and the data are always quite insufficient	The definition of what intends to be done is relatively precise and data are reasonably available or can be collected through fieldwork
Follow-up in SEA is performed through the preparation and development of policies, plans, programmes and projects	Follow-up in EIA is performed through the construction and implementation of the project or detailed plans
The strategy may never be put into practice given that the actions established in plans and programmes may never be implemented	Projects requiring an EIA are executed, once their feasibility is guaranteed

5.20. Both SEA and EIA apply in territorial water and Exclusive Economic Zones (EEZ), but not in international waters, where a number of international conventions and agreements apply for the protection of the marine environment, see section 11 (Appendix A).

Environmental Impact Assessment (EIA)

5.21. EIA is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. In the context of subsea cable deployment, EIAs, although not always required (see section 11, Appendix A), ensure that any environmental effects of cable laying and maintenance are taken into account before authorization is provided to lay a cable on the seabed. The extent to which a consent application requires an EIA depends on the regulatory process established in each particular country. It can range from the provision of relevant technical information and a statement of compliance with environmental accreditation, to a brief environmental review; to a comprehensive analysis that includes formal public and/or governmental consultation. Schedules for completing an assessment range from a few weeks to a year or longer. This depends on the quantity and quality of data needed, the level of documentation and consultation required, and the presence of sensitive environmental resources within the project's bounds.

5.22. The EIA process includes a preliminary phase of scoping (EC, 2011a), which is the process of determining the content and extent of the matters, which should be covered in the environmental information informing the EIA. It is designed to ensure that the environmental studies provide all relevant information on:

- The impacts of the project, in particular focusing on the most important impacts;
- The alternatives to the project (including activity, location, process, schedule among others);
- Any other matters to be included.

5.23. The scoping provisions of the EIA Directive include the option of requesting a scoping opinion from the relevant competent authority, which should be reviewed by environmental authorities. Some Member States include scoping as a compulsory process of the EIA, where consultation with both statutory and non-statutory consultees is required at this stage (EC, 2011a).

5.24. A formal EIA typically has six components (EC, 2013):

1. Description of the proposed project and its purpose;
2. Description of reasonable alternatives (e.g. in terms of location, technology, etc.) and also the non-action alternative;
3. Description of the environment likely to be significantly affected by the proposed project (covering all relevant environmental receptors (physical, biological and socio-economic));
4. Description of the potential environmental impact of the proposed project and its alternative, including an estimate of its significance;
5. Description of mitigating measures considered and an indication of the predictive methods, assumptions and data on which they are based (e.g. spatial or temporal limitations, replacement, re-establishment or restoration of affected environments); and,
6. Outline of monitoring and management programmes and any plans for post-project analysis. Assessment of any monitoring measures needed to ensure that the extent of an effect (mitigated or otherwise) is maintained at an acceptable level.

Habitats Regulations Assessment (HRA)

5.25. Under the Habitats Directive (see section 11, Appendix A), the implications of plans or projects on Natura 2000 sites need to be assessed in a so-called Habitats Regulations Assessment. Although Member States are responsible for determining the procedural requirements deriving from the directive, the European Commission, through guidance (EC, 2001b), proposes four stages as part of the process.

1. Stage 1 – Screening. Identification of the likely impacts upon a Natura 2000 site of a project or plan, either alone or in combination with other projects or plans, and consideration whether these impacts are likely to be significant;

2. Stage Two: Appropriate assessment. Consideration of the impact on the integrity of the Natura 2000 site of the project or plan, either alone or in combination with other projects or plans, with respect to the site's structure and function and its conservation objectives. Additionally, where there are adverse impacts, an assessment of the potential mitigation of those impacts;
3. Stage Three: Assessment of alternative solutions. Examination of alternative ways of achieving the objectives of the project or plan that avoid adverse impacts on the integrity of the Natura 2000 site;
4. Stage Four: Assessment where no alternative solutions exist and where adverse impacts remain. Assessment of compensatory measures where, in the light of an assessment of imperative reasons of overriding public interest (IROPI), it is deemed that the project or plan should proceed (it is important to note that this guidance does not deal with the assessment of imperative reasons of overriding public interest).

Subsea cable deployment

5.26. This section provides a short introduction into technical aspects of subsea cables, including power transmission and cable types, and sets the background to the methodologies used for cable deployment, including route selection, survey of route and final selection; cable system design and cable installation lying and/or burial. Consideration is also given to cable recovery that may be required as part of the cable maintenance and/or decommissioning.

5.27. The International Cable Protection Committee (ICPC) publishes recommendations[12] designed to facilitate quality improvement and define minimum standards for cable route planning, installation, operation, maintenance and protection. Guidelines relating to submarine cable activities are also published by the Subsea Cables UK group[13] and the OSPAR Commission (OSPAR, 2012).

<u>Power transmission and cable types</u>

5.28. Marine power transmission cables are designed to transmit electric current as Direct Current (DC) or Alternating Current (AC) transmission. Monopolar, bipolar or three-phase systems are different technical solutions in use. The selection balance between DC and AC cable selection is generally a technical or commercial issue (SCUK, 2015), determined by both the capacity and length of the transmission line. Usually electric power is generated as AC and delivered as AC to the consumers, and voltage conversation will be required if using DC transmission. Table 5.2 outlines the differences between these two types of transmission. In addition, inter array or collector cables (usually of 11kV, 33kV, or 66kV) are used for the collection of power from individual renewable energy devices, such as an individual turbine, to an offshore substation platform (SCUK, 2015).

[12] https://www.iscpc.org/publications/recommendations/
[13] http://www.subseacablesuk.org.uk/guidelines/

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Table 5.2: Characteristics of power transmission solutions. Source: Koops (2000); Soker et al (2000); OSPAR (2012)

	DC transmission	AC transmission
Rationale for use	Large Distances (over 50 km) and high transmission capacities (high voltage direct current - HVDC) In general, a DC line can transmit more power than an AC line of the same size.	Medium distances (less than 100 km) and high transmission capacities (high voltage alternating current - HVAC)
How	Direct Current is transmitted down a primary conductor and requires a return path provided via another conductor or via seawater using an anode/cathode. They have no induced voltages and currents and thus no losses from their metal jackets. Monopolar systems have been found to generate strong electromagnetic fields and do no longer meet environmental standards in many European countries. Instead, bipolar systems are used, which can use two-conductor cable or two single-conductor cables. The reduction of the emission of electromagnetic fields ideally reaches 100 % in coaxial cables.	Three-conductor cable – electromagnetic field is almost neutralised at the surface of the cable, and plastic is used instead of oil as stabilising material to fill the hollow space, preventing broken cables from emitting oil into the sea water. Single-conductor cable – includes one conductor for a single phase.
Examples of use	-Export cables used for the export of power from offshore renewable energy project usually over distances of 100 km from the landing point; -Interconnector cables (e.g. Skagerrak interconnector between Norway and Denmark – 127 km); -Transmission cables.	-Export cables used for the export of power from offshore renewable energy project usually up to distances of approx. 100 km from the landing point; -Interconnector cables; -Distribution cables, power supply of offshore platforms; -Transmission cables.
Disadvantages	High cost	High transmission losses with increase distance and high costs at 50-120 km

5.29. Cable conductors are usually made of copper with outer diameters of less than 30 cm depending on current-carrying capacity and amount of armour protection (ICPC, 2011), weights vary between 15 to 120 kg/m (OSPAR, 2008).

5.30. The cable industry today offers various types of insulation, including paper mass-impregnated (MI) cables; extruded plastic insulation (XLPE or cross linked polyethylene cables); as well as self-contained fluid filled (SCFF) or gas filled (SCGF) cables. These are described in Table 5.3.

Table 5.3: Cable types and insulations used. Source: Meißner et al (2006); BERR (2008)

Cable type	Characteristics
MI	Contain a fluid impregnated paper insulation that is not pressurized
SCFF	Contain conductors with hollow cores which provide a passageway for insulating fluid under static pressure provided by equipment at the cable terminals (pumping plants at the cable ends, feeding into a hollow conductor core). The insulating fluid maintains the electrical integrity of the cable, and prevents damaging ingress of water in the event of an underwater leak. Suitable insulating fluids are refined mineral oils or linear alkylbenzene (LAB).
XLPE / ERP	Equipped with insulations of a solid dielectric material. Usually used for operation at voltages up to 132Kv.
SCGF	Similar to SCFF above but insulation is pressurized with dry nitrogen gas.

Route selection

5.31. A successful route design requires extensive research and constraint planning in order to document key environmental concerns and restrictions that might conflict with the potential cable route (Red Penguin, 2012). Route selection should be carried out within a formal approval procedure and be integrated with EIA (OSPAR, 2012).

5.32. Once the potential cable landings to be connected have been identified, a desktop study (DTS) should be conducted in order to define the most efficient and secure route. The DTS should focus on environmental information about the area under study (e.g. seabed conditions and feasibility of subsea cable installation), and consider the location and history of existing nearby cables and other obstructions, such as areas with high risk of unexploded ordnance (UXOs), areas with marine archaeological interests, etc. The DTS should be scoped to also carry out a generalised UXO threat assessment regarding the presence (or otherwise) of UXO, which may indicate the need to undertake a full risk assessment on all or part of the route being considered (SCUK, 2015).

5.33. This also includes the identification and understanding of marine geopolitical boundaries (defined by UNCLOS, section 11, Appendix A) that a proposed route may encounter in order to avoid potential permitting and cable maintenance constraints (Carter et al., 2009). The extent to which a country regulates cable-related activities within its territorial seas and EEZ varies significantly, and such nuances need to be considered and understood at the planning stage of a cable project.

5.34. The DTS will provide a preliminary Straight Line Diagram (SLD) and Pre-Survey Route Position List (RPL), which is the centre line of the cable corridor. The cable corridor’s width will vary according to the level of natural and man-made hazards associated with the seabed and prevailing weather/tidal conditions and constraints across the project area identified by the DTS (SCUK, 2015). The cable route corridor selected should meet the most optimal way possible the following conditions in order to minimise or avoid environmental impacts (OSPAR, 2012):

- Protected as well as sensitive areas to disturbance or damage;
- Shortest possible length;
- Bundling with existing cables and pipelines, where it is safe to do so; and,
- Minimal number of crossings with other cables or pipelines to reduce the number of crossing structures.

5.35. The DTS will allow for the design of an efficient initial survey to fully characterise the proposed route and to avoid hazards and/or environmentally important zones that may not have been identified from existing information. Surveys normally include water depth and seabed topography, seabed type, landbased geophysical and geotechnical surveys (at landing points) as well as marine-based surveys (e.g. side-scan sonar, multi-meter and magnetometer surveys undertaken from specialist vessels), coastal and marine faunal and floral communities, and potential natural or man-made hazards (Carter et al., 2009; OWPB, 2015).

5.36. Information collected through surveys will provide environmental information used to inform environmental reports and assessments accompanying consent applications.

5.37. Once the overall project-concept and cable routing has been accepted and consented, the normal procedure is to undertake a detailed survey operation based on the DTS, including initial survey and UXO threat and risk assessment study. The detailed survey enables the project owner to determine the optimum route, cable lengths and protection requirements. This survey will also serve to identify the location of any third party crossings that might be on the cable route so any crossing preparations can be identified (SCUK, 2015), additional mitigation measures such as re-routing and micro-siting can also be applied at this stage where necessary (BERR, 2008).

5.38. Out of this route engineering phase, an accurate pre-lay RPL and SLD will be generated, which will be used to inform cable manufacture and installation company, forming the basis for subsequent export into the installation vessel navigation and cable lay computers (SCUK, 2015).

Cable installation

Landfall and beach works

5.39. Horizontal Directional Drilling (HDD) is often proposed at the landfall site, usually restricted to areas where there is poor access and a difference in beach levels, as it allows the cables within cable ducts to pass beneath both natural and artificial structures, such as roads or coastal defences. It is used as a mitigation measure to avoid damage where habitats may be more sensitive (e.g. chalk cliffs, saltmarsh, etc.) (BERR, 2008).

5.40. HDD involves the installation of underground pipes that provide a path for the insertion of subsea cables, this requires the drilling of two parallel boreholes with conduits, made of either high density polyethylene or steel, installed at each landfall location (Emera NL, 2014).

5.41. Geotechnical assessments are conducted before drilling in order to inform HDD borehole design. Site preparation activities, such as tree clearing and foundation preparation will normally be required prior to drilling.

Pre-installation

5.42. Prior to the installation of the subsea cable on the seabed, certain preparation operations may need to be undertaken (SCUK, 2015). These might include:

- Route clearance of known seabed features such as out-of-use cables. This ensures that the cable route is clear of any obstructions that may hinder the operation (Nemo Link, 2013a; Bald et al., 2014). A grapnel is often used for this operation (see Figure 5.1 below), which can penetrate to a depth of 1 m and have a width of 200 mm (Nemo Link, 2013a);
- Seabed preparation at crossing locations; and/or
- Pre-lay grappling operations in order to clear any debris from the cable route.

Figure 5.1: Grapnel. Source: Nemo Link (2013b)

5.43. Subsea cables installation can be undertaken in a number of ways, including surface lay, simultaneous lay and burial, and post lay burial, and may require specific crossing activities, or the implementation of specific protection measures. These methods are described below.

Surface lay

5.44. Purpose built ships and barges accurately place cables on or beneath the seabed, guided by the route survey. While divers may be used to assist installation in shallow water, deep water laying may involve Remotely Operated Vehicles (ROVs) (ICPC, 2011).

5.45. As a cable comes ashore it may be suspended by floats and guided into position by small boats and divers. Floats are detached or deflated and the cable is placed in its final position as determined by the route survey, which in very shallow water may be undertaken by divers (ICPC, 2011).

5.46. This is the simple, very speedy and cost effective way to install subsea cables where threat analysis allows.

Cable burial

5.47. Subsea cables are, however, usually buried to minimise the risk of damage by, for example, anchors and fishing gear (ICPC, 2011). The practice most commonly used in the North Sea. The amount of sediment displacement anticipated and the avoidance of sediment and morphology changes can inform the selection of specific burial techniques and depths to be used (OSPAR, 2012).

5.48. In water depths to approximately 2,000 m, cables are usually buried in a narrow (< 1m wide) trench cut by water jet or plough. They are typically buried 1 m and exceptionally up to 10 m beneath the seabed. The cable burial depth depends on factors like types of threats present, the type of habitat, the hardness of the sediment or the depth of water. Emu Ltd (2004) specifies typical burial depths dependent on seabed types (Table 5.4).

Table 5.4: Typical subsea cable burial depths. Source: EMU Ltd (2004)

Seabed type	Typical burial depths (m)
Exposed bed rock	0.0
Chalk	0.0 – 0.6
Stiff clay	0.4 – 0.8
Clay	0.6 – 1.2
Gravel	0.4 – 1.0
Coarse sand	0.4 – 1.0
Silty sand	0.6 – 1.2
Sand waves	0.0 – 3.0
Intertidal mud flats	0.6 – 3.0
Beach sand	1.0 – 2.0

5.49. BERR (2008) describes a number of specific methods for cable burial, including simultaneous lay and burial, a cost effective way of installing and burying the cable in the same operation. This is typically undertaken by a towed plough that has the power cable running through it. The plough lifts a wedge of soil and places the cable at the base of the trench before the wedge of soil backfills over the cable (BERR, 2008; SCUK, 2015). The plough can work in a wide range of soils, and can operate in shallow water and at depths up to 1500m. It is normally used where long lengths of cable burial are required (BERR, 2008).

5.50. Some seabed conditions may preclude the use of a simultaneous lay and plough burial solution. In these instances, a specialist trenching/jetting ROV might be used to bury the cable after it has been surface laid. ROV trenching/jetting machines can typically be used in softer sediments and can cause temporary localised plumes of seabed material (SCUK, 2015). Tracked cable burial machines can be operated in shallow waters and in depths up to 2000m. They are usually used on shorter lengths of cable burial work (BERR, 2008).

5.51. Free swimming ROVs can also be equipped with jetting and dredging systems, and can operate in post lay burial modes. They are limited to sands and clays, and are typically used on shorter lengths of cables, operating in water depths of 10m to 2500m (BERR, 2008).

5.52. Multiple cables in the same area are typically buried some distance apart from each other to allow for safe maintenance (ICPC, 2011) and minimise the effects of induced EMF on navigation and ecology. Spacing will depend on the footprint of any installation or burial equipment, and be informed by anchoring practices. Although it is considered that a corridor of 50m between each cable should alleviate any risk to either cable during installation and subsequent burial (Red Penguin, 2012), developers usually reduce this risk by increasing the distance between two cables, up to 500m (pers. comm., 2015).

5.53. Duration of the cable installation process is not only a cost factor, it also is an important aspect for generated environmental impacts. EMU ltd (2004) regard a progress rate of 1 km/h a typical rate in soft seabed materials, although the authors acknowledge it to be very variable.

Cable protection

5.54. Where cables cannot be buried, e.g. in areas of exposed bedrock, in areas where it is not legally required to bury them, or when there is a high risk of cable damage, the cable may require some form of protection (ICPC, 2011):

- Rock placement or mattressing can be used to cover the power cable and secure it to the seabed, or to create berms at third party crossings. Inert natural stone material should be used to minimise the degree of impact (OSPAR, 2012). This method is usually avoided in highly mobile sediments (JNCC and Natural England, 2011), and it is considered to sterilise the cable and leave it unrecoverable in the case of repair scenario. There may also be secondary scouring and other environmental impacts to consider (SCUK, 2015). Fronded concrete mattresses[14], in which buoyant fronds are built into the mattress, are considered to simplify deployment and provide additional protection against scouring and stabilisation.
- Articulate pipe. Cable pipes can either be fitted directly to the subsea cable and floated-out or can alternatively be installed by divers once the subsea cable has already been laid. Cable pipes can use ductile iron, a highly flexible and corrosion resistant material.
- Pre-cut trenching into which the cable is subsequently surface laid. This can be a reasonable solution in areas where there are mobile sand waves. Any trench that has been pre-cut, will need to be on the cable line and also remain open until the cable has been laid. This implies that it should only be undertaken a short time ahead of the main lay operation (SCUK, 2015).
- Rock cutting. In some areas, there may be a requirement to protect the cable as it traverses a seabed / shoreline comprising bedrock. In these cases, the use of specialist ROV's or other techniques may be required to cut a trench through the rock. It should be appreciated that the depth of the trench is only likely to be such that the top of the cable is below the level of the mean rocky seabed (SCUK, 2015).
- Cast anchoring, ducting. An example of this practice is provided by BMP[15], who use interlocking tubular half shells moulded in a high grade marine polyurethane system in order to accommodate a wide variety of cable diameters up to 350mm diameter.
- Use of special backfill materials for cable burial or to cover cables with reinforced concrete slabs or steel plates.

5.55. Periodic surveys will be required to check that cable remains secure. Danish regulations require a single post-installation survey to ensure correct burial depth, but no statutory post-construction environmental monitoring, although it is anticipated that other North Sea Countries may have stricter regimes, in particular Germany (P Skyt, pers obs, and interviewee response). Survey frequency and methodology is site-specific and should be developed to ensure consent compliance and best monitor areas of perceived risk along the subsea cable (The Crown Estate, 2015a and 2015b).

Cable operation

5.56. During operation, cables do not always lay flat and straight on the seabed, and unavoidable cable suspensions or freespans may occur due to seabed or installation conditions. Suspensions can form when a cable is suspended between points on an irregular seabed (e.g. rock outcrops), or is held under relatively high residual tension. This can cause damage to cables, including cable strumming, which can occur in areas where a cable is in suspension and the current can flow on all sides causing the cable to move at contact points, which can cause abrasion and mechanical fatigue in the cable. (The Crown Estate, 2015b).

Cable recovery

5.57. Subsea cables that are no longer used are usually left on the seabed depending on the age of the cable and the amount and type of protection used. This approach is usually considered the least

[14] http://www.subseaprotectionsystems.co.uk/concrete-mattresses
[15] http://www.subseacableprotection.com/products/cable-protection.cfm

environmentally damaging, given that habitats around cables usually adapt to them (JNCC and Natural England, 2011). In those cases where removable cable protection has been used in a soft sediment environment, removal is preferred, especially if the cable lies within a protected site (JNCC and Natural England, 2011).

5.58. Damage to cables requiring recovery and/or repairs may result from fishing and anchoring as well as exposure to high energy environments. As reported by CIGRE, average failure rate for all types of submarine power cables are 0.1114 faults/100km/year, occurring in an average of ten years after installation (The Crown Estate, 2015b). Repair of damaged power cables require specialist ships and cable jointing experts to replace the damaged section with new cable (ICPC, 2011). Recovery may also be undertaken following a need to clear congested routes.

5.59. Recovery generally entails:

- Location of the cable and, if a repair is required, identification of the faulted section;
- Retrieval of the cable with specially designed grapnels deployed from the repair vessel;
- Lifting to the surface for removal or repair, which may include cable sections to be replaced or insertion of additional cable protection.

5.60. Where the repair has been made in a buried section of cable, the cable is reburied by means of an ROV, water jetting the cable back into the seabed to a target burial depth equivalent to that when the cable was originally laid (KIS-ORCA[16]).

Environmental impacts and effects

Introduction

5.61. As shown in Table 5.5, during the laying, operation and removal of subsea cables, there is potential for a number of environmental impacts to occur, including disturbance, contamination, production of underwater noise, electromagnetic fields and heat emission, which can affect a number of different receptors, including other industries and marine users present in the vicinity of subsea cable deployments.

[16] http://www.kis-orca.eu/subsea-cables/maintenance-repair-operations#.VnLCb00SEzs

Table 5.5 Overview of how the effects of subsea cable installation and operation interact with environmental receptors. X = direct effect, O = indirect effect

Subsea cable impacts	Intertidal habitats	Offshore benthic habitats	Fish ecology	Marine mammals	Birds	Commercial fisheries	Navigation and shipping
Seabed disturbance	X	X	X		O	O	
Increase in suspended sediment concentrations and deposition	X	X	X		O	O	
Potential contaminant release from sediment	X	X	X	X		O	
Electromagnetic fields	X	X	X	X		O	
Thermal radiation	X	X					
Underwater noise and disturbance from vessel and installation activity			X	X	X	O	X
Exclusion of other industries from the area						X	X

5.62. For consistency across this report the following terms are defined as:

- Interaction: the link between an effect and the receptor. There must be an interaction for an impact to occur;
- Impact: consequence of an activity, predicted change in the baseline environment;
- Effect: consequence of impacts, usually measureable. Effects only occur when an activity or environmental impact is present within an environment that is sensitive to it.

5.63. This section provides a general overview of these potential impacts and considers their timescale (duration, frequency, reversibility), spatial extent and magnitude in relation to the different phases in the cable life. Effects on marine life and other industries are then described. Usual mitigation measures utilised in the industry are also described, accompanied by major knowledge gaps found in the literature reviewed.

5.64. It must be noted, however, that the nature, extent and significance of potential impacts caused by specific projects should always be determined on a site-specific basis as part of an environmental impact assessment.

Seabed disturbance

5.65. The installation, repair works and/or removal phase of subsea cables can cause physical disturbance and associated impacts including damage, displacement and removal of flora and fauna living on the seabed. This disturbance may result in the reduction of species diversity, abundance and biomass within the effect footprint (Dernie et al., 2003; OSPAR, 2012).

5.66. Compared to other offshore activities such as bottom trawling, ship anchoring or large scale dredging, seabed disturbance resulting from subsea cable activities are considered temporary and have a relatively limited extent (Carter et al., 2009; OSPAR, 2012), with the seabed usually returning to its original state (BERR, 2008). The impacts on benthic communities will depend on the sensitivity and conservation of the species that characterise the communities along the cable route (Defra, 2010).

5.67. The disturbance is restricted to a narrow strip of seabed, normally limited to an area 2-3 m either side of the cable (Bald et al., 2014; Carter et al., 2009), or in the order of 10 m width if the cable has been ploughed into the seabed (OSPAR, 2009).

5.68. Installation tools may have a footprint up to 10 m wide depending on the burial method used (NSN Link Limited, 2014; OSPAR, 2009). The level of seabed disturbance caused during clearance or installation is related to the device used, as well as the sediment conditions (BERR, 2008). Table 5.6 describes the seabed disturbance caused by different types of machinery.

Table 5.6: Seabed disturbance caused by different cable burial tools. Source: BERR (2008), OSPAR (2012)

Burial tool	Type of sediment	Disturbance mechanism	Potential effects
Plough	Sand, silt, all types of clay, weak rock, Hard rock / chalk/ gravel beds if using rock penetrating tooth or vibrating plough	Displaces the sediment as the plough moves along the seabed. This is then followed by natural backfilling of the trench which limits the level of disturbance and particle mixing.	Silt and structureless chalk are the most susceptible type of soil, and may remain in suspension for days.
Jetting system	Cohesion-less sediment	Soil can be liquefied or fluidised with water jets at relatively low velocities and pressures causing an increase in the soil volume. At high velocity/pressure soil can be eroded or scoured, transporting soil particles away. This also affects the trench deepening process, which may require several passes.	Material may suspend to the water column for prolonged periods (< day) and transported over longer distances than using ploughing.
	Cohesive sediment (clays)	The erosion / score rate is lower. Localised erosion and scour enables the jets to begin to form cuts in the solid material. Dredging systems may be used to remove cut material.	
	Weak rocks (including chalk)	It is very rare for a subsea jetting system to be deployed to attempt to cut trenches into a rocky seabed, and will often be accompanied by dredging.	
Dredging system	Sand, silt and certain clays	Dredging systems remove soil to create a trench by a process of suction. Dredging systems work best when the	Leads to greater sediment displacement than in the case of ploughing/jetting.

Burial tool	Type of sediment	Disturbance mechanism	Potential effects
		soil is in a slurry state, working better with small size particles. They are often used in combination with a jetting system that fluidises the soil prior to dredging. Once dredged, soil material can be deposited on a barge or dispersed into the sea away from the trench.	The impact on marine life will depend on ability for adaptation to sediment deposition.
Rock wheel cutter and chain excavators	Hard clays and rock. Sometimes used in sands and gravels.	The rock is cut to form a narrow slot (of around 0.5 to 1 m) into which the cable is placed. The material is broken down into constituent components (i.e. sand for sandstone; silt for siltstone, etc.).	The loose material becomes suspended. The movement of the chain can fluidise the granular soil in vicinity of the cutter and the disturbed material remains contained within the ground minimising the amount of soil dispersed.

5.69. The level of disturbance caused by ploughs is therefore considered to be lower compared to jetting techniques (OSPAR, 2012).

5.70. The application of cable protection structures along the cable route in areas characterized by soft sediments will also lead to the artificial introduction of hard substrates, leading to the direct loss of habitat, and may require separate licences by regulators. It is advised to avoid using these in areas of soft sediments. In addition, these structures or the submarine cables themselves, if not buried, will also provide a solid substrate for a variety of species. This 'reef effect' may lead to the introduction of non-local fauna and thus to an alteration of the natural benthic community (Kerchhof et al, 2007; Tyrell and Byers, 2007; OSPAR, 2009). In most cases effects will be localized although long-lasting.

5.71. New subsea cables today have an expected life of around 40 years, although the risk of cable failure increases after 10 years of the cable being installed (The Crown Estate, 2015b). Installation is therefore considered a singular event that will not occur again unless maintenance is required, or if the removal of the cable is needed at the decommissioning phase (Carter, Burnett and Davenport, 2014). Table 5.5 shows that seabed disturbance is likely to have a direct effect on intertidal habitats, offshore benthic habitats and fish and shellfish ecology, and an indirect effect on birds through the loss of prey availability.

5.72. Less stable habitats (coarse, clean sands) recover quicker than more stable habitats (mixed sediments, muddy sands and mud) (Dernie et al., 2003), and although sensitive species may show longer recovery periods (Dunham et al., 2015), in both instances the overall footprint on the seabed is likely to be small. However, as cables cover a large longitudinal area they are likely to encounter a variety of habitats at different depths (JNCC and Natural England, 2011).

5.73. Some mobile benthic species (for example, crabs) are able to avoid most disturbance whereas sessile (bivalves, tubeworms etc.) and sensitive species (such as slower growing or fragile species) will be more impacted (OSPAR, 2012). During cable burial, benthic species in the vicinity of the cable route may suffer direct mortality with disturbance areas occurring between 2 – 3 m each side of the cable (Bald et al., 2014; NSN Link limited, 2014).

5.74. The reproduction of certain fish species is linked to certain sediment types and can occur at certain yearly periods. Sediment spawning fish species, such as Atlantic herring (Clupea harengus) and sand eels (Ammodytes marinus) can also be affected through direct loss or injury to eggs and larvae. Sand eels display a high level of site fidelity in terms of habitat preference (Forewind 2014; Lancaster et al., 2014; Van der Kooij et al., 2008; Reid et al., 1999).

5.75. Cable installation will have some impact on foraging birds, specifically wintering and migratory birds, through the indirect loss of prey species. A disturbance may be of increase importance if within a designated Special Protected Area (SPA). The impact of prey availability is not usually considered significant in EIA terms and is usually justified by the ability of birds to forage in different areas.

5.76. Intertidal biotopes such as sand and mudflats display a low sensitivity to and high recoverability from temporary sediment displacement likely to occur from trenching, ploughing or jetting. Burrowing species are likely to re-establish themselves in the sediment and the displacement yields a high availability to birds for a short period of time. The recovery of these habitats is dependent on the hydrodynamics of the surrounding area, although sandy sediments are likely to recover in less than a year (Budd, 2004). A more long-term effect may also be seen if installation is required through a harder substrate.

Mitigation Measures

5.77. While cable installation has an effect that is limited in spatial extent and temporary in nature, the selection of the cable route will assist in avoiding sensitive habitats such as shingle banks, saltmarsh, biogenic reefs or areas that present important sessile (non-mobile) communities or species; as well as avoiding these at specific times of the year, when they may result important for migration, spawning or foraging areas among others; and cable burial / installation method will reduce impairments occurring during cable laying (BERR, 2008).

5.78. Government advisors recommend the use of cable burial whenever possible using techniques that minimise potential environmental impacts depending on sediment type (JNCC and Natural England, 2011), and HDD has been recommended in intertidal areas (Defra, 2010). This also includes the consideration of construction programmes. For instance, cable burial in tidal flats is recommended to take place at low tide, using vibration ploughs whenever possible (OSPAR, 2012). The consideration of species specific behaviours is also important. The restriction of cable installation activities to certain times of the year (Forewind, 2014a) can also minimise some of these disturbance impacts.

5.79. In terms of decommissioning, in some cases it may be advisable to leave cables and associated infrastructure on the seabed, this is particularly the case for cables where frond mattressing has been used. This is, however, always decided on a case-by-case basis (JNCC and Natural England, 2011).

Knowledge gaps

5.80. It is considered that direct impacts of subsea cables on seabed disturbance are well understood, with evidence on potential pathways for effect associated with specific machinery and sediment types currently available. There is however, limited information on quantification of material arising from cable burial operations. Additional research has, however, been identified as required by OSPAR (2012) regarding the regeneration period and capacity of sensitive habitats like Posidonia meadows, mudflats and reefs.

5.81. Intertidal habitats are known to be of special concern given that these are areas usually designated for protection of coastal natural structures and important habitats for coastal fauna, such as intertidal birds, as well as human visitors.

Increase in suspended sediment concentrations and deposition

5.82. During cable installation or recovery, seabed sediment will be re-suspended into the water column increasing suspended sediment concentrations (SSC) and creating sediment plumes that can have an effect, either positive or negative on habitats and species (Dernie et al., 2003). The scale of effect will vary dependent on the sediment size and the relative amounts of disturbance undertaken, but it is considered that the effect of sediment plumes created by subsea cable associated activities are of smaller magnitude than those associated with other marine activities, such as aggregate extraction.

5.83. Tidal flow and hydrodynamic currents control the sediments dispersion (BERR, 2008). The strength of these currents determines the extent of effect of the suspended sediment and in turn where it finally settles. Coarser sediments such as sand and gravel settles relatively close to the origin of disturbance, while finer sediments such as clay and silt can remain in suspension for a longer period of time creating a large impact footprint. However the greater the dispersion also results in a smaller level of deposition at one point.

5.84. The level of re-suspended sediment largely depends on the equipment being used and the sediment type. Modern equipment and techniques have reduced the volume of sediment re-suspended (e.g. ploughing creates less re-suspended sediment than jetting) (Nemo Link, 2013a). The majority of sediment deposition occurs within tens of meters of the cable route.

5.85. Hydrodynamic models can predict the dispersion and deposition and suspended sediments. When calculating the impact of a development it is important to take into account the existing baseline and activities occurring the area of study, as an increase in suspended sediment is unlikely to have a significant effect if existing suspended sediment concentrations are already high due to aggregate extraction or fishing activity (BERR, 2008). Yearly variation should also be considered, including the frequency of storms.

5.86. Different species show different sensitivities to the level of suspended sediment. Smothering is likely to have a direct effect on intertidal habitats, offshore benthic habitats and fish and shellfish species as well as an indirect on fish and shellfish prey species.

5.87. Benthic and intertidal communities in mobile sandy sediments are generally well adapted to regular disturbance (Nemo Link, 2013a). Benthic communities can recover quickly because they have natural adaptive behaviours gained from an environment that is subject to change (Carter et al., 2009). The type of grain often influences what species inhabit an area, with silts and sands characterized by opportunistic species and stationary species (e.g. tube-dwelling worms) associated with sands and gravels (Seiderer and Newell, 1999). Larsson et al., (2013) found that Lophelia pertusa (cold water coral) can cope comparatively well with enhanced particle deposition rates and SSC, although it may be vulnerable to high particle concentrations. Filter feeders can be affected through the clogging/blockage of filtration systems and the damage to feeding structures, which can result lethal (OSPAR, 2009). Sabellaria spinulosa, a protected Annex 1 habitat (under the Habitats Directive) and quite predominant in the North Sea is considered to be tolerant of increased suspended sediment and has high recoverability from smothering (Nemo Link, 2013a).

5.88. Mobile fish and shellfish species are expected to be able to move away from areas of increased SSC and areas of deposition. Fish eggs and larvae, however, are not as mobile and can be particularly sensitive to SSC and smothering. Increased SSC and subsequent smothering in breeding grounds for sediment spawning fish and shellfish may result in injury, abnormalities or lethal effects on eggs and larvae.

Mitigation measures

5.89. As mentioned in the previous section, mitigation measures aimed at reducing seabed disturbance and associated sediment plumes should focus on the adjustment of the cable route to avoid certain sensitive habitats and species, and consider different installation techniques and protection measures depending on the sediment type.

5.90. In order to promote recovery within the intertidal zone, material displaced as a result of cable burial activities should be back filled in order to reduce the potential for remobilisation of sediments and enables faster recovery of benthic organisms. Where sensitive habitats are present along the cable route and vegetation is subject to removal for clearance, it may be necessary to replant, enhance and or stabilise vegetation conditions after installation (BERR, 2008). Guidance relating to translocation and enhancement of saltmarsh habitats is provided by the Environment Agency (EA, 2005), RSPB (2005).

Knowledge gaps

5.91. As noted in the previous section, there is a need for further research on the quantification of material that is actually released in suspension by different machinery types. This could benefit from monitoring and modelling techniques to identify the fate of suspended material (BERR, 2008).

Potential contaminant release from sediment

5.92. Subsea cable installation may release/remobilise contaminants held within the sediment when the seabed is disturbed (BERR, 2008). The type of sediment will determine whether contaminants are likely to be held in the benthic environment, as well as the distribution rate. Sediment quality is assessed before a cable is laid and the cable route is designed to avoid any known contaminated areas (OSPAR, 2009; Meißner et al., 2006).

5.93. Contaminants, such as oil and heavy metals, are most likely found near the coastline, generally attached to fine sediments, although certain chemicals can persist in coarser sediments (BERR, 2008). The impact is of less importance when considering offshore areas. Contaminant release is only a concern in heavily contaminated locations; areas of particular concern include major ports, oil and gas developments, historical industrial areas, waste disposal or natural sinks (OSPAR, 2009). In coastal areas, the laying of cables can also lead to increased nutrient releases into the water column and consequently may contribute to eutrophication effects locally.

5.94. The release of contaminants usually occurs within a localized area for a short period of time during the installation and potentially during any maintenance activities or decommissioning, and should only be of concern near industrialised areas (Meißner et al., 2006; BERR, 2008).

5.95. Contamination effects on fauna have been intensively examined in a number of studies (Meißner et al., 2006). Contaminants released into the water column can cause effects on certain species if certain levels are reached, and they can also bioaccumulate through the food chain (BERR, 2008). Table 5.5 shows that contaminant release from sediment will potentially have a direct effect on intertidal habitats, offshore benthic habitats fish and shellfish ecology and marine mammals. There may be an indirect on commercial fishing if fish populations are affected.

5.96. The main exposure route to marine organisms from contaminants within the sediment is through direct digestion by benthic species or indirectly when those species are consumed (CEFAS, 2001). Contaminants that remain in solution can be up taken by organisms through passive diffusion, active uptake or absorption in the gut (CEFAS, 2001). Contaminants can include both organic and inorganic compounds. Many inorganic chemicals are toxic at low concentrations (e.g. mercury, cadmium and lead), while others are essential for life but can be highly toxic at high concentrations (e.g. copper, iron and zinc). Contaminants of concern include hydrocarbons, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, metals and alkylphenols (CEFAS, 2001).

5.97. Population level effects have been observed on fish that reside in contaminate coastal areas, with slower growth rates and higher mortality rates (McGourty et al., 2009). Fish have been shown to be very sensitive to PAH pollution, affecting both non-specific and specific immunity (Reynaud and Deschaux, 2006). A study within the North Sea and in the Baltic Sea, among others, found that contaminated sea-surface microlayers can be toxic to marine fish embryos (Baltic herring and Atlantic cod), producing significant mortalities or deformities (Wurl and Obbard, 2004; Kocan et al., 1987).

5.98. High levels of cadmium in sediment has shown not to affect the level of colonization by benthic taxa, however, trait features in benthic communities can be affected (Trannum et al., 2004). With increased cadmium levels, ecological function changed from permanent attachment and surface deposit feeding to shallow sediment dwelling and subsurface deposit feeding (Oug et al., 2012).

5.99. Marine mammals are at the top of the food chain and have been shown to be both bioaccumulators and biomagnifiers. A number of studies have shown the health risks to marine mammals from contaminants (Jepsen *et al.,* 2005). The stress induced by contaminants may combine with other stressors compounding any effects. Polybrominated diphenyl ethers (PBDEs) have been shown to be endocrine disruptors in grey seals (Hall et al., 2003). A causal relationship has been shown between mortality from infectious diseases and exposure to PCB concentration within harbour porpoise (Hall et al., 2006; Jepson et al., 2005).

5.100. Although physiological effects arising from the remobilisation of contaminants can be of great harm to marine ecological receptors it is considered that only small volumes of sediment are likely to be re-suspended from cable installation, and that careful route planning can avoid any known contaminated sediments keeping any pollution to a minimum.

Mitigation measures

5.101. As previously mentioned, it is important to consider the location of potential highly contaminated sites at the planning stage. Highly industrialised areas should be avoided by the cable route.

Electromagnetic fields (EMF)

5.102. Subsea cables contribute to the emission of electromagnetic radiation, generated as a result of the flow of electrical current in the cable (Gill and Bartlett, 2010).

5.103. AC power cables are the industry standard for offshore renewable energy facilities. DC cables are used for longer transmission lengths, either projects further offshore or for interconnector cables (see Table 5.2). Industry standards for subsea cables require shielding to block the electric field emitted using conductive sheathing. EMFs in this context therefore refers to the magnetic field and the electric field induced which are both within the range of detection by EM-sensitive marine species, such as sharks and rays (elasmochranchs) (Normandeau et al., 2011). Although it is theoretically possible to contain the magnetic field and hinder its transmission, the practicalities and cost implications make the option unfeasible (Gill and Bartlett, 2010). Magnetic fields can, however, be reduced by grouping cables.

5.104. There are different factors influencing the distribution of the electromagnetic field in the waters, such as voltage, electrical current, cable design and AC or DC. For both AC and DC cables the field intensity is directly related to the voltage on the cable. The magnetic field for the cables is strongest directly over the cable and decreases rapidly with distance (Normandeau et al., 2011). A polish case study (Andrulewicz et al. 2003) within the Baltic Sea found that the modification of the magnetic field within a few metres of the cable is significant and at a distance of 20 m any changes in the magnetic field did not exceed natural changes in the earth's magnetic field. A higher current within a cable results in a larger EMF in the sea and the seabed (Gill and Bartlett, 2010).

5.105. Magnetic sensitivity is understood to be associated with the orientation and direction finding ability of an organism (BERR, 2008). EMFs have the potential to affect feeding, predation, conspecific detection, navigation, orientation and reproduction (Normandeau et al., 2011). Table 5.5 shows that electromagnetic radiation has the potential to directly effect on fish ecology, marine mammals, intertidal habitats and offshore benthic habitats, as well as shipping and navigation. An effect on fish ecology may result in an indirect effect on commercial fisheries, although the subject has not been studied in enough detail to produce any conclusions on this.

5.106. Electroreception, the ability to sense weak electrical fields, has evolved in numerous vertebrates (marine mammals, fish groups inter alia elasmobranchs and invertebrates) the majority of which are aquatic species. These species are able to detect bioelectric emissions from prey and potential predators/competitors. Few invertebrates have also been investigated for an electric sense, although there is recent evidence in decapod crustaceans (Woodruff et al., 2013).

5.107. EMFs can have two potential effects on the behavior of elasmobranchs. The main impact is related to the ability of EMFs to potentially deter these species from feeding in and around the area where cables are buried (BERR, 2008), at the same time, however, there is potential for EMFs to attract them to these areas. Gill et al., (2009) found that lesser spotted dogfish and thornback rays were attracted to EMFs, with lesser spotted dogfish more likely to be present within the EMF zone and thornback rays showing increase movement around the cable when switched on. Yet, the responses were not predictable or consistent and the response also seemed to be both species and individual specific (Gill et al., 2009). Further research found that lesser spotted dogfish showed no preference between artificial (dipole) and natural (associated for example with live crabs[17]) DC electric fields, but had a strong preference for two DC fields and a less, but still significant, preference for AC fields over DC fields (Kimber et al., 2011).

5.108. Migratory fish species are only likely to utilize EMF's at specific stages of their life cycle, principally during migration (Gill and Bartlett, 2010). A number of diadromous migratory species rely on the Earth's magnetic field for orientation. Certain fish are able to detect voltage gradients despite not possessing specialized receptors (Gill and Bartlett, 2010).

5.109. Gill and Bartlett (2010) reviewed the current knowledge on the potential effects of EMF on the European eel, salmon and sea trout. They concluded that the EMF from subsea cables may interact with migrating eels and possibly salmon, if their migration routes take them over the cables, particularly in shallow water. It was undetermined whether there would be a biologically significant effect but the

[17] DC bioelectric fields emitted by live shore crabs have been estimated to be similar to those associated with 16 µA currents (Kimber *et al.* 2011)

effects could range from a temporary change in swimming direction to an avoidance response or delay to migration. Orpwood et al. (2015) studied the influence of AC magnetic fields on the swimming activity of European eels, a migratory species, in a controlled laboratory setting. No evidence of a difference in movement or any observations of startle or any other behavioral change was found. Orpwood et al., (2015) noted that the field strengths may be lower than encountered in the wild. Armstrong et al., (2015) found no significant different in approach, traverse or departure times of large Atlantic salmon to activated Helmholtz coils and no significant difference in the numbers of small post-smolts passing through the coils, in relation to magnetic field intensity of the sequence of magnetic field intensity.

5.110. In relation to marine mammals, it has been suggested that some cetacean species use geomagnetic cues to navigate over long distances of open ocean that do not have geological features for orientation (Fisher and Slater, 2010). It is therefore considered that anthropogenic sources of EMF have the potential to affect spatial orientation. This can result in increased energy usage, potential delays to migration or alterations to movements and, in a worst case scenario and indirectly, could result in strandings for marine mammals (cetaceans attempting to use geomagnetic topography for orientation) (Fisher and Slater, 2010; Normandeau et al., 2011).

Mitigation measures

5.111. The depth a cable is buried at does not affect the magnetic field strength or the associated induced electric fields, however burial does reduce the strength of the induced electrical field when compared to a cable placed on the sediment surface (CMACS, 2003). Burial also reduces the exposure of electromagnetically sensitive species to the strongest EMFs. Magnetic fields reduce with distance from the source and any effect from high intensity magnetic fields will be highly localized and can be potentially resolved by burial or armouring (Orpwood et al., (2015).

Knowledge gaps

5.112. The current level of research results in the implications of the potential effects of EMF (if any) originating from subsea cables remain unclear, with no significant impacts found to date. The majority of literature currently focuses on the elasmobranchs and lampreys that have specialized electroreceptors, however there is little understanding on how EMFs can affect other species such as cetaceans or migratory fish.

5.113. Limited species by species data is available. Even for studied species, research is mainly limited to a particular life history stage or natural behaviours and interactions. Knowledge of the sensory capabilities of certain species can be extrapolated to others, although this should always be done with caution. Research evaluating biological responses to anthropogenic EMFs is almost absent, and it still remains unknown whether any effect, if present, would be either positive or negative.

5.114. There has been no targeted monitoring specifically investigating whether distributions of crustaceans and molluscs have been affected by the presence of subsea cables, monitoring to meet other objectives has not revealed any evidence to show such an effect. Nevertheless there are uncertainties around the significance of this potential impact.

<u>Thermal radiation</u>

5.115. A certain amount of energy gets lost as heat when electricity is transported through subsea cables. This heat loss has the potential to cause an increase in temperature on the cable surface, potentially warming the surrounding ambient environment. Subsea cables installed on the sea floor do not heat up their surroundings due to the constant flow of water dissipating the thermal energy (Worzyk, 2009). However, buried subsea cables may result in sediment that is slightly warmer in the immediate vicinity (Worzyk, 2009).

5.116. The current suggestion is that the thermal effect is a small increase in temperature within a few centimetres of the cable (Boehlert and Gill, 2010). A study for the BritNed interconnector indicated that during the summer the immediate sediment temperature may increase between 0.5°C and 5.5°C through localized heating when the cable is buried at a depth of 1 m. At a burial depth of 3 m the increase in temperature was calculated to be between less than 0.5°C to 1.8°C. A field experiment on subsea power cables from Nysted offshore windfarm found the maximum temperature difference between control sites and cable sites was 2.5°C and the mean difference was 0.8°C (Meißber et al. 2006).

5.117. The only organisms likely to be affected by warming are burrowing species, as the water column will dissipate any surface temperature increase caused by subsea cables (NSN Link limited, 2014). The temperature increase will be small and highly localized, with most bottom dwelling organisms found within the top layers of the seabed (Borrmann, 2006).

5.118. The type of cable will often determine the level of thermal radiation that is emitted, with heat dissipation expected to be more significant for AC cables than for HVDC cables at an equal transmission rate (OSPAR, 2009). The majority of subsea power cables are designed to eliminate excessive loss of thermal radiation (Worzyk, 2009). Other important characteristics effecting the level of thermal radiation include transmission rate, sediment characteristics and ambient conditions (Meißber et al. 2006). Table 5.5 above shows that thermal radiation has the potential to have a direct effect on intertidal habitats and offshore benthic habitats.

5.119. It has been considered whether the localised, minor increase in temperature would actually result in a realistic impact upon environmental receptors, given the larger disturbance of the seabed (Boehlert and Gill, 2010). With seabed disturbance there is undoubtedly a recoverability factor once the cable has been buried, while thermal radiation from the cables operation would be constantly emitted. Tasker et al., (2010) as part of the Marine Strategy Framework Directive Task Group 11 recognised this lack of knowledge, but also recognized the relatively localized effects of anthropogenic heat input.

Knowledge gaps

5.120. There is a lack of field data on the effect of thermal radiation on benthic habitats, making it difficult to draw conclusions. This results in organisations, such as OSPAR, recommending the precautionary principle based on the assumption that there will be changes in physiology, reproduction or the mortality of certain species (OSPAR, 2009).

<u>Underwater noise and disturbance from vessel and installation activity</u>

5.121. The disturbance from vessel activity and installation activity can affect a range of receptors through underwater noise produced by both the vessel and machinery, increased vessel traffic or visual disturbance. However, vessel activity associated with cable installation occurs over relatively short time periods and is a singular event that may not occur again over the projects life cycle, unless maintenance work is required.

5.122. Underwater noise can be produced by vessels and machinery used during route clearance, trenching and backfilling, cable installation and introduction of cable protection. If HVAC cables are used, permanent vibration noise emission from the cable also needs to be considered (Meißner et al., 2006).

5.123. The Marine Strategy Framework Directive (MSFD) (see section 11, Appendix A) recognized three noise indicators that affect broad areas of the marine environment (Tasker et al., 2012):

- Low (< 1 Hz) and medium (1-20 Hz) frequency[18] sounds – multiple perceived negative effects;
- High frequency (< 20 Hz) impulsive sounds – sources such a sonar used on small vessels;
- Low frequency, continuous sound – mainly originating from shipping activity.

5.124. The maximum sound pressure levels from cable installation or operation are generally considered to be low (OSPAR, 2012), and are considered to be less disturbing to marine fauna than higher frequencies, contributing to background noise resulting from shipping, fishing and natural noise (wind and waves) in a lesser extent.

5.125. The primary source of noise has been shown to be emitted from the installation vessels (NSN link Limited, 2014; Meißner et al., 2006), which is similar to that of other ships and boats. Due to the high background levels of vessel traffic across the North Sea and the short term presence of the cable installation vessels over a short period of time it is unlikely to have any long-term effects on the surrounding environment.

5.126. Trenching noise has been found to be a mixture of broadband noise, tonal machinery noise and transients associated with rock breakage. The level of noise can be highly variable and dependent on the physical properties of the particular area of seabed that is being cut (Nedwell et al., 2003). In general, the power spectral density of cable trenching noise is only some 10 – 15 dB above the level of background noise, however, no reliable estimates of transmission loss or source level were able to be made (Nedwell et al., 2003).

5.127. Increased vessel traffic can also have an impact of a number of receptors, causing displacement in sensitive areas for foraging or breeding. At the same time, vessels can potentially release sewage, food waste, drainage water and grey water into the marine environment. Discharges from vessel can be potentially harmful to marine organisms causing organic enrichment, introduction of invasive species or increased chemical concentrations. The small number of vessels involved with cable installation result, however, in a small cumulative volume of any discharged released (NSN Link limited, 2014). Considering within the North Sea, there is a high existing level of vessel activity, any discharges from subsea cable installation vessels will only have a short term and localised impact. Vessels also must comply with the International Convention for the Prevention of Pollution from Ships (MARPOL) regulations, which reduces the risk of any impact further.

5.128. Table 5.5 shows that disturbance from vessel and installation activity will potentially have a direct effect on marine mammals and fish ecology and an indirect effect on birds.

5.129. In terms of underwater noise, compared to seismic surveys, drilling, pile hammering or military activities, noise generation related to subsea cable projects are not be considered to have the greatest potential for harming marine fauna (Meißner et al., 2006) and effects vary according to the hearing ability of each species. In general, fish are considered as low frequency hearers whereas marine mammals hear at high frequency (Meißner et al., 2006). Possible effects of underwater noise on marine organisms include attraction towards the source, avoidance, temporary hearing damage or permanent physical injury (Nedwell and Howell, 2004; Meißner et al., 2006).

[18] Noise frequency is the rate of oscillation of the sound pressure wave progressing through a medium such as water or air, measured in Hertz (Hz).

5.130. Sound is an important tool for communication in fish (Slabbekoorn et al., 2010), and hearing specialist species are the most sensitive (BERR, 2008; Popper and Hasting, 2009). The presence and noise produced by installation vessels and equipment has the potential to provoke fish displacement from the vicinity of operations, although highly localised and temporary, generally considered not to have a significant impact on fish resources (BERR, 2008) with noise levels anticipated to be below those believed to cause physical harm (NSN Link limited, 2014).

5.131. Nedwell and Howell (2004) investigated the noise emitted from the mechanical dredging and trenching for a pipeline near Shetland, showing that only a mild behavioural response can be caused in fish species, with the noise level being below the suggested avoidance threshold. In addition, the noise arising from these works is considerably greater than the equivalent for a subsea cable due to its greater size. It is considered that the area in which noise will be at a level high enough to cause a behavioural response in fish is likely to be around 50m of the cable site (Nemo Link, 2013a).

5.132. All marine mammals have evolved to use sound as an important aid in navigation, orientation, communication, foraging and hunting, and consequently, interference from anthropogenic sound has the potential to affect these uses (Southall et al., 2007). There are no clear indications that underwater noise caused by the installation of subsea cables cause behavioural reaction by marine mammals (BERR, 2008; OSPAR, 2009). An avoidance response to the sound may be expected but only within a limited extent and over a short time period.

5.133. At the same time, vessel traffic has the potential to directly impact seabirds through displacement from foraging areas both onshore and offshore (Langston, 2010). The level of disturbance is highly dependent on the species of bird and there have been numerous studies focusing on the quantification of disturbance for individual species often within the context of offshore renewable energy development and installation activities (Maclean et al., 2009; Langston, 2010; Thaxter et al., 2012; Furness et al. 2013).

5.134. The short time period of installation works on the foreshore (4 weeks for NSN link) (NSN link limited, 2014), limits the disturbance to bird species foraging in the intertidal area. Foraging birds will temporarily lose a small proportion of intertidal benthic habitat during installation. Offshore, disturbance will be highly limited, both spatially and temporally and would not be of major concern for birds if sensitive areas are avoided.

5.135. Marine mammals may potentially be disturbed by the presence of vessels particularly in sensitive locations such as seal haul out sites and foraging areas or during sensitive periods for instance breeding seasons (BERR, 2008). It has been shown that for grey seals vessel traffic abiding the conservation code of conduct of the area in Ceredigion (Wales) did not appear to induce any short-term behavioural responses (Lewis, 2006). The increased presence of installation vessels may cause increase in risk collision with marine mammals. Most lethal injuries are cause by ships 80m or longer and involve ships travelling 14 knots or faster (Laist et al., 2001), which are not of relevance to vessels used for cable installation, which work at low speeds.

Mitigation measures

5.136. Vessel activity and installation related disturbance can be effectively mitigated by avoiding cable installation operations in the vicinity of sensitive areas, such as known haul out sites, and during sensitive periods such as migration periods, breeding seasons or foraging patterns. Further offshore construction times should consider resting and wintering areas of ducks and seabirds as well as areas known for marine mammals, especially calving sites of harbour porpoise. The definition of time windows for cable laying can thus be a very effective measure for reducing environmental impact where necessary (OSPAR, 2012).

5.137. As a precautionary measure, given the conservation significance of marine mammal species often involved, it may be necessary to employ marine mammal observers on the installation vessel and to have a protocol in place to delay installation activities from occurring if marine mammals are detected within a predetermined distance from the installation vessel.

Knowledge gaps

5.138. Noise produced by different installation machinery needs to be further assessed in order to inform potential impacts on fish species and marine mammals (BERR, 2008). Only one study has looked at the noise emissions from cable installation as highlighted in OSPAR (2012). This is mainly due to the fact that noise is not considered a key environmental issue in association with subsea cables, especially when compared to seismic surveys, pile driving or military action.

Interaction with other industries from the area

5.139. Subsea cable deployment has the potential to impact on marine industries present in the area being considered for deployment, this includes impacts on commercial fisheries as well as other shipping and navigation activities, which at the same time can also result damaging to subsea cables.

Commercial Fisheries

5.140. Subsea cable deployment has the potential to impact on commercial fisheries through activities exclusion, impacts on targeted fisheries resource or due to alterations to fishing practices as a consequence of cable laying operations. This is considered to be a very localised effect and avoidable if planning measures and appropriate stakeholder engagement are implemented.

5.141. There are two main approaches to commercial fishing, the use of mobile gear (where the nets or lines are towed by vessels) and static gear (where nets, lines or pots are left in the environment for a period of time). The use of different methods will require the use of specialised vessels, such as bream trawlers, sine netters, trawlers and dredgers (BERR, 2008).

5.142. The main effects of cable laying on commercial fishing activity are related to the restriction to fishing grounds, temporary fish stock displacement or the snagging of fishing gear, which can consequently lead to reduced returns and/or increased costs for the fisheries industry. The actual significance of the effect would be highly site specific and dependent upon the duration of the installation process (BERR, 2008).

5.143. Fishing vessels are often prevented from fishing in the immediate area during cable laying and burial operations, restricting temporary access to fishing grounds, established by the designation of safety zones around work boats (BERR, 2008). For instance, under Danish legislation[19] all cables and pipelines are protected in a zone of 200m along each side of a subsea cable, where anchoring, trawling and extraction among other activities are restricted. Impacts associated with restriction to fisheries areas are considered very short-term and not significant.

5.144. During construction, fish displacement caused by vessel and installation disturbance (see above) or alterations to seabed habitats on which fish species rely on can take place (BERR, 2008). The

[19] Order No. 939 of 27 November 1992 on the protection of submarine cables and pipelines: http://www.dma.dk/SiteCollectionDocuments/Legislation/Orders/1992/27-11-939_Bek_nr_939_om_beskyttelse_af_søkabler_og_undersøiske_rørledninger_FINAL_(mål_eng).pdf

introduction of hard substrates, for example, can actually increase habitat diversity and commercial resources (BERR, 2008). Due to the short duration of construction and installation activities, these effects are considered to be of low magnitude.

5.145. The greatest risk associated with fishing-cable interactions is to trawlers, as they are dragged along the seabed and may 'snag' a cable, posing a significant danger to the vessel and its crew, and risk to damage the subsea cable. Trawl fisheries can operate in water depths to 1,500m and more (Carter et al., 2009)

Navigation and Shipping

5.146. Cable installation and maintenance activities, and associated vessel activity have the potential to increase the risk of collision with existing navigational users. It is considered that this risk is of temporary nature, and can be mitigated through careful planning and notification to Marine Coastguard authorities or any other relevant stakeholders. Subsea cable projects will often have a Navigation Risk Assessment in place establishing good practice and risk controls and protocols (BERR, 2008). At the same time, shipping activities, such as anchoring are considered a key threat to cable security.

Mitigation measures

5.147. In order to avoid conflict with fishing vessels and avoid damage to cables, it is recommended that information on fisheries activities is analysed and considered early at the planning stage, with submarine cables being buried where feasible, or suitably protected. For instance, trawls are designed to pass over seabed obstacles, and most cables in trawling depths are armoured, providing greater protection and lower fault rates (Carter et al., 2009).

5.148. Stakeholder engagement is also considered a useful tool for sharing knowledge and ensuring appropriate awareness of the risks and consequences to commercial fisheries and the shipping industry. For instance, in the UK, the KIS- ORCA[20] (Kingfisher Information Service – Offshore Renewable & Cable Awareness) project provides free cable awareness charts; electronic route position lists and digital information for chart plotters to fishing vessels and legitimate marine stakeholders. Key fishing organisations and stakeholders are working with the sector to promote this project and assist with the local distribution of the data. In addition, specific guidance at a regional or national level targeting collaboration between fisheries and subsea cable developers has been produced by the International Cable Protection Committee (ICPC) (Drew and Hopper, 2009), or with offshore renewable development by the Fishing Liaison with Offshore Wind and Wet Renewables Group (FLOWW) in the UK (FLOWW, 2014).

5.149. Appropriate safety and navigation risk assessments and protocols should be established in all instances to avoid or mitigate any conflicts.

Cumulative effects within the North Sea

5.150. The marine environment is highly complex with numerous environmental, social and economic interactions, with naturally occurring changes also affecting the baseline. Human activities within the marine environment include plans (industry wide development plans), projects (individual subsea cables) and activities (commercial fishing). With the future plans of developing the offshore grid in

[20] http://www.kis-orca.eu/

Europe and in particular the North Sea, it becomes increasingly important to consider the potential for cumulative effects from these developments.

5.151. Cumulative effects are defined as 'net effect of cumulative pressures' from past, present and reasonably foreseeable activities, including consideration to both direct and indirect effects from multiple activities (HELCOM/VASAB, OSPAR and ICES, 2012).

5.152. An individual effect alone may be considered insignificant, but the additive effect from multiple sources could result in a significant effect either positive or negative on the marine environment. Cumulative effects and in-combination effects have similar meanings and it is the legislative context which differs affecting how they are described and approached. The SEA Directive, the Habitats Directive and the EIA Directive (see section 11, Appendix A) are the legislative drivers for cumulative effect assessment (CEA). This exercise has been reviewed a number of times and there are different general and sectoral guidelines currently available. (EC, 1999; NOAA, 2012; IFC, 2013; RenewableUK, 2013). However, there is no defined statutory approach or consensus on how a CEA should be undertaken for subsea cable deployments, and there are a number of uncertainties that need to be clarified to the industry, including:

- Scoping of impacts to be considered, which will rely on evidence provided to support the EIA;
- Definition of temporal and spatial scale – which may need to be adapted to each receptor being considered;
- Identification of other projects, plans or licensable activities;
- Data confidence associated with other projects, plans or licensable activities;
- Assessment methodology (qualitative vs. quantitative assessment)

5.153. The contribution of subsea cable effects to cumulative or in-combination effects caused by installation, maintenance or decommissioning activities is generally considered to be limited because of the short-term nature of burial/recovery activities. During cable operation, given the current knowledge available on the actual significance of anthropogenic sources of underwater noise and EMFs, it is only possible to make educated assumptions about these cumulative effects (Gill and Berret, 2010). Of greatest concern are those species whose early life stages could experience repeated exposure to the same subsea cable. However, in many cases, changes in sensitivity to EMFs/thermal radiation is not well understood over life stages (Normandeau et al., 2011)

Data collection opportunities

5.154. The demand for marine data continues to grow as anthropogenic uses for the marine environment increase. There are a number of on-going research projects focusing on the impacts and marine infrastructure in the marine environment, for instance the INSITE programme[21] (INfluence of man-made Structures In the Ecosystem) is a major industry-sponsored project with the overall aim of providing stakeholders with the independent scientific evidence-base needed to better understand the influence of man-made structures on the ecosystem of the North Sea, which will run until end of 2017.

5.155. The demand for marine data has also led to the development of a number of marine data portals where project's information and environmental data are shared:

5.156. At a European level, the European Marine Observation and Data Network (EMODnet[22]) has been implemented as a long-term marine initiative from the European Commission Directorate-General for

[21] http://www.insitenorthsea.org/
[22] http://www.emodnet.eu/

Maritime Affairs and Fisheries (DG MARE) underpinning the Marine Knowledge Strategy 2020. EMODnet includes a total of seven portals that will be fully deployed by 2020:

- Bathymetry – Data on bathymetry (water depth), coastlines, and geographical location of underwater features: wrecks;
- Geology – Data on seabed substrate, sea-floor geology, coastal behaviour, geological events and minerals;
- Seabed habitats – data on modelled seabed habitats, based on seabed substrate, energy, biological zone and salinity;
- Chemistry – Data on the concentration of nutrients, organic matter, pesticides, heavy metals, radionuclides and antifoulants in water, sediment and biota;
- Biology - Data on temporal and spatial distribution of species abundance and biomass from several taxa;
- Physics – Data on salinity, temperature, waves, currents, sea-level, light attenuation, and FerryBoxes[23].
- Human activities - Data on the intensity and spatial extent of human activities at sea.

5.157. Within the EU Marine Science and Technology (MAST) framework, the European directory of Marine Environmental Data (EDMED[24]) was initiated by the British Oceanographic Centre in 1991. EDMED is an inventory of marine data and Data Holding Centres, considered as a European Standard for indexing and searching data sets related to the marine environment. There are currently 35 European partners working on the expansion of EDMED coverage.

5.158. In addition, SeaDataNet[25] is a pan-European standardized system for managing the large and diverse data sets collected by the oceanographic fleets and the automatic observation systems part of national oceanographic data centres of 35 countries, currently active in data collection.

5.159. There are also country specific portals such as the Crown Estates Marine Data Exchange[26] (UK) and the French Research Institute for Exploitation of the Sea (IFREMER)[27].

5.160. In addition, there is an opportunity for subsea cables and associated marine infrastructure to gather environmental data. You and Howe (2011) explain that submarine cables can be used to fill a hole, currently within scientific research, of long-term marine data sets from the sea bottom. The technology for cables to have multiple uses does exist, and a single cable could be utilized for telecommunications, power supply and transmitting scientific data (Bressie, 2012). For instance, in Florida, a subsea cable was used to create one of the longest time series of data on ocean water transport by measuring the volume of water transported by the Florida current over the past 25 years (You, 2011). Another example, also in the US, the ATOC project[28] WAS set up underwater recording devices in order to monitor ocean temperature fluctuations using nine monitoring stations, or segments of cable for quantitative comparison.

5.161. However multi-purpose infrastructure does not always simply comply with international law, and marine scientific research is subject to different regulation regimes as to those applying to the mere

[23] Ferryboxes are packages of instruments that are placed on board commercial vessels such as ferries to monitor temperature, salinity and other water properties.
[24] https://www.bodc.ac.uk/data/information_and_inventories/edmed/
[25] http://www.seadatanet.org/
[26] http://www.marinedataexchange.co.uk/
[27] http://wwz.ifremer.fr/
[28] http://www.subseacablesuk.org.uk/download/?Id=329&source=documents

deployment of subsea cables at sea. The deployment of cables for scientific purposes and its used for scientific data transfer has legal and practical difficulties (You, 2011).

5.162. UNCLOS does not define that multi-purpose cables are marine scientific research tools by definition and there is an on-going dispute over the meaning of the term 'marine scientific research'. Bressie (2012) suggests that the legal-regulatory cases can be separated into 'easier cases' and 'harder cases'. Easier cases that involve deployment on the high seas, and harder cases involving deployment within the EEZ and continental shelf-areas of certain coastal states.

5.163. There are concerns that multi-purpose cables will result in stricter jurisdictions assertions, which may cause new interpretations for international law (Bressie, 2012). The accessibility and availability of data collected from the cables is also an issue. The cable system owners will technically own the data that comes from the sensors and a commercially equitable way to distribute the data is required.

6. Questionnaire findings

6.1. Table 6.1 shows the metadata for the respondents of the online survey. There were 140 respondents in total. Consultancy was the category with the highest number of respondents. The majority of participants were senior experts.

Table 6.1: metadata on the respondents of the online survey.

Category	Responses (%)	Position				
		Director	Senior expert	Project expert	Assistant	Other
Transmission system operator	11	-	9	3	1	3
Cable installation/manufacturing company	3	-	2	1	-	1
Commercial subsea cable operator	6	1	4	2	-	1
Consultancy	26	6	14	12	3	2
Non-governmental organisation	3	-	2	1	1	-
Regulatory body	16	-	7	9	1	6
Academic	17	-	12	2	2	8
Not involved but interested	4	-	1		2	3
Other	13	1	3	4	2	8
	Total	8	54	34	12	32

6.2. The online survey demonstrates that **seabed disturbance** is considered a key concern for the marine industry. In total, 90 participants selected seabed disturbance as one of the three known environmental impacts associated with subsea cable deployment, by a large margin of over 50 responses (Figure 6.1). This represented a significantly greater concern than the next two concerns by order of frequency which were shoreline disturbance and suspended sediment and smothering, with 39 and 38 responses respectively. All three of these concerns are linked with the physical disturbance that the cable installation process causes.

6.3. The online survey results suggest that it is not a lack of knowledge around the shoreline disturbance of subsea cables that is causing an issue to development. The effect received a low number of responses in relation to knowledge gaps and the second highest in relation to impact affecting the development of cables.

6.4. The knowledge gap of highest concern is **the effect of electromagnetic fields (EMF)** (see paragraph 5.105 for effects), with 58 responses. Seabed disturbance was the second highest concern with 47 responses. The survey suggests there is a relatively broad perception that seabed disturbance is both a topic with a paucity of understanding of its effects; and an issue which affects subsea cable development the most. While there appears to be a lack of knowledge or awareness around EMF, it is widely considered that it is not affecting the development of projects. There was a level of consistency across stakeholder categories that there is a knowledge gap surrounding EMF (approximately 50% of participants from each category, 60% for regulators), aside from TSOs where this was less of a perception (approximately 19% of TSO participants)

6.5. The literature overview (section 5) found that there were gaps in our understanding of seabed disturbance, EMF, thermal radiation and noise. Although it was clear that all these impacts have a very limited extent. There is a lack of cable specific studies concerning noise because of the limited emphasis placed on the noise created by the installation subsea cables due to the minimal emissions created by other infrastructure (section 5).

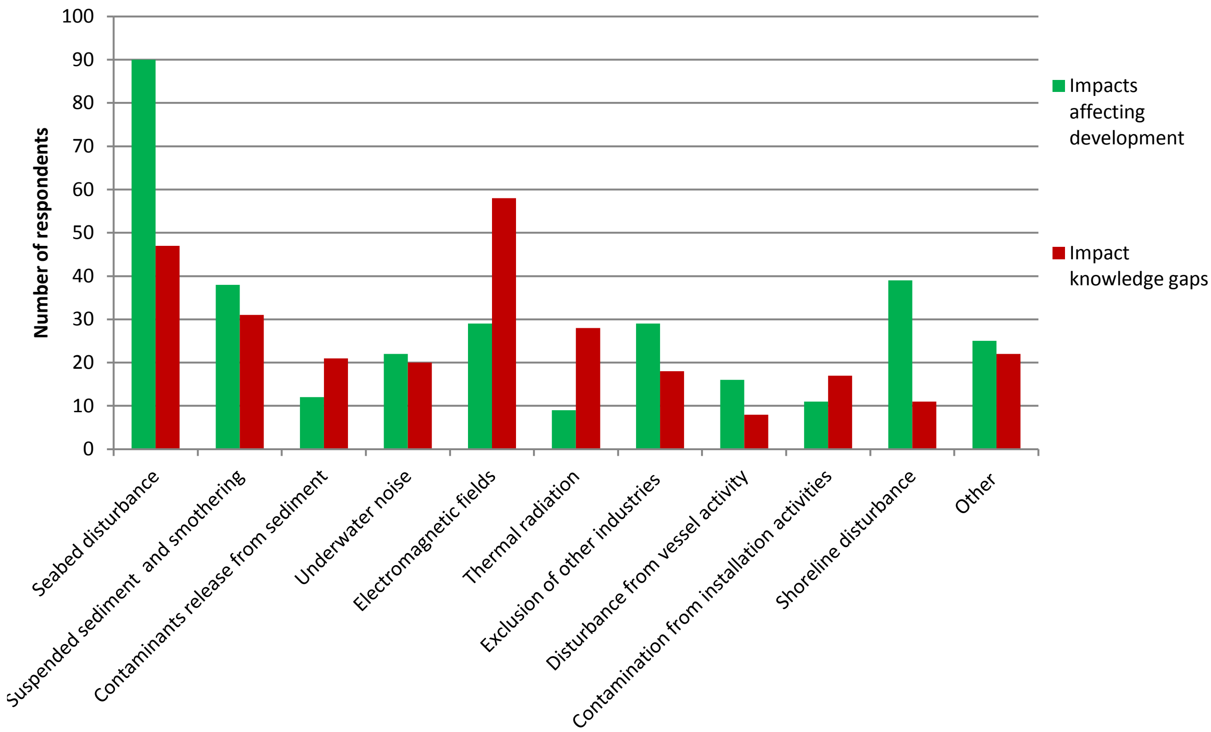

Figure 6.1 Participants' priority impacts affecting development and impact knowledge gaps. Green = the impacts that effect the development of a subsea cable. Red = where there is a knowledge gap. N = 140.

6.6. The environmental receptor considered to be the most sensitive to the effects of subsea cables is **offshore benthic habitats**. This receptor had 75 responses, followed by intertidal habitats with 45, marine protected areas with 44 and commercial fisheries with 42. The highest concern around a lack of understanding of the effects on environmental receptors is also surrounding offshore benthic habitats with 61 responses. Marine protected areas had the second highest number of responses with 39.

6.7. Both offshore benthic habitats and marine protected areas were considered by respondents to be areas which are sensitive to the development of subsea cables and where there is a lack of understanding around the effects of subsea cables.

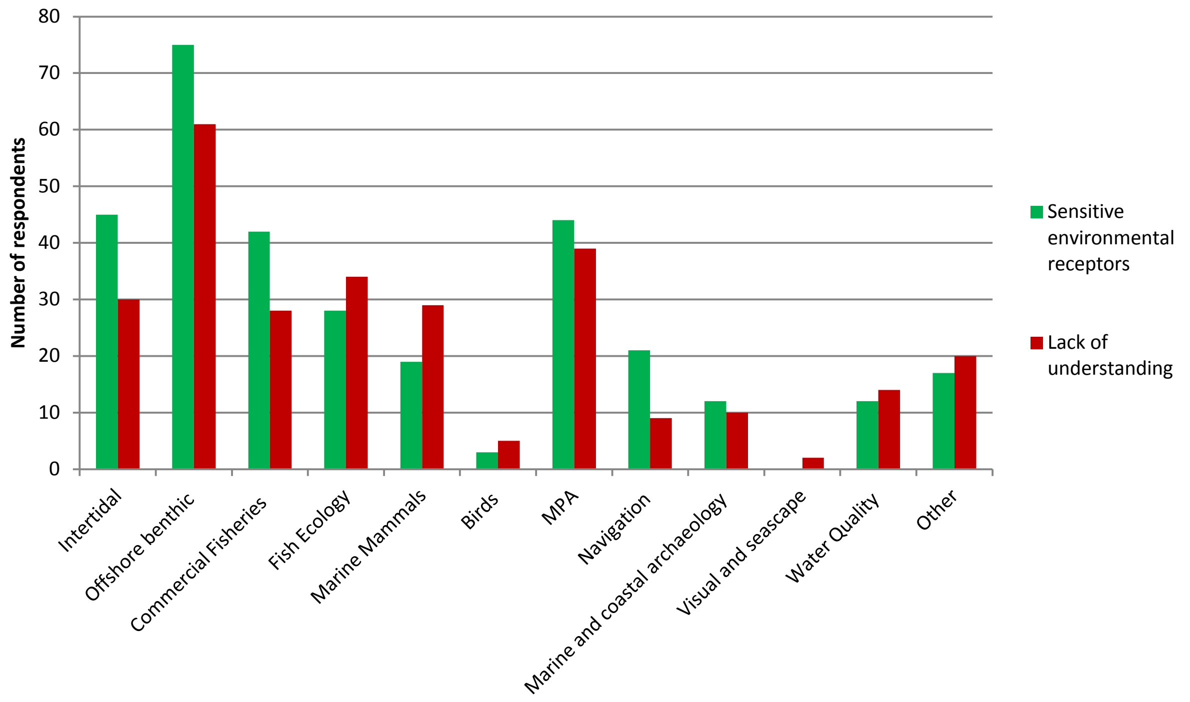

Figure 6.2 Participants' priority sensitive receptors and receptors with a lack of understanding. Green = the receptors that most sensitive to subsea cable installation and operation. Red = where there is a lack of knowledge on the effects of the receptor. N= 140

6.8. The differences between stakeholder categories were investigated to identify whether a respondents' position within the subsea cable industry was correlated with specific opinions and understanding on a given issue. There was a consistent agreement that seabed disturbance was the impact that most affected the development of subsea cables. There was some variation across stakeholder categories in relation to knowledge gaps surrounding the environmental effects of subsea cables. Only 10% of cable operator respondents felt there was a knowledge gap around seabed disturbance, in contrast to 63% of TSOs who felt there was a gap in the knowledge. There was also variance surrounding thermal radiation, the exclusion of other industries and suspended sediment and smothering (linked with seabed disturbance).

6.9. There were also varying responses from stakeholders on their opinion of which environmental receptors were most sensitive to the impacts of subsea cables. In total, 75% of the NGO and installation company respondents thought marine protected areas (MPAs) were sensitive to the effects of subsea cables while only 19% of consultants held such a view. Intertidal habitats were selected as an issue by 50% of regulators, installation companies and NGOs but only by 6% of TSOs. A high proportion of NGO respondents (75%) also felt there was a lack of understanding surrounding the effects on MPAs, while no installation companies thought there was a gap in the knowledge.

7. Discussion on key issues and data gaps

How can environmental assessments be improved?

7.1. An overview of the strategic planning and assessment processes is provided within section 5. The environmental assessment processes involved with the subsea cable industry are strategic environmental assessment, environmental impact assessment and habitats regulations assessment or other reports to inform the appropriate assessment.

7.2. From the project interviews, environmental assessments are regarded as effective and useful. Habitat Regulation Assessments are considered to be scientifically rigorous with strong legal mechanisms attached. EIAs are also deemed to be effective in that they are widely used and based on empirical information. SEAs would be more effective if they were more widely utilized by more offshore industries. There must be a legally binding plan in place for an SEA to be required, certain countries (e.g. UK) do not have such a plan for grid infrastructure and therefore an SEA is not carried out. DG Energy have recently invited tenders for an Environmental Baseline study for the development of Renewable Energy Sources, Energy Storage and a Meshed Electricity Grid in the North and Irish Seas, which includes an SEA for grid expansion across the North and Irish Seas (Ref: ENER/B1/2014-703).

7.3. Unless the assessment is for an interconnector specifically, cable structures are often associated with offshore renewable energy infrastructure and are therefore only a minor part of a larger assessment. Specifically focusing on subsea cable environmental assessments, their quality appears to be high and they achieve an objective of meeting the relevant environmental requirements and obtaining a permit. Presently the interviewee consensus view is that the current assessments are quite broad; and focusing the assessments more on key impacts would be beneficial. It was mentioned by several interviewees that the assessments could be more focused on the important issues and that the large size of cable EIAs, attempting to cover a wide range of topics, can become a hindrance. The scoping process of these assessments could be somewhat improved as currently very little is scoped out and therefore the process can be a meaningless process. For assessments to be more focused, an agreement would need to be reached between competent authorities and all the relevant stakeholders, on what impacts need to be assessed and the appropriate level of detail. Areas, which are least sensitive to the impacts of subsea cables, may well be able to be dealt with in less detail (e.g. visual and seascape, birds, marine archaeology; Figure 6.2).

7.4. Differing requirements between countries and authorities can prove an issue due to changing parameters, scopes and required level of detail.

What is the current level of knowledge surrounding the environmental impacts of subsea cables?

7.5. Subsea cables have been installed since the 1860s and it was the participants' general opinion that there is a reasonably good level of knowledge surrounding their associated environmental impacts. The adverse environmental effects of installation are relatively well understood and are lesser than those of other similar offshore industries such as oil and gas pipeline installation. Concerns unique to subsea cables include the effects of thermal radiation and electromagnetic fields emitted during the operational life of a cable.

7.6. There were inconsistencies on specific issues that some participants believed to be well understood and others believed there to encompass a knowledge gap. For instance, the **recoverability of habitats** has been considered to be both an area, which we understand well and also in which we need further research. These differences in opinions may be due to project-specific experiences, although the online survey results suggest there is a lack of understanding around the impacts on **offshore benthic habitats** and to a lesser extent **intertidal habitats** (Figure 6.2).

7.7. Clarification of the actual impact of the installation equipment appears to be needed as well as information on how the installation impact varies with different benthic habitats. The majority of techniques have been utilised for some time, but there is a lack of agreed guidance (OSPAR, 2012 Best Environment Practice, is available but has been disputed by industry members) on the realistic extent of the impacts. There is also a lack of knowledge of what guidance is available. The lack of clarification, could lead to a lack of understanding surrounding the effects on intertidal habitats and offshore benthic habitats (Figure 6.2).

7.8. Operational impacts have been considered to be both benign and an issue of concern. EMF is a potential impact that is unique to subsea power cables and is a topic that is consistently highlighted to illustrate the level of disagreement over its understanding and significance. The online survey results support this view of EMF as a knowledge gap, with the highest number of selections (Figure 6.1). Three viewpoints emerged on EMF:

- EMF research is not definite but there is no evidence of an impact from EMF;
- The information on EMF is speculative and the research tends to suggest there is no impact but research would ideally clarify this; and
- We don't know the impacts of EMF more research is needed.

7.9. It was highlighted during interviews and in the project literature review (section 5) that certain fish species can detect EMFs (inter alia Elasmobranchs, migratory teleosts); however laboratory based research has found varying levels of response to EMF (section 5). There has been extensive modelling surrounding EMF but little clarification over the actual effects. There is a lack of field studies on the impacts of EMF which, regardless of whether there is an issue or not, allows the question to be repeatedly raised. It has been suggested that continued research in this area is unnecessary and assessments should be focused on other issues and equally it has been suggested that further research is needed to clarify the impacts. A more **coordinated approach** by the authorities and other stakeholders to addressing this reoccurring question would be useful, reducing the pressure on one particular sector to solve the issue outright.

7.10. It was also mentioned in some interviews that the general lack of research into **thermal radiation** is an issue and that there is uncertainty surrounding the modelling of thermal emissions, although this topic is not as widely mentioned or discussed as EMF. German regulations state that conditions relating to sediment temperature must remain stable but it seems this is difficult to monitor and is related to ensuring certain burial depths. It is accepted that despite the uncertainty any impacts are highly localized.

7.11. Project specific issues play a role in understanding what information appears to be lacking. Where gaps in understanding have been specifically mentioned it tends to be related to an impact upon a specific feature such as salt marsh or seagrass beds. The inconsistencies in understanding the effects of subsea cables suggest that greater knowledge sharing is needed. The collation of existing knowledge and project experiences may well be preferential before additional scientific research is initiated.

Sensitive species and critical species during consenting

7.12. EMF appears to be an impact of which there is lacking some clarity and agreement over the actual effects. Corresponding with this, species that are sensitive to EMF, such as elasmobranchs or migratory fish, were mentioned a number of times as proving an issue during the consenting of subsea cables. Although no project was said to have been rejected consent because of the EMF sensitive species, the question of what is the actual impact is constantly being asked by the authorities.

7.13. In addition to EMF sensitive species, protected species and habitats were often mentioned. The level of protection around these species clearly warrants the discussion around the potential impact upon them. The online survey demonstrated a relatively high level of sensitivity and a low level of understanding surrounding marine protected areas (Figure 6.2). Biogenic reefs (inter alia Sabellaria spinulosa) and geo-genic reefs, seagrass beds and salt marshes were all provided as examples during the interviews of species that are of high consideration during the consenting of cable developments. It was also mentioned that these are areas where careful route planning can assist in avoiding or minimizing the impact.

7.14. Species seen as sensitive to the impacts of subsea cable development by the interviewees, corresponded with the species that proved an issue during consenting. EMF sensitive species were highlighted, along with marine protected areas and benthic habitats such as coral reefs, seagrass beds, mussel beds and intertidal habitats. It was reiterated by several interviewees that the scale of subsea cable development impacts are very localised; resulting in a potentially concentrated impact on sensitive species, with a reduced effect across a greater area.

How can grid assets be used to collect data and monitor the marine environment?

7.15. Participants were generally unaware of any cases when the subsea cable itself has been used to collect marine data. A clear idea on the purpose of this subsea cable monitoring would be needed. If the purpose is to collect general environmental data, then there is a question around what is the benefit of utilizing subsea cables specifically for this purpose. The type of data that could potentially be collected would need careful consideration and the data we have currently should be collated in order to avoid the unnecessary and expensive replication of data. If the scope is to monitor for the impacts resulting from subsea cables, questions are consistently asked about thermal radiation and EMF, and the cost implications of monitoring their potential impact, however buried cables may prove difficult to collect any data from. Anything protruding from the cables reduces the efficacy of burying cables, as it may prove a risk to the cable and other industries (inter alia commercial fishing). Cable emissions can be calculated with a reasonable level of certainty from the cable’s specifications, rather it is the resulting impact on the marine environment that is more difficult to determine.

7.16. There are cases where marine infrastructure, other than subsea cabling, has been used to collect environmental data, some of which could well be applied to the cable industry. Radars and cameras have been used to monitor bird behaviour (Offshore Renewables Joint Industry Project[29]), vessels have been used to collect water samples. During the interviews, fibre-optic cables were highlighted as having been used to monitor seismic activity and temperature. Reports of met-ocean (meteorological and oceanographic) data being collected from infrastructure were also mentioned. Projects from the oil and gas industry have shown cooperation around data access. Remotely operated underwater

[29] https://www.carbontrust.com/client-services/technology/innovation/offshore-renewables-joint-industry-programme-orjip/

vehicle (ROV) used for maintenance surveys on offshore platforms have in some cases been made the video footage available for biological monitoring (SERPENT[30]). Pre-construction surveys aimed at identifying suitable cable routes and post-construction surveys of cables aimed at assessing the burial depth of cables could well be combined with biological monitoring. Organisations from all the different stakeholder categories would have to be brought together to discuss and agree on the scope of the assessment to provide consistency across developments.

How can environmental and permitting issues be minimised?

7.17. In general the environmental impacts of subsea cables are accepted to be localized and small scale and an acceptance of this viewpoint may be beneficial to the industry, especially around the landfall aspects of the cables where there can be greater opposition to cable installation.

7.18. Some interviewees suggested that there seems to be a lack of clarity on the actual extent of effects resulting from different installation tools and how this relates to different habitats. Improved publically available guidance on this subject would be welcomed by the industry. What has been suggested is a synthesis document that could the form the basis of assessments and be referred to by both the authorities and other industry members. This could also include precautions surrounding any sensitive receptors.

7.19. A standardised approach to environmental surveying and assessment would provide a level of consistency to the procedures surrounding subsea cable development. There is a desire for the environmental assessments of subsea cables to remain focused on the key issues. Scoping is currently meant to identify key issues, however it does not seem to be effective as stakeholders are concerned that assessment of lower priority are routinely expected by regulators. If an agreement could be reached with stakeholders and authorities on what information is required to be presented then there would be less discussion surrounding the evidence and the focus can be kept on the conclusions that are drawn. Agreed management procedures that can be referred to would assist in removing the repetitive development of new procedures.

7.20. The sharing of experience is an aspect that has been mentioned in conjunction with a number of benefits. It has been highlighted as a way of understanding what data is available, providing a consensus among stakeholders on what the relevant impacts of subsea cables are, improving communication between stakeholders and assisting with the development of collaborative procedures. The post-construction reports are rarely made available and these are very important for feeding back impact information to environmental reports. A desire for an international platform for experience exchange has been referred to by every stakeholder category.

7.21. The importance of stakeholder consultation is clear. Transparency with other industries, especially those that may be directly affected by the installation of subsea cables (inter alia commercial fisheries and shipping), can play a key role in reducing any objections to the cable development. It is clear that the earlier the stakeholder consultation takes place the more effective it will be. Collaboration with stakeholders simultaneously has also proved to be effective, when correctly managed, as different positions can be discussed concurrently. Contractors tend to be involved only at the final stages of a project; there may be a benefit from an involvement at an earlier stage in order to include their technical input into a development.

[30] http://www.serpentproject.com/

7.22. Different participants placed a varying level of emphasis on the importance of cumulative effects. The majority of interviewees did not think the cumulative impacts of subsea cables are of particular concern compared to the activities of other industries such as commercial fishing. Those who mentioned cumulative impacts, it was often relating to the increased disturbance to the landfall/ intertidal aspect of projects. Guidance specifying how to assess cumulative impacts is currently lacking. Lessons may be able to be drawn from other industries such as the oil and gas industry, which have a high number of pipelines in the marine environment, especially within the North Sea. A formal procedure for assessing the cumulative impacts may benefit authorities and commercial industry alike. This requirement, however, is not just specific to the subsea cable industry as a lack of understanding of how to assess cumulative impacts appears in other industries.

What are the priorities for the future?

7.23. Emphasising the wider benefits of subsea cables would be beneficial to the industry as a whole. Interviewees mentioned that there is a general lack of awareness that over 90% of data is transported through cables. From an environmental perspective, cables for the seemingly minimal disturbance they produce, can have environmental benefits forming artificial reefs.

7.24. The standardization of the basis of project environmental management plans and mitigation procedures that can be referred to, would be beneficial in reducing the **constant replication of information**. Greater consistency between countries on the environmental requirements and assessment methodologies would help reduce the cross jurisdiction differences and allow knowledge to be shared between projects.

7.25. Generally there is the opinion that environment assessments need to remain focused on the key issues (as mentioned in paragraph 7.19). Clear guidance needs to be produced by the authorities on the environmental impacts of subsea cables and this should be developed with stakeholder input, to include their knowledge and to reach an agreement on the extent and significance of the impacts. A detailed analysis of monitoring programs would assist in realizing which impacts are an issue. An acceptance that **certain impacts can be screened out** needs to be recognized by the authorities allowing more time to be spent on the key issues and managing the installation process correctly.

7.26. There is a difference in viewpoints surrounding those that feel future research is needed and those that feel additional research will not clarify any questions that we do not already understand. Nevertheless **additional monitoring data** would help to further the understanding of the environmental effects of subsea cables. The focus should be on standardised studies that drawn conclusions which can be referred to within policy and development projects, rather than a constant production of scientific material. Interviewees suggested there is the potential for biological monitoring to be combined with post construction monitoring, currently focused on cable burial depth.

7.27. The **sharing of data** is an important area that seems to be lacking within the subsea cable industry and indeed across other offshore industries. There is a desire for the open access of data and for all monitoring data to be published. The UK Marine Data Exchange portal[31] is an example of how effective sharing of commercial monitoring data can be achieved. Many organisations are resistant to sharing data due to a competitive interest in the data collected, and a perception of "mis-use" of data if used out of context. The exchange provides access to survey data and reports collated during the planning,

[31] http://www.marinedataexchange.co.uk/

building and operation of offshore renewable energy projects and developers are obliged to submit the data collected as part of the consent conditions. A pan-European project of this kind would be more challenging to orchestrate with multiple different jurisdictions, although the precedent for Pan-European environmental data sharing does exist (for example: http://water.europa.eu/, Stanwell-Smith, pers obs). The data collation, curation and easy access are aspects that could be learnt from.

7.28. One interview mentioned the decommissioning of cables as an issue whether to leave in situ or remove complete which has a high cost and increases the environmental disturbance…

8. Conclusions

8.1. While there appear to be gaps in certain areas of our understanding of the impacts of subsea cables, holistically there seems to be a reasonably comprehensive knowledge on the marine environmental effects of subsea cables and projects have not been hindered by a perceived lack of knowledge. There are areas where clarification would undoubtedly help our understanding further and provide assistance during the environmental assessment phase. What appears to be lacking is an **exchange of experience between stakeholders** and easy access to data that have already been collected at a **European-wide scale**. This would also assist in consolidating opinions surrounding our understanding of environmental impacts and potentially enable the focusing of subsea cable environmental assessments.

8.2. The marine environment is becoming more crowded with increased offshore developments from renewable energy, shipping traffic, commercial fishing, aggregates and oil and gas. Subsea cables are an industry with a relatively minor environmental impact within this wider perspective however future cable permissions could be adversely influenced by a perception that cables pose a greater environmental risk than evidenced. Closer collaboration with related offshore industries would therefore be beneficial to the subsea cable industry when considering the issue of cumulative environmental impacts.

8.3. All project interview participants are positive about the benefits of an integrated subsea cable network and can see that for the integration of renewable energy it may be necessary. Greater coordination in the planning of these structures would be beneficial. The continued development of cables individually is widely considered to be sub-optimal and the development of a subsea cable grid would reduce the need for individual landfalls.

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9. Options and actions

9.1. There are a number of research studies and initiatives currently looking at how different human activities impact the marine environment, including the subsea cable industry. In this respect, a review of current knowledge and key gaps on the interactions of subsea cables with the marine environment has enabled the identification of priority actions that will assist the industry to secure its success. The following key options and actions should be considered by the subsea cable industry and key stakeholders:

Procedures

- Encourage the involvement of stakeholders from the outset of project planning.
- Encourage knowledge sharing, through proactive engagement, between stakeholders on project planning and environmental constraints to ensure a stronger collaborative approach.
- Investigate further the use of a singular data register outlining what environmental data are available – and to whom, which organisations have ownership of specific data sets and what data are available for purchase.

Guidance

- Develop an installation tool factsheet, which outlines the estimated level of disturbance for each tool and which installation tools are suitable for different habitat types. Similar guidance could be developed for decommissioning techniques, exploring what factors determine that subsea cables and associated structures are removed or kept on site.
- Update currently available "good-practice" guidelines with stakeholder consultation and input to encourage industry engagement
- Encourage the development of guidelines by relevant credible entities on the scoping of subsea cables environmental assessments, in order to focus the assessments on the key issues.
- Encourage the development of cumulative assessment guidelines taking into account the realistic effects of subsea cables and using lessons learnt from other industries.

Focused research areas

- Undertake a review of the differing requirements for environmental assessments across European maritime jurisdictions identifying opportunities for streamlining.
- Undertake a definitive study on EMF and Thermal emissions, bringing together a broad spectrum of relevant stakeholders in an expert workshop followed up with a synthesis of evidence and issues that is endorsed by the study participants; with the aim of reducing the perceived uncertainty over EMF and Thermal emission impacts.

10. References

Andrulewicz E, Napierska D and Otremba Z (2003) The environmental effects of the installation and functioning of the submarine SwePol HVDC transmission line: a case study of the Polish Marine Area of the Baltic Sea, Journal of Sea Research **49:** 337 – 345

Armstrong JD, Hunter DC, Fryer RJ, Rycroft P and Orpwood JE (2015) Behavioural Responses of Atlantic Salmon to Mains Frequency Magnetic Fields. Scottish Marine and Freshwater Science, **6 (9)** 22pp

Bald J, Hernández C, Galparsoro I, Germaán Rodrigues J, Muxika I, Enciso YT and Marina D (2014) Environmental impacts over the seabed and benthic communities of submarine cable installation in the Biscay marine energy platform. Proceedings of the 2nd international conference on environmental interactions of marine renewable energy technologies (EIMR2014622), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Outer Hebrides, Scotland.

Becker A, Whitfield AK, Cowley PD, Järnegren J and Næsje TF (2013) Does boat traffic cause displacement of fish in estuaries? Marine Pollution Bulletin **75**, issue 1-2, pp 168 – 173.

BERR (2008) Review of cabling techniques and environmental effects applicable to the offshore wind farm industry: technical report. Department for Business Enterprise & Regulatory Reform (BERR) in association with the Department for Environment, Food and Rural Affairs (DEFRA), 164 pp.

Boehlert GW and Gill AB (2010) Environmental and Ecological effects of ocean renewable energy development: a current synthesis. Oceanography, **23(2):** pp 68-81.

Borrmann CB (2006) Wärmeemission von Stromkabeln in Windparks – Laboruntersuchungen zum Einfluss auf die benthische Fauna. Thesis for a diploma, Rostock University and Institute of Applied Ecology Ltd, 82 pp.

Bressie K (2012) Using submarine cables for climate monitoring and disaster warning: opportunities and legal challenges. International Telecommunication Union (ITU), the Intergovernmental Oceanographic Commission of the United Nations Education, Scientific and Cultural Organisation (UNESCO/IOC) and the World Meterological Organisation (WMO) (www.itu.int/en/ITU-T/climatechange/Pages/default.aspx)

Budd GC (2004) Barren littoral coarse sand. In Tyler-Walters H and Hiscock K (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/16 [accessed at: 04/12/2015].

Bundesamt fur Seeschifffahrt und Hydrographie [BSH] (2013) The Spatial Offshore Grid Plan. Available at: http://www.bsh.de/en/Marine_uses/BFO/BFO-N2012_ComprehensiveSummary_INTERNET.pdf

Carter L, Burnett D and Davenport T (2014) The relationship between submarine cables and the marine environment. In: Burnett D, Beckman R, and Davenport T (Ed.) Submarine cables. The handbook of law and policy. Koninklijke Brill NV, Leiden, The Netherlands.

Carter L, Burnett D, Drew S, Marle G, Hagadorn L, Bartlett-McNeil D and Irvine N (2009). Submarine cables and the oceans: connecting the world. UNEP-WCMC Biodiversity Series No. 31. ICPC/UNEP/UNEP-WCMC, 64pp.

CEFAS (2001) Contaminant status of the North Sea. Technical report produced for Strategic Environmental Assessment – SEA2 (Technical Report TR_004), 101pp.

CMACS (2003). A baseline assessment of electromagnetic fields generated by offshore wind farm cables. COWRIE Report EMF - 01-2002 66. [Online] Available at: http://www.thecrownestate.co.uk/media/5859/km-ex-pc-emf-072003-a-baseline-assessment-of-electromagnetic-fields-generated-by-offshore-windfarm-cables.pdf [accessed on: 25/11/2015]

Council of European Energy Regulators [CEER] (2015) Status Review of Renewable and Energy Efficiency Support Schemes in Europe in 2012 and 2013. Available at: www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab4/C14-SDE-44-03_Status%20Review%20on%20RES%20Support%20Schemes_15-Jan-2015.pdf

Czech-Damal NU, Dehnhardt G, Manger P and Hanke W (2013) Passive electroreception in aquatic mammals. Journal of comparative physiology A: Neuroethology, sensory, neural and behavioural physiology, **199 (6)**: 555-563.

The Danish Government (2010) An integrated maritime strategy. Available at: http://www.dma.dk/sitecollectiondocuments/publikationer/sfs-samlet-maritim-strategi_3uk.pdf

De Decker J and Kreutzkamp P (2011) Offshore energy electricity grid infrastructure in Europe. A techno-economic assessment. Final report prepared by 3E, dena, EWEA, ForWind, IEO, NTU, Senergy, SINTEF. Available at: https://ec.europa.eu/energy/offshoregrid_offshore_electricity_grid_infrastructure

Defra (2010) Charting Progress 2. Feeder Report: Productive Seas. Available at: http://webarchive.nationalarchives.gov.uk/20141203181034/http://chartingprogress.defra.gov.uk/productive-seas-feeder-report-download

Dena (2005) Planning of the Grid Integration of Wind Energy in Germany Onshore and Offshore up to the Year 2020 (dena Grid study). Summary of the essential results of the study, Available at: http://www.dena.de/publikationen/energiesysteme/dena-netzstudie-i.html

Department of Enterprise, Trade and Investment [DETI]. 2012. Offshore Renewable Energy Strategic Action Plan 2012 – 2020. Available at: https://www.detini.gov.uk/sites/default/files/publications/deti/Offshore%20Renewable%20Energy%20Strategic%20Action%20Plan%202012-2020%20-%20First%20Year%20Progress%20Report_0.PDF.

Dernie KM, Kaiser MJ and Warwick RM (2003) Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology, **72(6)**: 1043 – 1056.

Drew SC and Hopper AG (2009) Fishing and Submarine Cables Working Together. Guidelines produced by Marine Data Systems for the International Cable Protection Committee 2nd Ed. 54pp.

Dunham A, Pegg JR, Carolsfeld W, Davies S, Murfitt I and Boutillier J (2015) Effects of submarine power transmission cables on a glass sponge reef and associated megafaunal community." Marine Environmental Research, **107:** 50-60.

Emera NL (2014) Horizontal directional drilling. Maritime Link between Newfoundland/Labrador and Nova Scotia. Available at: www.EmeraNL.com

EMU Ltd (2004) Subsea Cable Decommissioning – A Limited Environmental Appraisal. Report commissioned by British Telecommunications plc, Cable & Wireless and AT&T, Report no. 04/J/01/06/0648/0415, available from UKCPC

Environment Agency (2005) Saltmarsh Management Manual. Report prepared by Royal Haskoning. Joint Defra / Environment Agency Flood and Coastal Erosion Risk Management R & D Programme, Technical report SC030220, 129pp.

European Commission (1999). Guidelines for the assessment of indirect and cumulative impacts as well as impact iteractions. Report to ECDG11 Environment Nuclear Safety and Civil Protection, 172pp.

European Commission (2001a) Guidance on EIA Scoping. Available at: http://ec.europa.eu/environment/archives/eia/eia-guidelines/g-scoping-full-text.pdf

European Commission (2001b) Assessment of plans and projects significantly affecting Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/ECC. Available at: http://ec.europa.eu/environment/nature/natura2000/management/docs/art6/natura_2000_assess_en.pdf.

European Commission (2003) Commission's Guidance on the implementation of Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment. Available at: http://ec.europa.eu/environment/archives/eia/pdf/030923_sea_guidance.pdf

European Commission (2008) Second Strategic Energy Review. An EU energy security and solidarity action plan. Available at: http://news.bbc.co.uk/2/shared/bsp/hi/pdfs/14_11_08euenergy.pdf

European Commission (2011) Priorities for 2020 and beyond. A blueprint for an integrated European energy network. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/2011_energy_infrastructure_en.pdf

European Commission (2013) Guidance on the application of Environmental Impact Assessment procedure for large-scale transboundary project. *Environment,* 18pp. DOI: 10.2779/35899.

European Commission (2014) A policy framework for climate and energy in the period from 2020 to 2030. Communication from the Commission to the European parliament, the council, the European Economic and Social Committee and the Committee of the Regions. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN

European Commission (2015) Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. Renewable energy progress report. 16pp. Available at: http://eurlex.europa.eu/resource.html?uri=cellar:4f8722ce-1347-11e5-8817-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Network of Transmission System Operators for Electricity [ENTSO-E] (2014a) ENTSO-E position on European Union policy framework for climate and energy in the period from 2020 to 2030. Available at: https://www.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/140516_ENTSO-E%20position%20on%202030%20climate%20and%20energy%20framework.pdf.

ENTSO-E (2014b) 10-year Network Development Plan. Available at: https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/Documents/TYNDP%202014_FINAL.pdf

European Ocean Energy (2013) Industry vision paper 2013. Available at: http://www.oceanenergy-europe.eu/images/Publications/European_Ocean_Energy-Industry_Vision_Paper_2013.pdf

European Wind Energy Association [EWEA] (2010). Powering Europe - Wind energy and the electricity grid. Available at: http://ewea.org/fileadmin/ewea_documents/documents/publications/reports/Grids_Report_2010.pdf#page=5

EWEA (2011) Maritime Spatial Planning. Supporting offshore wind and grid development. Available at: http://www.ewea.org/fileadmin/ewea_documents/documents/members_lounge/1._Make_the_right_connections/Offshore_Wind_Industry_Advisory_Group/110921_EWEA_briefing_on_Maritime_Spatial_Planning.pdf

EWEA (2015) The European offshore wind industry. Key trends and statistics 2014. Available at: http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2014.pdf

FAO (2015) Fisheries and Aquaculture topics. Fish contaminants. Topics Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 25 November 2015]. http://www.fao.org/fishery/topic/14815/en

Fisher C and Slater M (2010) Effects of electromagnetic fields on marine species: A literature review. Report prepared on behalf of Oregon Wave Energy Trust. 26pp. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Effects_of_Electromagnetic_Fields_on_Marine_Species.pdf.

Fishing Liaison with Offshore Wind and Wet Renewables Group [FLOWW] (2014). Best Practice Guidance for Offshore Renewables Developments: Recommendations for Fisheries Liaison. Available at: http://www.thecrownestate.co.uk/media/5693/floww-best-practice-guidance-for-offshore-renewables-developments-recommendations-for-fisheries-liaison.pdf

Forewind (2014) Dogger Bank Creyke Beck A & B Offshore wind farm. Sandeel clarification note. Brown & May Marine. 49pp. Available at: http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN010021/2.%20Post-Submission/Representations/LIR%20and%20SoCG/Forewind%20-%20Appendix%2021%20of%20SoCG%20with%20JNCC%20and%20NE%20%28Offshore%29.pdf

Furness RW, Wade HM and Masden EA (2013) Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management, **119:** 56 – 66.

Greenstreet SPR, Holland GJ, Guirey EJ, Armstrong E, Fraser HM, and Gibb IM (2010) Combining hydro-acoustic seabed survey and grab sampling techniques to assess “local” sand eel population abundance. ICES Journal of Marine Science, **67:** 971–984.

Gill AB and Bartlett M (2010). Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage Commissioned Report No.401, 43pp.

Gill AB, Huang Y, Gloyne-Philips I, Metcalfe J, Quayle V, Spencer J and Wearmouth V (2009). COWRIE 2.0 Electromagnetic Fields (EMFs) Phase 2 Report. EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Contract No. COWRIE-EMF-1-06. Ref: EP-2054-ABG. Final Report. March 2009.

Gill AB, Gloyne-Phillips I, Neal KJ and Kimber JA (2005). The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. [Online]. Available at: http://www.thecrownestate.co.uk/media/5892/km-ex-pc-emf-072005-cowrie-15-electromagnetic-fields-review.pdf [Accessed 30/11/2015].

Hall AJ, Hugunin K, Deaville R, Law RJ, Allchin CR and Jepson PD (2006) The risk of infection from polychlorinated biphenyl exposure in the harbour porpoise (Phocoena phocoena): A case-control approach. Environmental health perspectives, **114 (5)**: 704 -711.

Hall AJ, Kalantzi O and Thomas GO (2003) Polybrominated diphenyl ethers (PBDEs) in grey seals during their first year f life – are they thyroi hormone endocrine disrupters? Environmental pollution, **126 (1)**: 29 – 37.

Health, Food Chain Safety and Environment (2014) Marine Spatial Plan for the Belgian part of the North Sea. Available at: http://health.belgium.be/eportal/Environment/MarineEnvironment/MarineSpatialPlanning/19087505_EN?ie2Term=brochure?&&fodnlang=en

HELCOM/VASAB, OSPAR and ICES (2012). Report of the Joint HELCOM/VASAB, OSPAR and ICES Workshop on Multi-Disciplinary Case Studies of MSP (WKMCMSP), 2-4 November 2011, Lisbon, Portugal. Administrator. 41 pp.

International Cable Protection Committee [ICPC] (2011) About submarine cables (presentation). Available at : https://www.iscpc.org/publications/

International Finance Corporation [IFC] (2013) Good practice handbook. Cumulative Impact Assessment and Management. Guidance for the private sector in emerging markets, 102pp.

Jacques S, Kreutzkamp P and Joseph P (2011) Offshore Renewable Energy and Maritime Spatial Planning. Recommendations for Adaptation and Development of Existing and Potentially New International Marine Spatial Planning Instruments. Available at: http://www.seanergy2020.eu/wpcontent/uploads/2011/11/111020_Seanergy2020_Deliverable3.2_Final.pdf

Jepsen PD, Bennett PM, Deaville R, Allchin CR, Baker JR and Law RJ (2005) Relationships between polychlorinated biphenyls and health status in harbor porpoises (Phocoena phocoena) stranded in the United Kingdom. Environmental Toxicological Chemistry, **24 (1):** 238 – 248.

Joint Nature Conservation Committee [JNCC] and Natural England (2011). General advice on assessing potential impacts of and mitigation for human activities on MCZ features using existing regulation and legislation. Available at: http://www.jncc.defra.gov.uk/pdf/MCZ_ActivitiesAdvice_Final.pdf

Kerchhof F, Rumes B, Jaques T, Degraer S, Norro A (2010) Early development of the subtidal marine biofouling on a concrete offshore windmill foundation on the Thornton Bank (southern North Sea): first monitoring results. Underwater Technology **29:** 137-149

Kimber JA, Sims DW, Bellamy PH and Gill AB (2011) The ability of a benthic elasmobranch to discriminate between biological and artificial electric fields. Marine Biology **158 (1):** 1-8.

Kimber JA, Sims DW, Bellamy PH and Gill AB (2013) Elasmobranch cognitive ability: using electroreceptive foraging behaviour to demonstrate learning, habituation and memory in a benthic sharks. Animal Cognition, **17(1)**: 55-65, DOI 10.1007/s10071-013-0637-8.

Kocan RM, von Westernhagen H, Landolt ML and Furstenberg G (1987) Toxicity of sea-surface microlayer: Effects of hexane extract on baltic herring (Clupea harengus) and atlantic cod (Gadus morhua) embryos. Marine environmental research **23 (4)**: 291 – 305

KOOPS FBJ (2000). Electric and magnetic fields in consequence of undersea power cables. In: ICNIRP: Effects of Electromagnetic Fields on the Living Environment, pp. 189 – 210

Laist DW, Knowlton AR, Mead JG, Collet AS, and Podesta M (2001). Collisions between ships and whales. Marine Mammal Science, **17 (1)**: 35-75 pp

Lancaster J (Ed.), McCallum S, Lowe AC, Taylor E, Chapman A and Pomfret J (2014). Development of detailed ecological guidance to support the application of the Scottish MPA selection guidelines in Scotland's seas. Scottish Natural Heritage Commissioned Report No.491. Sand eels –supplementary document

Langston RHW (2010) Offshore wind farms and birds: Round 3 zones, extensions to Round 1 & Round 2 sites & Scottish Territorial Waters. RSPB Research Report No. 39. Sandy: RSPB. 42pp

Larsson AI, Lundälv T, van Oevelen D (2013) Skeletal growth, respiration rate and fatty acid composition in the cold-water coral *Lophelia pertusa* under varying food conditions. Marine Ecology Progress Series **483**: 169–184. doi: 10.3354/meps10284

Lewis KM (2006) Habitat use, haul-out behaviour & site fidelity of grey seal (Halichoerus grypus) along the Ceredigion Marine Heritage Coast, Wales. Unpublished MSc thesis. University of Wales, Bangor

Maclean IMD, Wright LJ, Showler DA and Rehfisch MM (2009) A Review of Assessment Methodologies for Offshore Windfarms. COWRIE Ltd.

Madsen PT, Wahlberg M, Tougaard J, Lucke K and Tyack P (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Marine Ecology Progress Series **309**: 279-295 pp.

Magagna D and Uihlein A (2015) Ocean energy development in Europe: Current status and future perspectives. International Journal of Marine Energy, **11:** 84 – 104. DOI: http://dx.doi.org/10.1016/j.ijome.2015.05.001

McGourty CR, Hobbs JA, Bennett WA, Green PG, Hwang HM, Ikemiyagi N, Lewis L and Cope JM (2009). Likely population-level effects of contaminants on a resident estuarine fish species: Comparing Gillichthys mirabilis population static measurements and vital rates in San Francisco and Tomales Bays. Estuaries and Coasts, **32 (6)**: 1111 – 1120.

Meißner K, Schabelon H, Bellebaum J, and Sordyl H (2006) Impacts of submarine cables on the marine environment: a literature review. Federal Agency of Nature Conservation/ Institute of Applied Ecology Ltd

National Oceanic and Atmospheric Administration [NOAA] (2012) Guidance on cumualtive effects analysis in environmental assessments and environmental impact statements. Issue number 1.

Nedwell JR and Howell DM (2004) A review of offshore windfarm related underwater noise sources. Subacoustech Report to COWRIE. Report Reference: 544R0308, November 2004.

Nedwell JR, Langworthy J, and Howell D (2003). Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms and comparison with background noise. Subacoustech Report to COWRIE. Report Reference: 544R0424, November 2004.

Nedwell JR, Parvin SJ, Edwards B, Workman R, Brooker AG and Kynoch JE (2007) Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. COWRIE Ltd. COWRIE NOISE- 03- 2003. 85pp

Nemo Link (2013a) Environmental Statement Volume 1: Environmental Statement and Figures. National Grid Nemo Link Ltd/ Elia Asset S.A. 244pp

Nemo Link (2013b) The Nemo Link– Electrical interconnector between United Kingdom and Belgium. French section, Technical document. Project description. CREOCEAN/Elia Asset S.A.

Normandeau, Exponent, Tricas T and Gill A (2011) Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

NSN Link Limited (2014) Norway-UK Interconnector. UK Marine Environmental Statement. National Grid. 310pp. Available at: http://nsninterconnector.com/pdf/P1568_RN3057-Norway-UK-Environmental-Statement.pdf

Offshore Wind Programme Board (2015) Overview of geophysical and geotechnical marine surveys for offshore transmission cables in the UK. Available at: http://www.thecrownestate.co.uk/media/501901/owpb-grid-group-overview-of-geophysical-and-geotechnical-marine-surveys-for-offshore-wind-transmission-cables-in-the-uk.pdf

Orpwood JE, Fryer RJ, Rycroft P and Armstrong JD (2015) Effects of AC Magnetic Fields (MFs) on Swimming Activity in European Eels Anguilla anguilla. Scottish Marine and Freshwater Science, **6(8):** 22pp.

OSPAR (2008) Background Document on potential problems associated with power cables other than those for oil and gas activities. – Publication Number: 370/2008, 50pp.

OSPAR (2009) Assessment of the environmental impacts of cables. Biodiversity Series. Publication Number: 437/2009, 19pp

OSPAR (2012) Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation. OSPAR 12/22/1, Annex 14. 18pp.

Oug E, Fleddum A, Rygg B, and Olsgard F (2012) Biological traits analyses in the study of pollution gradients and ecological functioning of marine soft bottom species assemblages in a fjord ecosystem. Journal of Experimental Marine Biology and Ecology, **432-433:** 94 – 105.

Partidário M (2012) Strategic Environmental Assessment Better Practice Guide. methodological guidance for strategic thinking in SEA. Available at: http://ec.europa.eu/environment/eia/environment/pdfinfo.htm

Popper AN and Hastings MC (2009) The effects of human-generated sound on fish. Integrative Zoology, **4:** 43-52.

Red Penguin Associates Ltd (2012) Export transmission cables for offshore renewable installations. Principles for cable routeing and spacing. The Crown Estate. Available at: http://www.thecrownestate.co.uk/media/451390/ei-km-in-pc-cables-export-transmission-cables-for-offshore-renewable-installations.pdf.

Renewable UK (2013) Cumulative Impact Assessment Guidelines. Guiding principles for cumulative impacts assessment in offshore wind farms. 24pp. Available at: http://www.renewableuk.com/download.cfm/docid/FC6B39D6-8F96-4B75-AA346E8F073288FC

Reynaud S and Deschaux P (2006) The effects of polycyclic aromatic hydrocarbons on the immune system of fish: A review. Aquatic Toxicology, **77 (2):** 229 – 238.

Robinson LA, Rogers S, Frid CLJ (2008) A Marine Assessment and Monitoring Framework for Application by UKMASS and OSPAR - Assessment of Pressure and Impacts. Phase II: Application for Regional Assessment. Contract No: C-08-0007-0027.

Royal Society for the Protection of Birds [RSPB] (2005) The Saltmarsh Creation Handbook: A Project Manager's Guide to the Creation of Saltmarsh and Intertidal Mudflat. 128pp.

Seiderer LJ and Newell RC (1999) Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging. ICES Journal of Marine Science, **56:** 757-765.

Slabbekoorn H, Nouton N, Opzeeland IV, Coers A, Cate CT and Popper AN (2010) A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution, **25:** 419-427.

Söker H, Rehfeldt K, Santjer F, Strack M and Schreiber M (2000). Offshore Wind Energy in the North Sea. Technical Possibilities and Ecological Considerations - A Study for Greenpeace. http://www.greenpeace.org/international/Global/international/planet-2/report/2006/3/offshore-wind-energy-in-the-no.pdf

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene Jr. CR, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA, and Tyack PL (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals **33:** 411-521.

Subsea Cables UK [SCUK] (2015) Subsea Cables UK Guideline No 14 Power Cable Installation Guidelines. Available at:
http://www.subseacablesuk.org.uk/download/?Id=333&source=guidelines

Tasker ML, Amundin M, Andre M, Hawkins A, Lang W, Merck T, Scholik-Schlomer A, Teilmann J, Thomsen F, Werner S and Zakharia M (2012) Part VIII Managing Underwater Noise in European Waters: Implementing the Marine Strategy Framework Directive. In: Popper, A.N and Hawkins, A. The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology, **730**: 583-585.

Tasker ML, Amundin M, Andre M, Hawkins A, Lang W, Merck T, Scholik-Schlomer A, Teilmann J, Thomsen F, Werner S and Zakharia M (2010). Underwater noise and other forms of energy. Marine Strategy Framework Directive: Task Group 11 Report.

Thaxter CB, Lascelles B, Sugar K, Cook, ASCP, Roos S, Bolton M, Langston RHW and Burton NHK (2012) Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. Biological Conservation **156:** 53-61 pp.

The Crown Estate (2015a) Overview of geophysical and geotechnical marine surveys for offshore wind transmission cables in the UK. Available at: www.thecrownestate.co.uk/media/501901/owpb-grid-group-overview-of-geophysical-and-geotechnical-marine-surveys-for-offshore-wind-transmission-cables-in-the-uk.pdf.

The Crown Estate (2015b) PFOW Enabling Actions Project: subsea cable lifecycle study. Available at: www.thecrownestate.co.uk/media/451414/ei-pfow-enabling-actions-project-subsea-cable-lifecycle-study.pdf

TradeWind (2009) Integrating wind. Developing Europe's power market for the largest integration of wind power. Available at: www.uwig.org/TradeWind.pdf

Trannum HC, Olsgard F, Skei JM, Indrehus J, Øveras S and Eriksen J (2004) Effects of copper, cadmium and contaminated harbour sediments on recolonization of soft-bottom communities. Journal of Experimental Marine Biology and Ecology, **310 (1)**: 87 – 114.

Tougaard J (2008) Sensitivity of cetaceans to electromagnetic fields: Technical note on the NorGer subsea cable connection. NERI Commissioned Report to NIRAS. NERI, Roskilde. 20pp.

Tyler-Walters H and Jackson A (1999) Assessing seabed species and ecosystems sensitivities. Rationale and user guide, January 2000 edition. Report to English Nature, Scottish Natural Heritage and the Department of the Environment Transport and the Regions from the Marine Life Information Network (MarLIN). Plymouth, Marine Biological Association of the UK. (MarLIN Report No. 4.).

Tyrell MC and Byers JE (2007) Do artificial substrates favour non indigenous fouling species over native species? Journal of Experimental Marine Biology and Ecology. **342**: 54-60.

Van der Kooij J, Scott BE and Mackinson S (2008). The effects of environmental factors on daytime sand eel distribution and abundance on the Dogger Bank. Journal of Sea Research, **60:** 201-209.

Walday M and Kroglund T (2002) Europe's biodiversity – biogeographical regions and seas: the North Sea. European Environment Agency. EEA Report No 1/2002. [Online] Available at: http://www.eea.europa.eu/publications/report_2002_0524_154909/regional-seas-around-europe/page131.html/#2.4 [accessed 25/11/2015]

Woodruff DL, Cullinan VI, Copping AE, Marshall KE (2013) Effects of electromagnetic fields on fish and invertebrates. Pacific Northwest National Laboratory, Task 2.1.3. Effects on Aquatic organisms. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22154.pdf.

Worzyk T (2009) Submarine Power Cables: Design, Installation, Repair, Environmental Aspects. Springer Science & Business Media, 11 Aug 2009 Technology & Engineering. 313 pp.

Wurl O and Obbard JP (2004) A review of pollutants in the sea-surface microlayer (SML): A unique habitat for marine organisms. Marine pollution bulletin, **48 (11-12):** 1016- 1030.

You Y (2011) Using Submarine Communications Networks to Monitor the Climate. ITU –T Technology water report, November 2010.

You Y and Howe B (2011) Turning submarine telecommunications cables into a real-time multipurpose global climate change monitoring network. SENSORCOMM 2011: The fifth international conference on sensor technologies and applications. 7pp. ISBN: 978-1-61208-144-1

11. Appendices

Appendix A - Overview of international and European legislation relevant to the planning and deployment of subsea cables and environmental considerations

Legislation	Relevance
International Legislation	
The Geneva Conventions of the Continental Shelf (CTS) and High Seas (CHS), 1958[32]	Both conventions are the product of the (first) United Nations Conference on the Law of the Sea. The CTS sets out in detailed provisions the main rules on the territorial sea and the contiguous zone. Its rules address, in particular, baselines, bays, delimitation between States whose coasts are adjacent or face each other, innocent passage and the contiguous zone. The CHS defines the high seas as all parts of the sea not included in the territorial sea and internal waters. It deals specifically with the freedoms of the high seas and the rights and obligations of States, including the laying of submarine cables and pipelines.
Convention on Wetlands of International Importance (the Ramsar Convention 1975)[33]	Intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It designates Ramsar sites, which are afforded protection and need to be considered in cable route selection and impact assessment.
United National Law of the Sea (UNCLOS) 1982[34]	UNCLOS establishes a comprehensive regime covering all aspects of the seas and oceans. The rights and duties of all states were recognized, balancing the interests of coastal states in offshore zone with the interests of all states using the oceans. Coastal state exercise sovereign rights and jurisdiction in the exclusive economic zone (EEZ) and on the continental shelf, including the lay and maintenance of submarine cables. Coastal states may establish conditions for cables entering their territorial seas. The core legal principle applying to international subsea cables are as follows: • Freedoms to lay, maintain and repair cables outside of territorial seas; • National obligations to impose criminal and civil penalties for

[32] http://legal.un.org/avl/ha/gclos/gclos.html
[33] http://www.ramsar.org/sites/default/files/documents/library/manual6-2013-e.pdf
[34] www.un.org/depts/los/convention_agreements/.../unclos/unclos_e.pdf

Legislation	Relevance
	intentional or negligent injury to cables; • Special status for ships laying and repairing cables; • Indemnification for vessels that sacrifice anchors or fishing gear to avoid injury to cables; • Obligations of cables crossing earlier laid cables and pipelines to indemnify repair costs for crossing damage; • Universal access to national courts to enforce treaty obligations.
UNECE Convention on Environmental Impact Assessment in a Transboundary Context 1991 - The Espoo Convention	Introduces specific rules for conducting an EIA of activities located on the territory of one contracting party, defined as the Party of origin, and likely to cause significant adverse transboundary impact in another contracting party, defined as the affected Party (Article 2). This may be of relevance for subsea cables crossing the territorial seas of other countries.
The Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention) 1998	The OSPAR Convention is an important mechanism through which Governments of the western coasts and catchments of Europe, together with the European Union, cooperate to protect the marine environment of the North-East Atlantic. The Convention has four annexes dealing with specific areas, including Annex III on the prevention and elimination of pollution from offshore sources, and Annex IV on the assessment of the quality of the marine environment. The OSPAR Convention works according to UNCLOS, in particular Part XII and Article 197 on the global and regional cooperation for the protection and preservation of the marine environment.
European legislation	
Directive 2001/42/EC 'Strategic Environmental Assessment' – SEA Directive	The SEA Directive applies to a wide range of public plans and programmes, and it is mandatory for those prepared for energy, agriculture, forestry, and fisheries among others. Plans and programmes include those co-financed by the European Community, as well as any modifications to them: - 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 by Parliament or Government, and -which are required by legislative, regulatory or administrative provisions. The Directive has the objective of providing for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development. Plans associated with the integration of cross-country / individual countries offshore grids will be subject to the SEA Directive.
Directive 85/337/EEC (as amended) 'Environmental Impact Assessment' – EIA Directive	The EIA Directive applies to a wide range of individual public and private projects. Projects listed in Annex I of this Directive are considered to have a significant effect on the environment, and for these EIA is mandatory. For projects on Annex II, the requirement for EIA is at the discretion of Member States, who will screen a project to determine the potential effects of the proposal. Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the

Legislation	Relevance
	decisions are made The EIA Directive currently does not explicitly impose an EIA requirement on cable-laying projects. An EIA may, however, be required by the permitting system of individual contracting parties. Offshore intra-array, inter-array and export cable routes part of an offshore wind or wave farm will be assessed as part of the overall project EIA.
Directive 92/43/EEC (as amended) – The Habitats Directive Directive 71/409/EEC (as amended) – The Birds Directive	The Habitats Directive sets out the requirement to assess the potential effects of development on conservation areas designated at a European level. The Habitats Directive, together with the Birds Directive establishes a network of internationally important sites designated for their ecological status. This is known as the Natura 2000 network, and includes Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). The requirement to assess effects on the Natura 2000 network is known as Habitats Regulations Assessment (HRA).
Directive 2008/56/EC - Marine Strategy Framework Directive (MSFD)[35]	The MSFD requires EU member states to put in place measures to achieve or maintain good environmental status in their seas by 2020.

[35] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056

Appendix B – The questionnaire

Marine Environmental Impacts of Subsea Cables, RGI

Tier 2 Questionnaire – In-depth interviews (26/11/2015 – 17/12/2015)

Interviewer Name:

Interviewee details

Name:		
Position: (please highlight one)	Director	Senior expert
	Project level expert	Assistant
	Other (specify	
Organisation name:		
Organisation category: (please highlight one)	TSO	Cable installation/ manufacturing company
	Commercial subsea operator	Consultancy
	NGO	Regulatory body
	Academic	Not involved but interested
	Other	
Email:		
Telephone:		

Q1 **What environmental assessment processes have you utilised, been engaged with or are aware of recently?**

Prompt: EIA, SEA, Environmental monitoring, Marine spatial planning, Statutory monitoring, academic research

Q2 **How effective were the environmental assessments described in Q1?**

And how could they have been improved?

Prompt (dependent on what assessments they have been engaged in): Did they achieve their objective, is the data collected useful (too short-term?), was the assessment in your opinion needed in the first place, is further research needed

Q3 **Please can you give your opinion on the current knowledge of the marine environmental effects of subsea cables in relation to subsea power cables**

Q3 (A) **What are your experiences / your reasons for highlighting these environmental effects?**

(good if interviewee can refer to specific projects – the EIA etc. can then be cross-referenced in follow-up to get a better understanding of the problem)

Q4 **What do you think the major knowledge gaps on the marine environmental effects of subsea cables are?**

Prompt: Relating to what has been mentioned in the previous question, what do we not know or needs further research

Q 4 (A): **Have you experienced these gaps on projects you have been involved in? (which) ?**

Q 4 (B): **What knowledge gaps do you think should be prioritised for future research?**

Q5 **In your opinion are certain species or species groups a critical issue during the consenting of subsea cables?**

Note: Certain stakeholders may not have an in-depth knowledge of consenting.

Q5 (A): **Why do you think this (in response to Q5)? What experiences have brought you to this conclusion?**

Q6 **Are there specific species, species groups or habitats that are particularly sensitive to the environmental impacts of subsea cables?**

Q6 (A): **Do you have experiences with this from specific projects?**

Q7 **Are you aware of cases where subsea cables/marine infrastructure are used to monitor the marine environment? Do you think this is an opportunity? How could this function?**

Q8 **What tools could help to reduce environmental and permitting difficulties?**

Prompt: harmonized procedures, register of available data, increased data availability, experience exchange workshops

Q9 **Reflecting on our discussion so far in your opinion what should be the future priorities surrounding the environmental impacts of the subsea cable industry? What steps should be taken next?**

Q10 **What is your opinion on the expansion of a subsea cable network across the North Sea, in relation to the environmental impacts and cumulative effects?**

(If needed, question could be prompted by "in relation to.. renewables, energy security, environmental impact…")