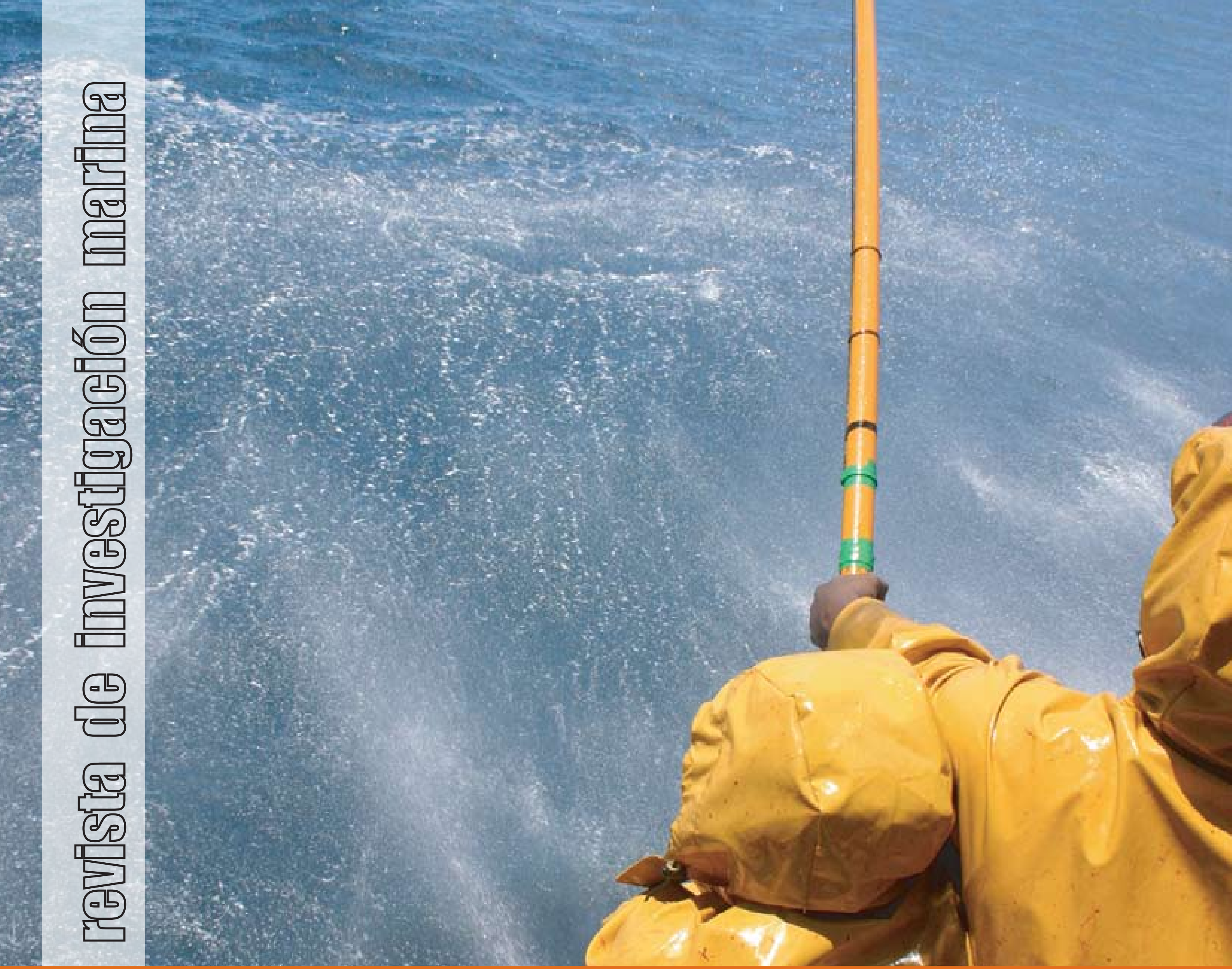

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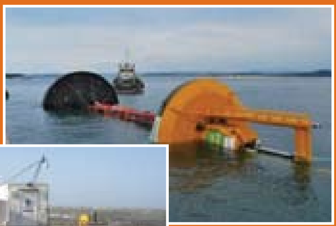

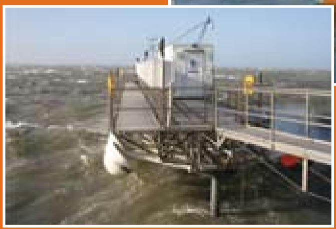

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Protocol to develop an environmental impact study of wave energy converters

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Abstract

The Plan of Renewable Energies 2005-2010, in Spain raised an ambitious objective: at least, 12% of the total energy consumption must come from renewable sources in 2010. Nevertheless, no form of marine energy is among the research and development areas identified by the above mentioned Plan. One of them, wave energy technology, is still in an embryonic phase of development, but it has the potential of helping to reach the objectives of renewable energy production proposed by the Plan. For this purpose, as well as solving the technical difficulties of the development of the wave energy devices, we must clear the uncertainties and address the likely environmental effects that this kind of technologies could produce on the marine environment during installation, operation and decommissioning.

In this context, the Ministry of Science and Innovation of the Spanish Government launched in 2005, the Strategic Outstanding Project on Marine Energy, led by Tecnalia (www.tecnalia.es). The main objective of this project is the technological development of marine energy converters; the project joins together the main Spanish developers of these devices and the supporting industry and technology agents, the latter being led by Tecnalia. Within this project, the 5th work package (WP), devoted to the study of the environmental impact of wave energy converters on the marine environment, is led by AZTI-Tecnalia (www.azti.es). The main objective of this WP is to provide the basic information, specific data, and the analysis, study and evaluation methodologies needed for the adequate environmental impact assessment of the marine wave energy technologies. Most environmental effects of these technologies may be limited to the operational life of any device deployment. Effects on physical environment can be restricted to the placement of hard structures and cables, visual impacts, noise and modification of the local hydrodynamic environment. Effects on the biota cannot be defined with certainty. Monitoring and mitigation by adaptive management will address specific issues as they arise.

This work provides an early-stage review of likely environmental effects of wave energy to inform project developers, territorial authorities and interested parties. It aims to introduce a first step to developing a risk management framework, which future project developers and territorial authorities can use to predict, prevent and deal with the environmental impacts of the deployment of wave energy converters in Spain.

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1. Introduction

Spain has been experiencing for fifteen years a relevant growth in energy consumption and energetic requirements. Our growing and excessive energetic dependence on import sources, reaching 80% in recent times, and the necessity to preserve the environment and guarantee sustainable development, have forced to seek efficient formulae for a beneficial use of green energy resources. Renewable energies are less dependant on external sources, and at the same time, they guarantee a continuous and sustainable future supply. Therefore, a substantial growth in renewable energy sources, together with a relevant improvement in energetic efficiency, comply with economical, social and environmental requirements, being the corner stone to accomplish international compromises on environmental issues (MITC, 2005).

Both the European Union and Spain are interested in the development of renewable energy sources, initially stated in the drafting of a White Paper for a Community Strategy and Action Plan on Renewable Energy 1997 written by the European Commission in 1997 within the framework of the Community Energy Policy. Spain adopted this Plan by means of the Law on the Electricity Sector, 54/1997, 27th November, followed by the Spanish Renewable Energy Plan (REP) 2005-2010 (MITC, 2005), which constitutes a revision of the Ministry of Public Works Plan on Spanish Renewable Energy 2000-2010, approved by Council of Ministers on 30th December of 1999, in force up to that moment.

Thus, REP 2005-2010 (MITC, 2005), aimed at an ambitious general objective, consisting on reaching a minimum of 12% of the total consumption from renewable energy sources by 2010.

According to MITC (2005), global consumption from renewable energy has increased around two million and seven hundred thousand annual tons of oil equivalent (toe), from the REP approval up to 2004. This is a significant growth, even though it is insufficient to reach agreed objectives. On the other hand, primary energy consumption during that time period and energetic requirements have grown much faster than expected, mainly due to a significant increase in electricity demand and fuel consumption for transportation. Such a fast growth is much higher than desired; moreover, it indirectly makes the fulfilment of the relative objective for renewable sources difficult, as the primary demand to be covered by such energy source increases.

A need to diversify and increase the amount of renewable energy sources derives from this situation, i.e., *Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal European market* (WEC, 2007b; CE, 2008; Lund y Mathiesen, 2008). At the same time, spatial limitations that affect on-land commissioning of renewable energy harnessing devices (both solar and wind energy) has promoted studies in the line of profiting from the energetic capabilities of the marine environment, either using mature technologies such as wind power or, in the long-term, developing new technologies such as harnessing marine energy from waves, currents or tides (Tseng *et al.*, 2000; Pelc y Fujita, 2002; Vantorre *et al.*, 2004; Ivanova *et al.*, 2005; Falnes, 2007; Valério *et al.*, 2007; WEC, 2007a; Agamloh *et al.*, 2008a,2008b; Marine Coastal Community Network, 2008).

Transforming marine energy into usable energy can be considered to be at present null along the Spanish coast, and symbolic at a global scale, as it can be observed in Figure 1.

Nevertheless, several examples of harnessing marine energy set a historical precedent, which boosted the development of modern systems, such as tide watermills (by means of turbines, wheels and runner stones) for cereals and salt. Great Britain can set a good example registering 140 watermills, 150 in France (90 of which are in Brittany) and 250 between the Gulf of Biscay and the Strait of Gibraltar. The oldest watermill on the European coastline was built in Dover between 1066 and 1086, and during the 12th century several mills were built between Great Britain and the Basque Country. The location of such watermills was dependant on a minimum tide of 2 meters, and most of them were built in sheltered areas, mainly estuaries.

The closest and most important instance on profiting from marine energy sources to produce electricity is the tidal power plant in La Rance, France, which harnesses tide energy and has got an installed power of 240 MW. Regarding operative wave energy plants, there are two small plants in Islay, Scotland and in the Faroe Islands, Denmark (http://www.wavegen.co.uk).

The maximum astronomic tide along the Spanish shore occurs in the South-East end of the Gulf of Biscay, in the coast of the Basque Country; however, relative differences within the Cantabrian Sea are minor. Maximum amplitude of the astronomic tide is set around 4.8 m, average amplitude is 1.5 m and perigean spring tides reach 4 m. The whole Cantabrian coast and Galician Atlantic coast fall into the category known as low mesotidal regime during neap tides and high mesotidal regime during spring tides (Borja and Collins, 2004).

Now-days, installations benefiting from sea level oscillation to generate energy count on tidal amplitude significantly higher than the rest of the Spanish coast. The closest and probably oldest reference of this way of harnessing energy is La Rance tide power plant in Normandy, France, next to the English Channel, where the maximum tidal amplitude can reach values of 15 m.

Due to relatively moderated amplitude of tides, it can be said that the Spanish coastline, in general, does not stand out for being an area of powerful currents. Marine currents are mainly caused by three factors:

- Wind
- Tide
- Density gradients

The most intense currents are generally caused by the effect of wind and tide, while currents induced by differences of intensity have got spatial and general movement scales known as mesoscales (structures from tens to hundreds of kilometres in size).

Wind is a fundamental factor in current generation; nevertheless, wind, or to be more precise tangential tension provoked on the sea surface, decreases with deepness in a quadratic way. Transposing to figures, it is considered that the

Figure 1. Distribution of areas in the world where marine harnessing devices are installed.

superficial current speed is approximately between 2 and 6% of the wind speed, taking a typical value of 3%. Therefore, at a significantly high wind speed of about 100 km·h^{-1}, which occurs only a few hours per year in the Spanish shore, a current value of 2 to 6 km/s applies. In fact, current values above 1 m/s can be considered rare (occurring less than 5%). These superficial speeds rapidly decrease at a higher depth inside the water column, being at 20 m depth generally lower than 20-30 cm·s^{-1}. The biggest instrumental data base known about the Spanish coastline is the ESEOO project (Establecimiento de un Sistema Español de Oceanografía Operacional, http://www.eseoo.org/productos/index.htm).

Concerning currents of a tidal origin, they are generally weak, due to the lack of significant tides in the Mediterranean coast, on the one hand, and the narrowness of the continental platform in the Galician and Cantabrian coastlines, on the other hand. In fact, tidal current values higher than 20-30 cm/s can only be found around the mouth of small estuaries in the Cantabrian coast. However, there are well-known localized exceptions: shallow water areas, such as the area of Cape Trafalgar in Cadiz, or strong windy areas such as the Ebro delta, where currents can reach an important speed.

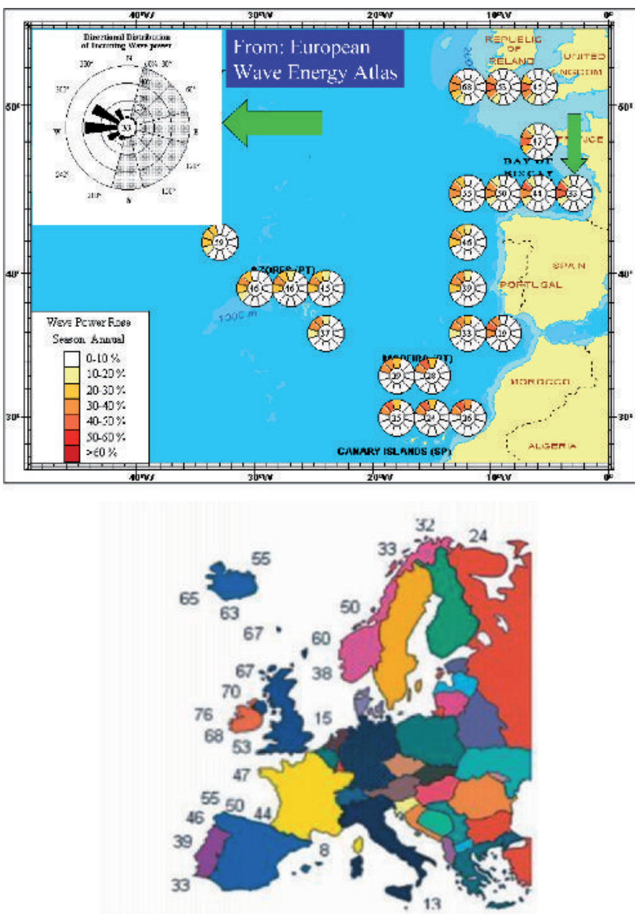

Figure 2. (A) Wave rose and (B) average annual energy in Europe (TWh). According to the European Wave Energy Atlas.

Wave energy source in deep waters (deeper than 100 m) is estimated to be between 1 and 10 TW (Panicker, 1976), and according to the World Energy Council (WEC, 2007a) the potential exploitable wave energy is higher than 2 TW. In shallower areas, waves partially lose their energy, but specific seabed type can concentrate wave energy in coastal areas (Pousa *et al.*, 1995; Thorpe, 1999). Due to this fact, commissioning of harnessing devices and transferring energy to land is more feasible in these areas. Furthermore, it is considered that, when harnessing devices are fully developed, the exploitable resource will vary from 104 and 750 TWh·year^{-1} (Wavenet, 2003) and could reach 2.000 TWh·year^{-1}, approximately 10% of the world's energy consumption with an investment of 820 million Euros (Thorpe, 1999). According to Jones and Rowley (2002), the wave energy industry growth can reach 100 million Dollars per year in 2010. If we consider that electricity demand is 1 TW (IEA, 2004), wave energy has got a relevant potential to cater for global energy demand (Prest *et al.*, 2007).

In the EU, we must highlight the initiative to develop wave energy assessment studies along the Atlantic coast, especially in Ireland and Portugal.

Previous estimations on wave energy in the European Atlantic Ocean come from the European Wave Energy Atlas (http://www.sei.ie/Renewables/Ocean_Energy/Ireland%E2%80%99s_Wave_Energy_Resource/), estimating the average annual energy arriving to these coasts between 70 and 32 kW·m^{-1} (Figure 2). Portugal is a close example where estimations of wave energy potential in its coast reach values as high as 130 TWh·year^{-1} (Gato y Falcao, 2007).

Going back to the Spanish coast, an accurate inventory on wave energy source is currently inexistent. Taking into account that France is estimated to receive marine energy onto its coast at a rate of 417 TWh per year, and considering the similar size and orientation of the Spanish coastline, we can deduct the energy potential of Spain reaching similar values.

Recent analysis, such as Galparsoro *et al*. (2008), estimates that the maximum accessible energetic potential at less than 60m depth along the Basque Country's coastline is 2 TWh.

Even though the highest energy potential is located on the Atlantic coast, wave energy potential analysis is also being carried out in the Mediterranean coast (Figure 3), like the example made by Roses (2007), in order to complement energy supply, especially in some areas of the Catalonian and Balearic coasts.

However, wave energy harnessing devices are not found amongst development areas identified by the Ministry of Industry, Tourism and Trade, MITC (2005), as this technology is still in an early development stage, and yet, it is clearly aimed at reaching the renewable energy objectives set by the MITC (2005).

Nevertheless, there are several initiatives around the world that can trigger expectations on fully operational devices, connected to the electricity network, within 5-10 years (Michel *et al.*, 2007). They can be regarded as an alternative development opportunity of a traditional energetic and industrial sector, adding the special interest of being renewable energy, and in this sense the Spanish coast has got a huge

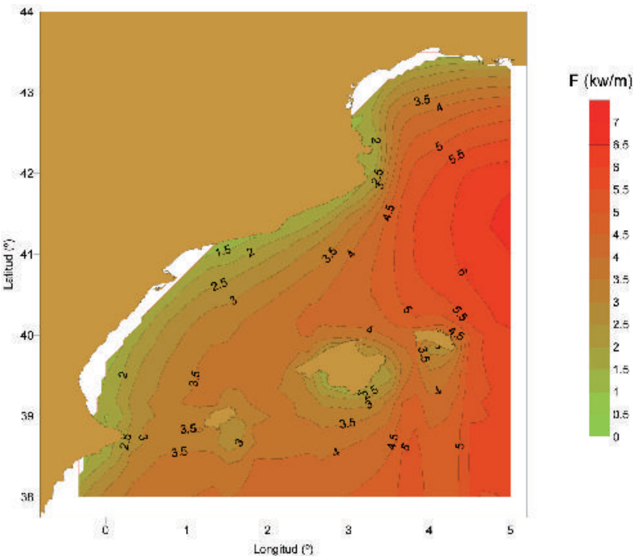

Figure 3. Incident Energy estimate in kh/m in the Catalonian-Balearic Sea during the time period 2000-2005. According to Roses (2007).

potential. In terms of selecting the most convenient site and assessing environmental impact, precise information would be required, together with a suitable methodology to guarantee the exploitation's sustainability.

A feasible development of marine energy exploitations should overcome any technical and economical difficulty, and also provide a solution to the potential environmental impact which the associated structures' commissioning, operation and decommissioning may cause. Besides, planning, anticipation, site selection, and coexistence with other marine activities are vital considerations to be made when carrying out an initial analysis.

Due to its early development stage and lack of referenced data accounting for environmental surveillance of specific projects, there is great uncertainty in relation to the potential environmental impact of wave energy harnessing devices (Michel *et al.*, 2007). This impact mainly stems from the technical characteristics of the devices, being classified as follows:

1. Onshore equipment: They are installed on the coast, and therefore their commissioning and maintenance are easier than the rest of prototypes, but they can only harness energy from waves that have partially lost their energy when they arrive to the coastline.
2. *Nearshore equipment*: They are located in shallow waters, at 10-25 m depth.
3. *Offshore equipment*: They are located on seabeds deeper than 40 m where they benefit from wave regimes with a higher potential. In this field, there are multiple designs and prototypes, unfortunately most of them are in a development phase.

The environmental impact of a wave energy park may be divided into commissioning, exploitation and decommissioning periods. The main effects during the commissioning period may be classified into four types: (a) habitat destruction due to invasion/occupation; (b) dredging for the cable installation; (c) disturbance to fish and marine mammals caused by noise, muddiness, electromagnetic fields, etc. and; (d) competence of the structure with existing activities such as fishing, navigation, etc.

Caused by this development state of wave energy harnessing devices described above, present legislation on Environmental Impact Assessment (EIA) does not contemplate this type of projects within the EIA legal framework. Therefore, projects will follow this procedure only if required by local regulation and requested by the environmental council of the Autonomous Community (regional government, in Spain) where the project is registered, given that they may affect the environment significantly, even if they are not compiled neither in Annex I nor II of the Royal Decree Law RDL 1/2008.

In any case, it is necessary to mention that Royal Decree 1028/2007, on 20th July, came to force as a regulatory example, to booster and establish an administrative proceeding to process license application of electricity generation on territorial seas, and it also anticipates a simplified proceeding for renewable technologies different from wind-power technologies.

According to present legislation, Environmental Impact Studies (EIS) must guarantee a proper identification, anticipation and interpretation of environmental impacts derived from the commissioning, exploitation and decommissioning of the project, and must contribute to determine the suitability of technical measures, as well as proposals to control, amend and monitor adverse environmental impacts.

Other countries that have started to develop activities on marine energy are currently experiencing diverse situations. Portugal only requests an Environmental Incidence Study, while Great Britain's authorities demand an EIA (Cruz, J., 2008). These differences may lead to a benefit of certain countries which are less strict on environmental issues if investors are attracted to implement marine energy structures in their waters.

Besides, environmental impact on a given country caused by the commissioning of a marine energy plant can seriously damage the development and credibility of such an incipient industry. That is why Wood *et al*. (1996), after revising 112 EIS, came to the conclusion that the quality of environmental impact studies needed to be improved by means of establishing a control mechanism or procedure to control such quality. Therefore, a minimum content must be guaranteed in an environmental impact study with a double objective: (i) guaranteeing a correct protection of the marine environment and (ii) avoiding unnecessary studies and analysis, and focusing on truly important matters instead.

In this respect, the *Protocol to Develop an Environmental Impact Study of Wave Energy Harnessing Devices* developed by AZTI-Tecnalia (Solaun *et al.*, 2003) established a first antecedent in Spain.

2. Objetive

The objective of this study consists in determining the minimum content that any EIS must cover in relation to the environmental impact analysis of the commissioning, operation and decommissioning of wave energy harnessing devices and related equipment, i.e.:

a. Project Description.
b. Environmental Inventory.
c. Impact Identification and Assessment.
d. Impact Hierarchy.
e. Proposal for Protection and Mitigation Measures.
f. Proposal for an Environmental Monitoring Program.
g. Synthesis Document.

3. Methodology

An exhaustive bibliographical compilation has been carried out in the present work, with the aim of identifying all relevant data sources accounting for the potential impact of wave energy harnessing devices. Such compilation was made using the following sources and data bases:

- Isi Web of Knowledge.
- Aquatic Sciences and Fisheries Abstracts (ASFA).
- Fisheries Information and Services (FIS).
- Science Direct.
- CSIC's bibliographic data base (Spanish National Research Council).
- Scirus.
- Google Scholar.

The aforementioned databases gather information on scientific papers, congress presentations, governmental reports, etc. Some key words used in searches are the following:

- Renewable energy: marine wind power plants and wave energy plants.
- Environmental impact.
- Marine resources: seabirds, fish, mammals, benthic communities, etc.

Apart from the aforementioned databases, documentation of our own at AZTI-Tecnalia has been used, as well as detailed searches on the Internet with similar key words.

Both actions have resulted in a total compilation of 348 bibliographical references.

In terms of edition, this work has been written according to the present legislation on EIA. To be more precise, the following legal texts have been taken into account:

- Council Directive 97/11/CEE of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.
- Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 providing for public participation in respect of the drawing up of certain plans and programs relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC.
- Law 62/2003, of 30 December, on fiscal, administrative and social measures.
- Legislative Royal Decree 1/2008, of 11 January, through which the revised text of the Law of the Environmental Impact Assessment of Projects is approved.

Advice from the following document has also been taken into account in the present work:

Solaun, O., J. Bald and A. Borja, 2003. Protocolo para la realización de los estudios de impacto ambiental en el medio marino. AZTI-TECNALIA, Instituto Tecnológico y Pesquero (Ed). Bilbao. 79 pp.

4. Environmental impact assessment

4.1 Introduction

EIA can be defined as the process of identifying and assessing potential consequences of projects, plans, programs or legislative actions related to physical-chemical, biotic, cultural and socioeconomic components of a given environment (Canter y Sadler, 1997), based on the idea that decisions taken for a project should be more appropriate if based upon a thorough analysis than if they are not (Gómez-Orea, 1992).

The latter author distinguishes two types of approach when defining an EIA. From the administration's point of view, the EIA is a process or set of administrative proceedings that conclude in the approval, amendment or refusal of a project depending on its incidence upon the environment and the assessment of the consequences for the affected society.

This process is based upon a fundamental technical tool, i.e., the EIS, whose aim is to identify (cause-effect relationships), predict (quantify), assess (interpret) and prevent (preventively amend) the environmental impact of a project in case it is developed.

According to Canter and Sadler (1997), citing the proposal made by authors such as Barret and Therivel (1991), an EIS ideal system:

1. Would apply to all projects that could be regarded as having a significant environmental impact and would consider all significant impacts.
2. Would compare alternatives for the proposed projects (including the possibility of no-action), their management techniques and amendment measures.
3. Would generate an EIS where the importance of potential impacts and their specific characteristics were made clear both to experts and non-experts to the subject.
4. Would include a wide source of public information and administrative procedures binding quality revision of that environmental impact study.
5. Would set reasonable arguments for the competent authority's decision making process, being capable of setting compulsory practice.
6. Would include monitor and control procedures.

4.2 Spanish and International Regulations

The environmental degradation suffered during the 20th century concluded in several countries establishing legal procedures and rules in an attempt to cope with such situation. Corrective measures, also known as palliative measures, and preventive measures were developed. In this respect, the EIA's compulsory legal precedent is the *National Environmental Policy Act* (NEPA) of the United States of America, coming to force in 1969, and constituting the basic rule for environmental protection in the USA.

The European Union (EU), at the time the European Economic Community (EEC), introduced the concept of environmental prevention and assessment in the Third Environmental Action Programme (1982-1986), considering the promotion of preventive policy integration in economic planning.

As a result, the *European Directive 85/337/CEE on the assessment of the effects of certain public and private projects on the environment*, later modified by the Council Directive *97/11/CEE of 3 March 1997* was approved, maintaining the essential principles described in the NEPA of the USA.

Regardless implications on environmental policies and administrative management in the Member States, this directive concentrates on the environment from a wide perspective, and thus, it establishes that environmental impact assessments shall properly identify, describe and assess the effects on men, fauna and flora; - soil, water, air, climate and landscape; - the interaction of those parameters; and - goods and cultural patrimony (Campillo y Méndez, 1990a,1990b).

At present, the *Directive 2001/42/CE of the European parliament and of the Council*, refers to the environmental impact assessment of certain plans and programmes establishing a framework for the acceptance of future projects listed in Annexes I and II of the *Directive 85/337/CEE.* Each country in the EU has incorporated the cited regulation within their national legislative framework.

Spain has transposed this European regulation by means of the *Legislative Royal Decree 1302/1986 of 28 June, on the Environmental Impact Assessment*, whose execution procedure was approved in 1988 by *Royal Decree 1131/1988.*

After a minor amendment in Annex I by *Law 54/1997, of 27 November, on the Electricity Sector*, the first significant amendment of *Legislative Royal Decree 1302/1986* was made by *Law 6/2001, of 8 May*, and previously by *Royal Law-Decree 9/2000, of 6 October*, which transposed *Council Directive 97/11/CE, of 3 March 1997*, and amended certain faults after transposing *Council Directive 85/337/CEE, of 27 June 1985*, that had been reported by the European Commission. In 2003, *Law 62/2003, of 30 December, on fiscal, administrative and social measures* amends *Legislative Royal Decree 1302/1986* in four of its rules.

Finally, in 2006 two significant amendments were made to the aforementioned Legislative Royal Decree. Thus, *Law 9/2006, of 28 April, on effects assessment of certain environmental plans and programmes* introduced important changes to comply with Communitarian requirements listed in the above mentioned directives, as well as to clarify and rationalize the environmental impact assessment procedure.

On the other hand, *Law 27/2006, of 18 July, on the regulation of information access, public participation and justice access rights on environmental issues*, allowed the adaptation to basic regulations on environmental impact assessment to *Directive 2003/35/CE of the European Parliament and of the Council, of 26 May 2003, providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC*.

This amendment meant for the real and practical recognition, by means of the EIA procedure, of the public participation according to the European Commission's Agreement for the United Nations of Europe on information access, public participation in decision making processes and justice access on environmental issues, signed in Aarhus on 25 June 1998.

The quantity and relevance of the amendments done, showed the necessity for approving a compiling text based upon principles of judicial security, which regulates, clarifies and harmonizes the existing norms on environmental impact assessment projects. Such a text was passed by means of *Legislative Royal Decree 1/2008, of 11 January, approving a compiling text of the Law on Environmental Impact Assessment Projects*.

This compilation is limited to Environmental Impact Assessment Projects and does not include Environmental Assessment of plans and programmes regulated by *Law 9/2006, of 28 April, on the effect assessment of certain environmental plans and programmes*.

In general, the above mentioned regulation establishes, on the one hand an administrative procedure for EIA, and on the other hand, a set of projects that will have to follow this proceeding.

4.3 The Procedure for EIA

The legal regime for EIA is described in chapter II of the *Legislative Royal Decree 1/2008*, and is divided in two sections. A first section covers the environmental impact assessment for projects in Annex I (those projects that must compulsorily submit an impact assessment).

A second section regulates the environmental impact assessment for projects in Annex II and those projects, even if they are not included in Annex I, that may affect directly or indirectly protected areas under the Natura 2000 Network.

When specifically referring to projects on wave energy, competences belong to the State's General Administration as they are located in the Maritime-Terrestrial Public Domain (MTPD).

In this case, the lead agency is the General Council on Energy Policy and Mines of the Ministry of Industry, Tourism and Trade, and the responsible authority is the General Council on Environmental Quality Assessment of the Ministry of Rural, Marine and Natural Environment.

4.3.1 The Procedure for those Projects Observed in Annex I

The procedure for EIA for projects observed in Annex I will include the following actions:

a. Request of submission of the project to EIA.
b. Determination of EIS' scope.
c. Development of EIS.
d. Public information and inquiries.
e. Environmental Impact Statement (EISt).

Figure 4 shows the approximate order and deadlines of the procedure for projects included in Annex I of the Legislative Royal Decree 1/2008, of 11 January, through which the revised text of the Law of the Evaluation of the Environmental Impact of Projects is approved.

4.3.1.1 Application for Submission to an EIA

The developer will apply to the agency in charge assigned by the Autonomous Community for submission of the project to an EIA. The application will include an initial document of the project covering, at least, the following points:

Definition, characteristics and location of the project.

Alternatives taken into account and their potential impact analysis.

Territorial and environmental diagnosis of the project's affected area.

Projects which had to be authorized or approved by the State's General Administration, will apply and address all relevant documentation to the lead agency. Once conformity is granted, the lead agency will forward the documentation to the responsible authority to initiate the EIA proceedings.

4.3.1.2 Determination of the EIS Scope

Establishing the scope and level of accuracy of the environmental impact study will be determined after the responsible authority has consulted the affected Public Administrations on the initial document of the project. The consultation can be extended to other juristic or natural persons, both private and public, committed to environmental protection.

Deadlines for projects, which must be authorized or approved by the State's General Administration to report to the developer on both replies to consultations and the environmental impact study scope and level of accuracy, is three months from the reception of application and initial document by the responsible authority.

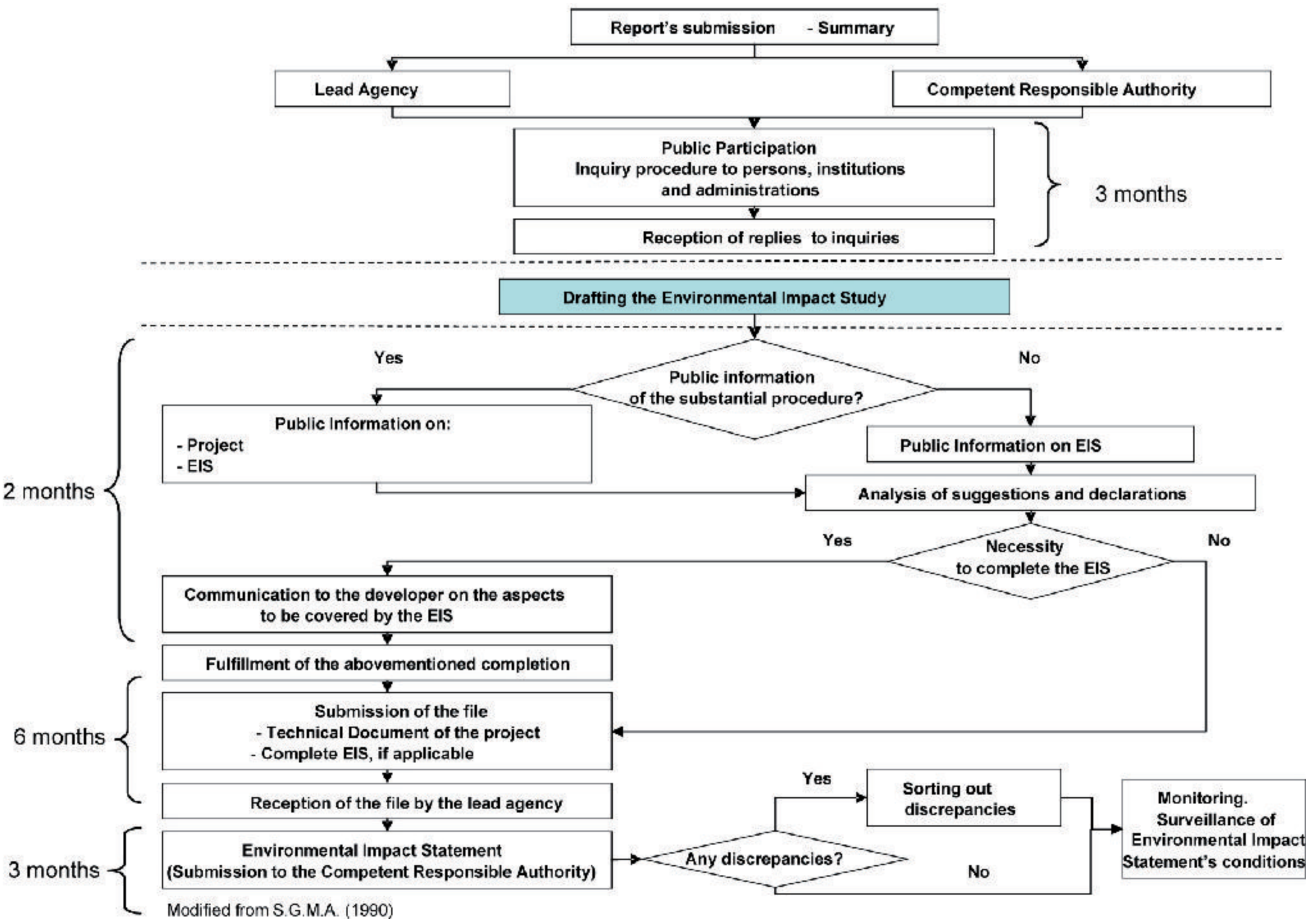

Figure 4. EIA Proceedings and approximate deadlines for projects included in Annex I of Legislative Royal Decree 1/2008.

4.3.1.3 Development of an EIS

Projects that must undertake an EIA will also develop an EIS, whose scope and level of accuracy will be determined by the responsible authority. Such study will at least account for the following contents:

a. General description of the project, giving information on its size, design, and also development stage and foreseeable future requirements regarding the use of land and other resources. Estimate on the quantity and typology of dumped residues, as solid or energy emissions (including surface pollutants, running and underground waters, air, land and substratum, noise, vibration, light, heat and radiation).
b. A discussion on the main alternatives and ground arguments for the adopted solution based upon its environmental effects.
c. An environmental inventory defining the influenced area's antecedents or base line for the project.
d. Assessment of both direct and indirect foreseeable effects of the project on population, flora, fauna, soil, air, water, climate, landscape and goods including historical and archaeological patrimony, on social relationships and public order, disrupting elements such as noise, vibration, smells, luminescent emission and any other environmental incidence derived from its development. Interaction of all these factors will also be taken into account. Prediction methods used in the assessment of environmental effects will also be reported.
e. Measures to either reduce, eliminate or compensate significant environmental effects.
f. Environmental Monitoring Program.
g. Summary on the study and conclusions in a plain language. If applicable, report on the technical difficulties encountered when gathering information to develop the study.

4.3.1.4 Public Information

The lead council will submit the EIS and any other requested reports to a public information procedure. Such procedure will last a minimum of 30 days.

During the public information procedure, the lead council will inform of all relevant aspects related to the authorization proceedings of the project, especially focusing on the following aspects:

a. The application for approval of the project.
b. The fact that the project is under an EIA procedure.
c. Responsible authority that will resolve the proceedings, which may provide relevant information, including the deadline to present suggestions, appreciations, declarations and inquiries.
d. Nature of either decisions taken, or, if applicable, of the drafts and decisions likely to be adopted.
e. Information availability of the EIS, dates and place or places where this information will be made available for the general public.
f. Identification of participation modalities.

Simultaneously, the lead agency will inquire the affected Public Administrations, which had previously been inquired in relation to the definition of scope and level of accuracy of the EIS, and will present the following information, which shall be made available for any person applying for it:

a. All information gathered in the EIS.
b. All relevant documentation received by the lead agency before having replied to the public information proceedings.

The lead agency will reply to any person applying for information, and to every affected Public Administration on the right to participate in the procedure and on the moment when they may exercise such a right. This notice will state the responsible authority to which suggestions and declarations shall be addressed. Deadline shall not be less than 30 days.

Results of inquiries and public information shall be taken into account in the project by the developer and the lead council when granting the authorization.

4.3.1.5 Environmental Impact Statement (EISt)

Once the public information stage has finished, and earlier in time to the administrative resolution on the development or, if applicable, issuing the work permit for installation or specific activities, the lead agency shall forward the file to the responsible authority, together with their comments on the fact that an EISt is required, establishing suitable measures to be developed in order to protect natural resources and the environment.

Deadlines to address the file to the responsible authority and require an EISt shall be fixed by the Autonomous Community.

In case the project needs to be authorized or approved by the State's General Administration, the deadline to address the file to the responsible authority shall be six months from the end of the public information period and the deadline to require an EISt shall be three months.

The EISt of the project or activity will expire if execution had not begun within the period established by the Autonomous Community, being the project authorized or approved. In such case, the developer shall initiate new EIA proceedings for the project.

Projects which must be authorized or approved by the State's General Administration will begin within a period of five years.

The developer of any project or activity under EIA must inform the lead agency in advance on the date when such project or activity will begin.

These decisions are partly binding for the developer. The lead agency forwards their decisions to the responsible authority and, if they agree, they will turn these decisions in totally binding for the developer, who must develop the project accordingly.

In case the responsible authority's resolution is adverse, being the lead agency's agreeable, the Council of Ministers (or authority endowed with this competence) will be in charge of solving the conflict (Cintora, 1996). It might occur that superior instances may neglect the Environmental Impact

Declaration, and work may be done without the proposed measures or against what is established by the Environmental Impact Statement.

4.3.2 The Procedure for those Projects Observed in Annex II

The procedure for those projects observed in Annex II and projects not included in Annex I which may affect directly or indirectly areas belonging to the Natura 2000 Network will cover the following actions:

1. Application for determination of submission or not to an EIA.
2. Determination of submission or not to an EIA.

4.3.2.1 Application for Determination of Submission or not to the EIA process

A juristic or natural person, either public or private, who is committed to develop a project included in Annex II, or a project non included in Annex I which may affect directly or indirectly areas belonging to the Natura 2000 Network will demand that the competent entity assigned by each Autonomous Community will determine if such project must be subject of the EIA process, according to the criteria established in Annex III of *Legislative Royal Decree 1/2008*.

Such application will be submitted together with an environmental document of the project with, at least, the following content:

a. Definition, characteristics and location of the project.
b. The main alternatives analysed.
c. A potential impact analysis on the environment.
d. Preventive, amendment and compensatory measures for an appropriate protection of the environment.
e. A monitoring method to guarantee the fulfilment of the protection and amendment measures and directives mentioned in the environmental document.

For projects that shall be authorized or approved by the State's General Administration, the application and documentation mentioned in the previous point shall be submitted to the lead agency, and once conformity is granted, all documentation shall be forwarded to the responsible authority to determine if the project must be submitted to an EIA or not.

4.3.2.2 Determination of Submission or not to an EIA

The entity receiving the application mentioned in the previous point will determine if the project must be submitted to an environmental impact assessment within the deadline established by the Autonomous Community.

The responsible authority shall reply within three months from the following day upon reception of the application and environmental document, after having inquired administrations, persons and institutions that might be affected by the project's development and making available for them the environmental document of the project.

In case the information gathered in the inquiry stage determines that the project shall be submitted to an EIA, the scope and level of accuracy of the EIS, together with the feedback from inquiries will be reported to the developer so that he can pursue the proceedings in accordance with section 1 of the Legislative Royal Decree 1/2008 (see 4.3.1).

4.4 Projects Submitted to an EIA Procedure

Considering the activities submitted to assessment, communitarian regulations establish compulsorily assessable projects and let Member States choose to include others, due to the fact that environmental issues may vary from one country to another depending on socio-economical factors and the current state of their environment.

Table 1 shows a comparison between projects submitted to EIA in Spain and those that Solaun *et al*. (2003) consider they should be submitted (at different levels), taking into account only the ones which are closely related to the marine environment.

In this respect we must say that, even though they are not covered by Spanish legislation, some projects such as aquariums, installations with a lower productivity than legally specified, underwater emissaries, resource exploitation, wave energy harnessing devices, etc., may be submitted to an EIA procedure given that the competent authority requires that.

4.5 Other Applicable Regulations

The submission to an administrative procedure to install a marine energy plant has faced us with the problem of the Spanish littoral management.

An important portion of the peninsular and insular Spanish territory; the public shore, lacks a regulation catering for its peculiarities. The maritime part of the MTPD has no regulation. And precisely, the fact that the maritime part of the MTPD hosts various activities, most of them incompatible, e.g. aquiculture, traditional fishing, recreational sports, exploitations, amusement activities, wind power parks, wave energy plants, current mills, highlights the necessity of this space to be regulated.

The littoral is owned by the State, which grants appropriate concessions for its occupation, but the State does not manage the littoral, that is, its usage is not regulated.

Therefore, regional sector titles (inland water fishing, sports, shellfish fishing, aquiculture, etc.) will influence the spatial planning capacity of the State and the MTPD and the State's sectorial competence (ports of general interest, defence, public works of general interest or being developed in more than one Autonomous Community, etc.) will affect the regional competence over spatial and town planning.

Taking into account the previous context and focusing on the marine energy problem within the Spanish territory, we find a recent trend towards regulating the administrative process to implement electric power plants in the sea. Such regulation had been requested for several years by the energy sector, particularly, by the renewable energy sector; we are referring to *Royal Decree 1028/2007, 20 July 2007, establishing the administrative procedure for processing applications for the authorization of electricity generating facilities in territorial waters*.

Table 1. Projects related to the marine environment, compulsorily submitted to an EIA procedure (Annex I) in accordance with Legislative Royal Decree 1/2008, of 11 January, through which the revised text of the Law of the Evaluation of the Environmental impact of Projects is approved and some examples that should be included.

PROJECTS' GROUP	Annex I	Annex II	SOME EXAMPLES
Agriculture, silviculture, aquiculture and stockbreeding		• Facilities for intensive aquiculture with a production capacity higher than 500 tons per year.	• Introduction of foreign species with restocking or aquaculture purposes. • Intensive and extensive restocking. • Exploitation of renewable resources (fish, seaweed, molluscs, etc.) • Creation of artificial biotopes (reefs)
Agroindustry		• Industrial facilities dedicated to packing and canning of animal and vegetal products. Facilities whose raw material is of an animal origin, except for milk, with a production capacity higher than 75 tons per day of finished products, and facilities whose raw material is of a vegetal origin with a production capacity higher than 300 tons per day of finished products (quarterly average values). • Industrial facilities dedicated to fish flower and oil manufacturing, given that the following circumstances occur simultaneously:.(i) located outside an industrial area; (ii) located nearer than 500 m to a residential area; (iii) occupying an area of at least 1 hectare.	• Marine product processing industrial plants (canning, salting, boiling industries)
Extractive Industry	• Deposit exploitations linked to present dynamics: fluvial, fluvial-glacial, littoral or wind. Those deposits and peat sites that may be scientifically interesting due to its content in vegetal fossil for paleontological and paleoclimatic reconstruction. Exploitation of marine deposits. • Exploitations located in environmentally protected sites or within an area from which it can be seen from any of its boundaries, or that may represent a detriment to its natural value. • Marine dredging to extract sand in higher volumes than 3.000.000 $m^3 \cdot year^{-1}$. • Oil and natural gas extraction for commercial purposes in case quantities are higher than 500 tons per day for oil and 500.000 cubic meters per day for gas in each concession.	• Oil perforations • Marine dredging to extract sand (projects non included in Annex I)	
Chemical, Petrochemical, Textile and Paper Industries		• Warehousing of petrochemical and chemical products (projects non included in Annex I)	

PROJECTS' GROUP	Annex I	Annex II	SOME EXAMPLES
Extractive Industry	• Deposit exploitations linked to present dynamics: fluvial, fluvial-glacial, littoral or wind. Those deposits and peat sites that may be scientifically interesting due to its content in vegetal fossil for paleontological and paleoclimatic reconstruction. Exploitation of marine deposits. • Exploitations located in environmentally protected sites or within an area from which it can be seen from any of its boundaries, or that may represent a detriment to its natural value. • Marine dredging to extract sand in higher volumes than 3.000.000 $m^3 \cdot year^{-1}$. • Oil and natural gas extraction for commercial purposes in case quantities are higher than 500 tons per day for oil and 500.000 cubic meters per day for gas in each concession.	• Oil perforations • Marine dredging to extract sand (projects non included in Annex I)	
Chemical, Petrochemical, Textile and Paper Industries		• Warehousing of petrochemical and chemical products (projects non included in Annex I)	
Energy Industry	• Raw oil refineries (excluding companies which produce only lubricants from raw oil), as well as gasification and liquefaction plants producing at least 500 tons of coil from bituminous shale per day. • Piping for gas and oil transportation with a bigger diameter than 800 mm and longer than 40 km. • Warehousing of oil by-products higher than 100.000 tons. • Industrial facilities for the production of electricity, steam and hot water with thermal power higher than 300 MW.	• Underground warehousing of combustible gases. Facilities with a higher capacity than 100 cubic meters. • Oil and gas pipelines (projects non included in Annex I), excluding urban soils, longer than 10 km.	• Exploratory drilling programs • Hydrocarbon production programs • Oil refining plants
Infrastructure Projects	• Commercial, fishing and recreational ports. • Jetties and piers for loading and unloading vessels with a GRT (Gross Register Tonnage) higher than 1350 tons. • Onshore works to deal with erosion and maritime works which may alter the coastline, such as, dikes, pier, jetties and other constructions of sea protection walls, excluding maintenance and reconstruction of these constructions, when they reach, at least, 12 meters wide in relation to neap tides. • Dams and any other structure aimed to retain or store water, given that the additional or new volume of stored water is higher than 10.000.000 cubic meters.	• Artificially replenished beaches whose volume of added sand is higher than 500.000 m^3, or which may require the construction of dikes or jetties (projects non included in Annex I).	• Filling in marine, shore, lake and fluvial areas. • Underwater emissaries for residual water. • Underwater pipelines. • Residential development in near to coast areas. • Touristic development in protected, coastal and insular areas. • Touristic development in protected or non-protected natural environments, coastal and insular areas, and seabed's use.

PROJECTS' GROUP	Annex I	Annex II	SOME EXAMPLES
Hydraulic Engineering and Water Management Projects		• Construction of navigable channels, ports of internal navigation, coursing works and river bed and margin defence projects when the affected area is longer than 2 km and are not included in Annex I. Any works made to avoid risks in an urban area are excluded. • Installations with desalting and water salubring purposes with a new or additional volume of 3.000 cubic meters per day. • Dams and other installations aimed to retain of store water, given that any of the following suppositions occur: (i) big dams as defined in the Technical Regulation on dam and reservoir security, approved by Order of 12 March 1996, when they are not included in Annex I; (ii) other installations aimed to retain water, non included in the previous point, with a new or additional storing capacity higher than 200.000 cubic meters.	• Plans or specific actions that, even if they are located far away from the coast, may affect the marine environment: basin plans, ocean dumping, etc.
Other	• The following projects in relation to activities listed in Annex I, not having reached threshold values established thereby, and if they are developed in specially sensitive areas as defined in the application of the Council Directive 79/409/CEE, of 2 April 1979, and Council Directive 92/43/CEE, 21 May 1992, or in wetlands listed in the Ramsar Agreement: • Marine Dredging. • Piping for chemical products, gas and oil transportation with a diameter bigger than 800mm and longer than 10km. • Projects listed below, given that they are developed in a specially sensitive area according to Council Directive 79/409/CEE, of 2 April 1979 and Council Directive 92/43/CEE, of 21 May 1992, or in wetlands listed in the Ramsar Agreement: • Theme Parks • Coursing works and projects for the defence of natural resources. • All projects included in Annex II when an environmental impact assessment is required by regional regulations.	• Gaining land to the sea. • Projects which are not listed in neither Annex I nor II, when regional regulations and the responsible authority of the Autonomous Community where the project is located require so, given that relevant environmental effects may occur. • Any change or amendment of projects mentioned in Annex I and II, once they are approved, executed or in development in case this modification or amendment is not included in Annex I and may have relevant adverse effects on the environment, i.e., in case any of the following cases occur: (i) significant increase of emissions to the atmosphere; (ii) significant increase of dumping to public river beds or to the littoral; (iii) significant increase of residues; (iv) significant increase of natural resources' usage; (v) effects in specially protected areas according to Council Directive 79/409/CEE, of 2 April 1979 and Council Directive 92/43/CEE, of 21 May 1992, or in wetlands listed in the Ramsar Agreement.	• Development of adventure sports in fragile sites. • Creation of protected spaces. • Power plants (including wave, current and wind energy). • Aquariums

Regulations on wave energy need to disentangle the competence network on this issue, and this is perfectly explained in the argumentation of RD 1028/2007, where it is mentioned that:

"Special characteristics of authorizations and approval proceedings for electric power development in the sea, together with the numerous Administrations concerned and diverse nature of regulations applicable in these cases, prove the need of passing a unique norm which totally covers the whole proceedings".

4.5.1 Coast Law and MTPD

The *Coast Law, 28 July 1988,* offers a legal framework on territorial sea occupation, together with issues affecting the fishing sector and safety conditions for maritime navigation. Management and surveillance competences on MTPD, which the territorial sea belongs to, lie upon the General Council on Coast and Ocean Sustainability which forms part of the Ministry of Rural, Marine and Natural Environment. Coast Demarcation Departments are their representative in each coastal province and Autonomous Community.

Therefore, the development of projects on electric power in the territorial sea must comply with the legal requirements regulating the conditions to process administrative titles granting a certain territory's occupation (both previous and during the project's development) and the dispositions in terms of deadlines, transference and extinction.

4.5.1.1 Occupation of the MTPD

The Coast Law establishes in article 3.2 that the following areas belong to the State's MTPD:

The shore, including the territorial sea and inland waters, together with their seabed and subsoil.

It is also considered public land the maritime terrestrial zone, beaches and dunes, whose occupation is required for transport purposes linking power plants to the electricity distribution network.

A zone of restricted use is established around the MTPD land regulating protection rights, forbidding high voltage power lines, exceptional proceedings due to well proved public use that may require an authorization of the Council of Ministers, without detriment to town planning approved by a competent administration. Such exception is not valid given that the area is located on the coast forming a beach, wetland or any other specially protected area.

The Autonomous Community is in charge of granting the authorization, being informed by the Coast Service Peripheral.

Uses which may imply special circumstances of intensity, safety or profitability and therefore, require works and installations in the MTPD, can only be sheltered under the administrative title in the Coast Law.

4.5.1.2 Previous Conditions before a MTPD Occupation Proceedings

The MLPD can only be used for activities or installations which, due to their nature, cannot be located anywhere else. The administrative title varies depending on time permanence, work requirements and/or fixed or removable installations. Therefore, an authorization is required to use the public land by a removable installation or personal property within one year time period. Other cases require an administrative concession.

The following documents must be provided to apply for a title:

a. The applicant's credentials
b. Presentation of a basic project.
c. When the MTPD is not used by the Administration, an economical-financial study will be provided describing the exploitation's planning, considering several repayment alternatives in relation to estimate income, public fees and, if applicable, division of its constituent factors as a basis for future revisions; expenses, including the project, works, royalties and taxes, preservation and energy consumption, personnel and any other expenses to maintain the exploitation. And if amendment measures are taken, expenses derived from the monitoring plan to survey efficiency and net profitability of such measures will also be analysed.
d. An initial 2% deposit of the execution budget of the project must be paid, which will get to 5% after being granted a title. Deposits are irrevocable and automatically executed by the competent entity. This deposit will be reimbursed after one year from the date of acknowledgement which confirms that works are developing according to the approved project.

The basic project written by a qualified technician must cover the following contents:

a. Characteristics of installations and works.
b. Area of MTPD to be used.
c. Report explicitly declaring the fulfilment of the Coast Law and all general and specific regulations on the project's development and execution. The project's development must be compatible to the current town planning and it must be thereby mentioned in the project.
d. Basic project criteria, work planning and, if applicable, residual water evacuation plan.
e. Maps, representing the boundary management of the used area and its area of influence.
f. Photographic report of the area.
g. Works' budget.

Once the title is granted and before works start, a construction project shall be presented, which could have been submitted substituting the basic project.

It is important to mention that the project must foresee the works' adaptation to the surroundings and influence on the coast where it is located. This is done by means of a study of the littoral dynamics referred to that specific coastal physiographic unit which shall contain the following analysis:

a. Transport capacity of the littoral.
b. Sedimentary balance and coastline evolution, both before and after the works.
c. Maritime climate, including wave statistics and directional and scalar spectra.
d. Bathymetry up to seabed that may not be modified, and

balance profile of the affected coastline in plant and profile, geological nature of seabeds.

e. Marine biosphere conditions.
f. Available sand and rock resources and their suitability to predict dredging or sand transfer.
g. Monitoring plan.
h. Minimization proposal, if applicable, of work consequences and possible amendment measures.

4.5.1.3 Administrative Title Proceedings

Procedures for authorization and concession have similar proceedings, simplified in the case of an authorization.

a. Authorizations

An authorization procedure starts when the application, together with credentials identifying the applicant and representative person, as well as previously related documentation, is presented in the Coast Service Peripheral.

Once the project is examined, after paying the applicable fees, field confrontation will follow, aimed at determining its suitability and feasibility.

A project's report will be submitted to Guildhalls, where the object of authorization may be developed, and to the Autonomous Community, the competent entity in navigation issues in case the works or installation may imply a risk on maritime safety, and any other entities that may be involved.

Authorizations with analogous criteria are granted by the Coast Service Peripheral.

b. Concessions

Regarding concessions, the Project must be submitted for public information for a time period of twenty days, simultaneously to the report to official entities. In case consent is granted, the applicant will comply with the conditions set thereby. In case of agreement, the Ministry of Rural, Marine and Natural Environment will discretionally determine if the concession is finally granted.

c. Application deadlines

Application deadlines of the files are set to be four months for authorizations and eight months for concessions.

4.5.1.4 Title's Effects

a. Expiration date

Authorizations expire in one year.

Concessions are granted for two different time periods:

Those concessions, whose nature locates them in MTPD, as they play a role or provide a service, require its occupation within a time limit of 30 years.

Use of public service, which cannot be located in an adjacent territory due to the coastline physical configuration where it must be located, have got a time period of 15 years.

b. Transfer

Concessions are not transferable by means of *inter vivos* trust. In spite of that, concessions which serve as ground for a public service will be transferable if the Administration approves a transfer to a certain contract of service management, and those being linked to research permits or exploitation concessions included in the mines and hydrocarbons' regulation.

c. Extinction

In all cases of extinction of a concession, the State's Administration will decide on the works and installations' maintenance or their decommissioning and removal of the public domain and the area protected by rights of use for the interested person and at his own expense.

If a decision of maintenance is made, exploitation and installations' use will be continued by any of the management procedures established by coast regulation or contracts of the public sector.

4.5.1.5 Damage in the MTPD

May some uses provoke damage on the public or private domains, the State's Administration will be entitled to demand from the applicant as many reports and economic guarantees as they are regulated as prevention, the replacement of affected goods and corresponding compensations.

4.5.2 Royal Decree 1028/2007

With the aim of achieving different objectives established in each energy and environmental policy, a variety of regulations have been passed at different levels; communitarian, national and regional, promoting and supporting renewable energies in general, or some of them specifically, to achieve several goals established in such energy and environmental policies.

At an international level, the United Nations' Convention on the Law of the Sea of 1982 in article 56, grants to coastal states sovereignty rights "*for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the sea-bed and of the sea-bed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds*", granting the exclusive right to construct and to authorize and regulate "*installations and structures for the purposes provided for in article 56 and other economic purposes*".

At a European level, apart from existing regulations in some Member States such as Denmark, United Kingdom or Netherlands, we must cite at least the *Green Book of the Commission on renewable energy resources* and the *White Book for a strategy and communitarian action plan on renewable sources of energy*, where the feasible overall wind energy penetration thresholds for 2010 are outlined. Directive 2001/77/CE of the European Parliament and of the Council, of 27 September 2001, on the promotion of electricity produced from renewable energy sources in the internal electricity market, in article 6, urge Member States to assess the existing regulation framework to rationalize and speed up authorization procedures of electricity generating installations from renewable energy sources.

At a national level, there are few regulations referring to marine wind energy, the most recent are found in Royal Decree 661/2007, regulating the production of electricity under a special regime. In its second article the possibility for wind power installations located in the territorial sea to make use of the special regime of electricity is foreseen.

Apart from this accessible and generic reference, little more can be found in the Spanish Law concerning this form of generating electric power until *Royal Decree 1028/2007, 20 July 2007, establishing the administrative procedure for processing applications for the authorization of electricity generating facilities in territorial waters*.

In spite that RD 1028/2007 focuses on marine wind energy, it also contemplates in article 32 authorizing other electricity generation technologies of a renewable marine nature located in the territorial sea, but it only foresees a simplified procedure which is regulated by a subsidiary character in accordance with *Royal Decree 1955/2000, 1 December 2000, regulating the activities of transport, distribution, commercialization, supply and authorization procedures for electrical power plants*, without establishing a minimum power limitation.

RD 1955/2000 establishes that construction, extension, modification and exploitation of all electric installations mentioned in article 111 require the following administrative procedures:

Request of Administrative Authorization: refers to the project's draft of the installation as a technical document.

Approval of the Execution Project: refers to the specific project of commissioning and allows the applicant to start building up.

Exploitation Authorization: allows, once the project is executed, to power up the installations and proceed to their commercial exploitation.

4.5.2.1 Request for an Administrative Authorization

As previously mentioned in the section above, the procedure starts when a request for an Administrative Authorization of the installation is made in accordance to article 122 of *RD 1955/2000*.

Such request must be addressed to the Directorate General for Energy Policy and Mining, and might also be forwarded to the Department or Division of Industry and Energy of the Government Delegations or Sub-Delegations of the province where the installation requesting this administrative authorization is located for the construction, extension, modification and exploitation of electric installations to be produced, transported and distributed. Likewise, these requests may be addressed to the entities mentioned in article 38.4 of *Law 30/1992, 26 November, on Rules governing general government institutions and Common Administrative Procedure*.

Such request must comply with the requirements listed in article 70 of *Law 30/1992, 26 November, on Rules governing general government institutions and Common Administrative Procedure*:

1. Name and surname of the stakeholder, and if applicable his/her representative, together with the preferred address for notifications.
2. Facts, arguments and request clearly stating the nature of the application.
3. Place and date.
4. Applicant's signature or credentials testifying his/her motivation conveyed in any form.
5. Entity, centre or administrative institution to which it is addressed.

This request will have attached a project's draft of the installation, including:

1. A report informing on the following specifications:
   i. Location of the installation, and in case it involves transport or distribution power lines, origin, trajectory and end of the line.
   ii. Aim of the installation.
   iii. Main characteristics of the installation.
2. Maps of the installation at a minimum scale of 1: 50,000.
3. Budget estimate.
4. Annexes for Government Institutions, entities and if applicable, companies devoted to public service or general interest services which may have goods or services affected by the installation.
5. Any other information that the responsible institution of dealing with the file may consider necessary.

Together with the administrative authorization request, the applicant shall address to the Directorate General of Policy and Mining a receipt from the Deposit General Agency after presenting a guarantee for a sum of 2 % of the total budget of the installation. This guarantee will cover the provisional deposit required in article 88.1 of *Law 22/1988, 28 July, on Coasts*, together with the guarantees regulated by articles 124 or 59 bis, or if applicable, 66 bis of *Royal Decree 1955/2000*.

The authorization procedure is determined by the Directorate General of Energy Policy and Mining. According to RD 1955/2000, the resolution and notification shall occur "within three months from receipt of the request for administrative authorization" (art. 128.1).

The administrative authorization request can be submitted together with the application of an EIA according to what was aforementioned in section 4.3.

Likewise, proceedings for the occupation of the MTPD according to the Law on Coasts will be initiated (see section 4.5.1). The Directorate General for Coasts will determine the occupation of the MTPD considering the EIS (statement) and conditions stated in the authorization of the procedure by the

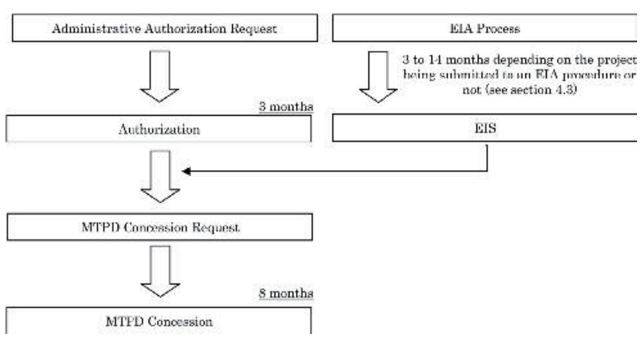

Figure 5. Summary of an administrative procedure for projects on wave energy harnessing in accordance with RD 1028/227.

Directorate General for Energy Policy and Mining.

Thus, the administrative procedure for projects on wave energy harnessing can be summarized as shown in Figure 5.

Therefore, RD 1028/227 regulates exclusively the project drafts' authorization of installations for electricity generation, thus this is far from fulfilling its intended objective of regulating, in an integrative way, a unique administrative procedure of authorization for wind power parks. Instead, it is only aimed at providing a specific regulation on one of the authorizations (the project draft), mentioned in RD 1955/2000, to add certain previous requirements in the subsequent administrative procedure.

4.5.2.2 Approval of the Execution Project

The applicant of the authorization will submit to the division or, if applicable, the Department of Industry and Energy in the Government Delegations o Sub-delegations of the province where the installation will be developed, a request addressed to the Directorate General of Energy Policy and Mining, as required in article 70 of Law 30/1992, of 26 November 1992, on Rules governing general government institutions and Common Administrative Procedure (see previous section), together with the execution project based on the relevant specific Technical Regulations.

Divisions, or if applicable, Departments of Industry and Energy in the Government Delegations o Sub-delegations of the provinces where the installation will be located and developed, will be responsible for processing the request for approval of the execution project and shall resolve and grant the consent within three months.

The competent administration may consult other affected institutions, entities or companies devoted to public service or general interest services in charge of goods and rights in the area so that they can set relevant technical conditions within twenty days.

4.5.2.3 Exploitation Allowance

Once the project is executed, the relevant request for certificate to come into service will be submitted to the Divisions or Departments of Industry and Energy in the Government Delegations o Sub-delegations of the province where the file has been processed.

This request will be submitted together with a certificate of end of works signed by a qualified technical engineer, mentioning the installation developed according to the specifications described in the approved execution project, and also the requirements set in the relevant specific Technical Regulations.

4.5.3 Law 3/2001, on the State's Marine Fishing

Article 20.1 establishes that "any kind of work or installation, removable or not, that is intended to be developed or installed in external waters, together with any material's extraction, shall require a prescriptive report of the Ministry of Food, Agriculture and Fisheries, at present known as Ministry of Rural, Marine and Natural Environment, and the affected Autonomous Communities, regarding living marine resources' protection and preservation".

Marine Strategy Framework Directive 2008/56/EC

According to this Directive, marine strategies must aim at preventing and reducing ocean dumping with the objective of progressively reducing pollution. A wave energy park's impacts, such as noise or interference with other activities, may be understood as pollution according to the Directive's definition. Thus, in article 3.8 pollution is defined as "direct or indirect introduction in the marine environment, as a result of human activity, of substance or energy, including underwater noise of human origin, which may provoke detrimental effects and damage to living resources and marine ecosystems, including loss in biodiversity, risks to human health, interference with marine activities…".

5. Description of the project

5.1 Introduction

The introduction in the description of the project is aimed at setting a framework of the project covering at least the following contents:

- Context: present situation of renewable energies, reasons why the project should be developed, public interest of the project.
- Brief definition: what the project consists in.
- Objective: exploitation, trial, research, tests… the project may have a miscellaneous objective.
- Promoter: public entity, private enterprise, etc.

The project may be a commercial installation to exploit a specific technology or an infrastructure for various technologies to make tests, trials and demonstration of a pre-commercial exploitation.

5.2 Location of the Project

Geographical location of the future project and brief description of the area should be provided. Coordinates of the open sea area to be demarcated (for off-shore installations) should be provided, together with coordinates of the harnessing devices, size of the total occupied area, etc.

Graphic documentation clearly explaining the installation's location must be provided.

5.3 Components of the Installation

Components of marine energy installations shall be different depending on the type of technology used. Electric power devices or converters (known as WEC or Wave Energy Converters) and cables for electricity transport are the same for most of the projects; however, the rest of auxiliary components may vary depending on the installation's location. Moreover, occupation of both sea surface and seabed depends upon the converter and moorings installed.

Thus, WECs can be classified according to the following criteria:

a. According to their location with regards to the coastline. This is the most commonly used classification in both scientific and industrial sectors:

- *Onshore or first generation*; devices lying on the seabed in shallow waters, integrated in fixed structures such as breakwaters or rocky cliffs (Figure 6).
- *Nearshore or second generation;* located at 10 to 30 m water depth and close to the coast (Figure 6).
- *Offshore or third generation;* further located from coast at 50 to 100 m water depth (Figure 6).

b. According to the harnessing principle:

- *Fluid Pressure Difference*: consists in an open chamber under sea level where the alternate pattern of wave movement raises and lowers the water level displacing the internal air volume, which consequently displaces a turbine generating energy.
- *Buoy bodies activated by waves*: they are devices made up of a floating part which is moved by waves. Energy is extracted in various ways profiting from the alternate movement of this element.

Overflowing and/or impact systems: they are devices which are driven by waves forcing water to pass over a structure, what leads to an increase of its power potential, kinetic energy or both of them. In the impact system, an articulated or flexible structure functions as transfer media.

c. According to their orientation towards the wave front:

- *Punctual Absorber*: they are cylindrical buoy bodies indifferent to wave direction and small sized compared to average wavelength.
- *Multi-Punctual Absorber*: they are platforms where many buoys are linked functioning simultaneously.
- *Attenuator*: elongated buoy bodies which are oriented parallel to the waves' forward movement, and absorb energy in a progressive and directional way.
- *Terminator*: structures which are oriented perpendicular to the waves' direction and absorb energy at once.

It is important to highlight that, the present state of the art for the exploitation of marine energy is diverse. Many harnessing concepts have been developed at different stages and there is not a centralized fostering and financing policy, as public entities lack a clear strategy on the matter. However, this is a growing industry and there are several on-going projects. Therefore, it would be possible that new technologies which are not mentioned in this report appear in a recent future deploying connection systems and standardized components which have not been developed up to-day.

The best developed technologies at present include devices in different shapes, sizes and harnessing principles. Classifications usually organize them by the method for energy profit and orientation to wave.

For the purpose of this report, wave energy converters have been classified by location with respect to the coastline, due to the fact that they will be made up of different components, and consequently have different impacts on the environment.

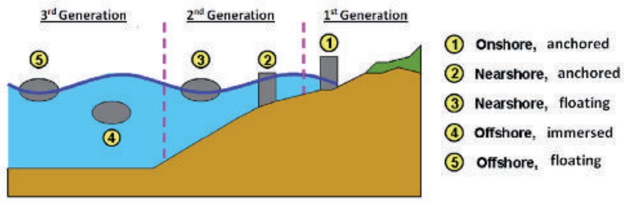

Figure 6. Types of wave energy harnessing technologies considering its location with respect to the coastline.

5.3.1 Onshore Installations

Wave energy onshore harnessing devices are a minority these days. Most of them are integrated in coastal constructions such as docks or protection dikes, although some are built on a cliff or rocky area.

Some of them such as the pilot station in Pico, Portugal, or the EVE's (Basque Entity of the Energy) prototype in Mutriku, Guipúzcoa, Spain; use the principle of oscillating water column. For this purpose, an open chamber is built up on their base, where waves come in, making the air column above sea level comprise and move a turbine.

Onshore wave energy installations have the advantage that they do not need the installation of a submarine cable as they are located inland, integrated in civil work structures such as dikes or docks. The main components are the harnessing device and the cable. Mark buoys for navigation must be always used in the port or constructions where they are located.

5.3.1.1 Civil Work

This deals with the construction of a dike or breakwater structure which forms part of the system. These structures are generally used as protection against waves and serve as a physical support where equipment is fixed.

Sometimes onshore equipment can also be installed on a cliff or rocky area on the coast, such as Pico in Portugal or the Land Installed Marine Powered Energy Transformer (LIMPET),in Scotland. In these cases, only a chamber containing turbines needs to be built.

5.3.1.2 Wave Energy Converters

The most advanced technologies are working at present on chamber shaped structures lying on the littoral or civil work structures. A concrete chamber is the main structure of the WEC. Several turbines, in contact or not with water, are located in this chamber and generate electricity when they are moved by the air column displaced by water.

Within this category, the most relevant prototypes are the LIMPET and the Seawave Slot-Cone Generator (SSG).

a. LIMPET

Developed by Wavegen (www.wavegen.co.uk), a Scottish subsidiary company of Voith Siemens Hydro Power Generation from Germany. Two systems are offered: *onshore* and *near-shore*.

The LIMPET is a system with turbines which is being currently commercialized. It is based upon the oscillating water column compressing and expanding air in a chamber and forcing it through a conduct which moves a Wells-type turbine and a turbo-generator which will produce electric current (Figure 7).

These systems are usually located on the coast and in areas exposed to a strong swell. They can also be located *nearshore* directly lying on the seabed and designed to operate up to 15 m depth.

At present, there is a LIMPET system in an experimental station of 500 kW which was installed in 2000 on the island Islay, West Scotland, and it has produced energy for the national network since then.

The first commercial wave energy plant based on Wavegen's technology was installed in Mutriku, Guipuzcoa, Spain. 16 turbines integrated in a breakwater would generate an electric power of 300 kW, and therefore, could supply up to 250 dwellings. This plant is expected to be operative at the end of 2009.

On 22 January 2009, it was also approved the *Siadar Wave Energy Project* (SWEP) on the Siadar Bay, Orkney Islands, Scotland (http://www.npower-renewables.com/siadar/index.asp) where up to 4 MW of electricity will be generated.

b. SSG

WAVEenergy AS (http://www.waveenergy.no) was created in April 2004 to develop the SSG. The SSG is a wave energy converter based on the principle of *overtopping* which uses three deposits built one on top of the other where wave potential energy is stored (Figure 8).

Water captured in deposits goes through a turbine to produce electricity. Using multiple deposits results in a higher total efficiency compared to a unique deposit structure. These days, turbines working under the same axis are being developed to achieve a more uniform generation of electric power. The SSG can be used as an *offshore* floating or fixed structure or as an *inshore* coastal structure integrated in a breakwater.

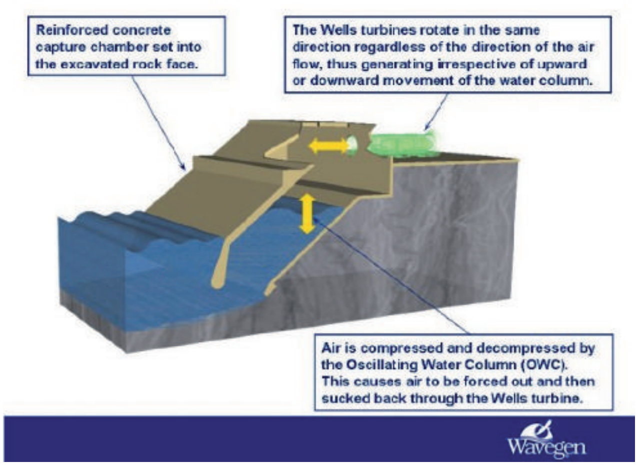

Figure 7. LIMPET wave energy converter. From www.wavegen.co.uk.

5.3.1.3 Terrestrial Cable

Onshore installations do not use submarine cable but a conventional cable adapted to the evacuation needs of the device, which transports the electricity generated by the energy turbine converters. This cable will be buried within either the same civil work, in case it is built or underground and protected as required, up to the transformer.

5.3.1.4 Transformer

Electricity generated by these devices can reach different frequency and voltage compared to the electric network. That is why it must be transformed for its injection by means of a transformer located nearby the installation, generally underground or within the structure.

5.3.2 Offshore Installations

This kind of installations are typically located between 40 and 100 meters depth, which is ideal for energy harnessing purposes, just a few miles away from the coast. A submarine cable will be associated to this installation transporting electricity to the coast. An *offshore* installation usually implies delimiting a restricted area for navigation, where surface WECs will be installed (they are usually floating structures), together with cables, connectors and mooring systems on the seabed.

5.3.2.1 Submarine Cable

A main component in a wave energy installation is the cable, as it connects the device to the electric network. Depending on the connection system, different designs are possible, but the following parts are usually identified:

- **Static Cable:** is a power cable going from the beach to a connection box, which is not designed to be moved nor bended, but to stay still.
- **Dynamic Cable:** is a submarine cable designed to be bended in case maintenance operations require that.
- **Umbilical Cable:** they link the WECs to the dynamic cable, and they are also designed to be bended as they are connected to the device and therefore under constant voltage.

The cable's route will strongly depend upon orography, bathymetry and seabed typology distribution in the installation's

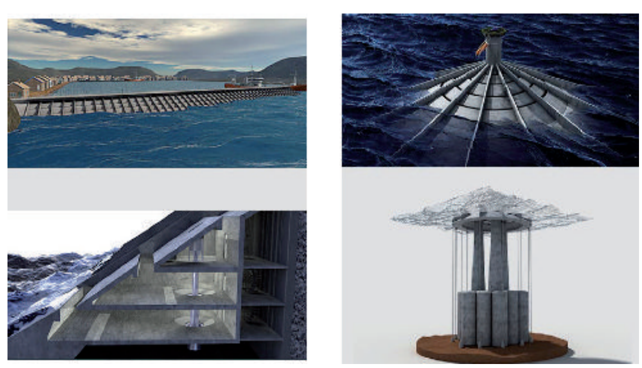

Figure 8. Seawave Slot-Cone Generator (SSG).

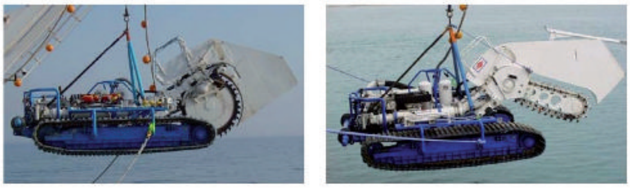

Figure 9. Cable Embedding Vehicle 03 by LD TravOcean (www.ldtravocean.com).

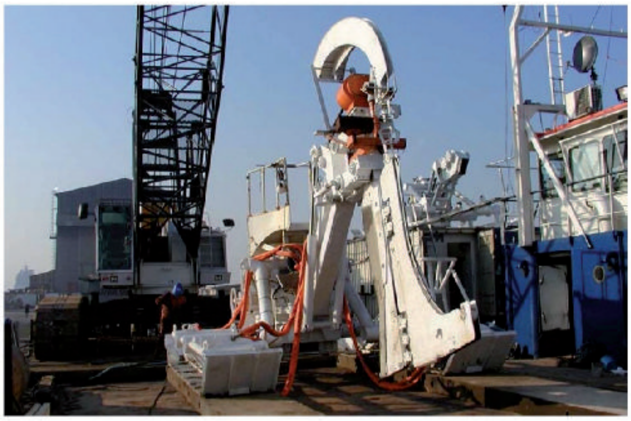

Figure 10. Plough by LD Bravocean (www.ldtravocean.com).

Figure 11. Towed Jetting Vehicle 06 by LD TravOcean (www.ldtravocean.com).

area. In general, the cable will tend to pass through sandy seabed where it can be buried without digging a trench.

The installation of a submarine cable is a complex process where highly specialized equipment is required. Depending on the seabed typology, the slope and depth of a certain stretch, different techniques should be applied.

a. Installation of the cable

There are various installation methods of a submarine cable depending on the seabed typology it will lay in.

In rocky seabed, a technique called *trenching* will be used, consisting in digging a trench with highly specialized machinery operated from the installing vessel (Figure 9). The cable is put in the trench and the rock extracted is put back into the hole thereafter.

In sandy seabed, both *ploughing* (Figure 10) and *jetting* techniques can be used. The cable is inserted in the furrow

Figure 12. BMH for a telecommunications cable entry in Marseille (France).

made on the sediment with a high pressure jet expelled by a machine (Figure 11).

In all cases, the cable is located on the trench and the extracted sediment is put back in a natural way immediately after the machinery passes by covering the trench.

At a certain depth, it is considered that the swell effect on the seabed is minimal, that is why sometimes the cable is decided to simply lay on the seabed; in case this is soft and sandy, the cable will bury itself due to its own weight.

Depending on the area's activities and other factors, the cable may need to be protected by an external pipe, breakwater materials, etc.

b. The route of the cable

The route where the cable will run must be accurately described, providing graphic information to explain it. The route will strongly depend on the sediments' distribution on the seabed and also the slope. Consequently, sandy seabed and a soft slope are regarded as the most convenient. The submarine cable will probably run along the MTPD and territorial sea.

c. Landing of the cable: Beach Man Hole

The site where underwater cable turns into terrestrial cable is called *Beach Man Hole*, also referred to as BMH, that is, a coffer or underwater concrete chamber of approximately 3x3 meters of base (Figure 12). Due to the fact that submarine cable is more expensive than terrestrial cable, this coffer will be located near the coastline so that the change can be made as soon as possible.

The cable's transition from the BMH to the subtidal area can be made by means of a tunnelling and channelling technique in a PVC tube known as *Horizontal Directional Drilling* (HDD), whose main characteristic is a null effect on the intertidal area as it goes through such area underground (Figure 13).

d. Electrical Installation

In general, wave energy installations have a submarine cable to land where the transition to terrestrial cable occurs. Electricity will be transformed into the appropriate voltage in the substation to be connected to the national electricity network. If the substation can be built up near enough to coast, the BMH can be located there. Depending on the voltage of the terrestrial cable, the electrical installation will be aerial or underground, and therefore impacts will be different.

e. Maintenance

Some of the commonest reasons for cables failing in transmission are: i) impact from dredging equipment, moorings and fishing arts; ii) electrical insulation broken by thermal, electrical or mechanical stress; iii) manufacturing or installation faults; iv) scouring due to friction with seabed; v) fish bites.

Maintenance works on the cable may include the following tasks:

- *Onshore work*: check-up of BMH and the cables' course to land, monitoring of the buried cable and remote testing of the cable from the terminal station.
- *Offshore work*: repairing the submarine cable, burying the cable after reparation and check-up made by a professional diver or a Remotely Operated Vehicle (ROV). This is usually surrounded by cameras, put together with a cable detector, to find the cable when it is not visible, thereby being able to determine how deep it is buried. Likewise, they usually have two arms to unearth the cable by jetting and proceed to check the cable.

If reparation needs to be done, the underwater cable will be hoisted to the surface to be repaired. The cable's connection will be done on board a vessel, and afterwards the cable will be buried back to place with a similar tool to the aforementioned.

A vermiform bivalve, known as *Teredo navalis,* has been found in warm waters; even though it usually eats wood, it may cause damage in other structures including submarine cables. That is why some installers recommend using a protection against this organism.

5.3.2.2 WECs

These days, most WECs being deployed are designed to be installed *offshore*, and many use floating devices. There are all kinds of converters as mentioned before. Some of them are point absorbers, have a buoy shape, they are cylindrical and due to their axial symmetry are indifferent to swell direction. They are generally manufactured in steel and use chains and anchors to be grabbed to seabed. Thus, under this category we can highlight the following prototypes:

a. Multiple Resonant Chambers (MRC)

Developed by the company ORECon Ltd (http://www.orecon.com), which is a subsidiary of Plymouth University. The prototype MRC is a system that uses multiple resonant chambers to keep electricity generation at a wide range of wave types (Figure 14). For this purpose, it counted on six oscillating water columns, fit to a different wave frequency to maximize the use range, and thus, improve its efficiency.

In February 2008, Orecon got financing for a real scale device, and on March 2009, Orecon announced they will be looking forward to test this technology in Wave Hub's installations in England (www.wavehub.com). Meanwhile, in May 2009 they founded a high risk company, together with the Portuguese Eneolica, with the objective of building up the first MRC system with 1.5 MW.

b. Ocean Energy Buoy (OE Buoy)

This system was developed by Ocean Energy Ltd (http://www.oceanenergy.ie), a company which was founded in 2002 to build up WECs. Operation is based on the water column oscillation which is turned into rotation in a unidirectional air turbine (Figure 15).

This system is built according to minimal maintenance principles, low anchoring strengths, simple design and few mobile parts. The system has been developed since 2002;

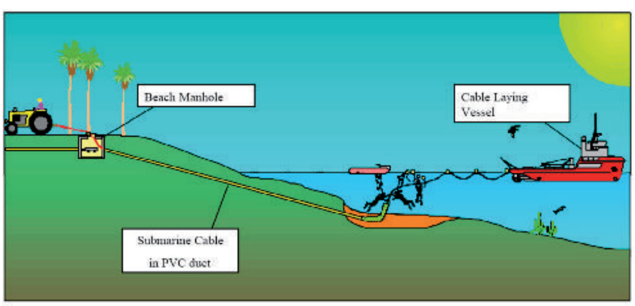

Figure 13. Landing of the underwater cable. From Holroyd and Byng (2000).

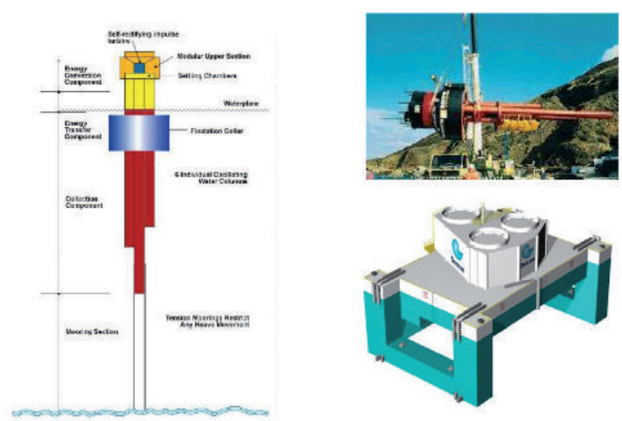

Figure 14. MRC or Multiple Oscillating Water Column.

Figure 15. OE Buoy developed by Ocean Energy Ltd.

Figure 16 Wave Dragon System. From http://www.wavedragon.net/.

Figure 17. WavePlane System. From http://www.waveplane.com/.

it started as 1:50 scale tests in the Hydraulics and Maritime Research Centre, also known as HMRC, located in Cork, Ireland. With the object of achieving more accurate results, the system was also tested at a 1:15 scale in the Central School at Nantes (France).

c. WaveDragon (http://www.wavedragon.net/)

This is the first *offshore* system connected to the electricity network. The Wave Dragon's idea is based upon the principle of traditional hydraulic stations applied to a floating platform in the sea: water goes through a trap door and it is stored in a reservoir (over sea level) to preserve that potential energy (Figure 16). Afterwards, water is released through turbines, which turn the potential energy in kinetic energy, obtaining electricity by means of rotating generator.

Amongst many other projects, it is important to mention the 1:4.5 scale prototype which has been tested for 3 years (2003-2006) in Nissum Bredning, Denmark. The prototype shows "V" shaped deflectors, which make the wave higher, and consequently, a bigger amount of water passes through the trap door. Performance is significantly improved when it is anchored deeper than 40 m, as wave energy is harnessed before it loses strength due to seabed friction; a good distance from coast is from 5 to 25 km. Results were presented in the Workshop on Performance Monitoring of Ocean Energy Systems INETI taking place in Lisbon, 6 to 17 November 2006 (http://pmoes.ineti.pt/).

d. WavePlane

This system was developed by the company WavePlane A/S (www.waveplane.com) from Denmark, a member of OE CA (Ocean Energy Coordinated Action) of the European Union. A WavePlane is a triangular floating structure with entry channels on both sides and an anchoring point in the middle. This design guarantees that both the anchoring point and water entry are facing the swell (Figure 17).

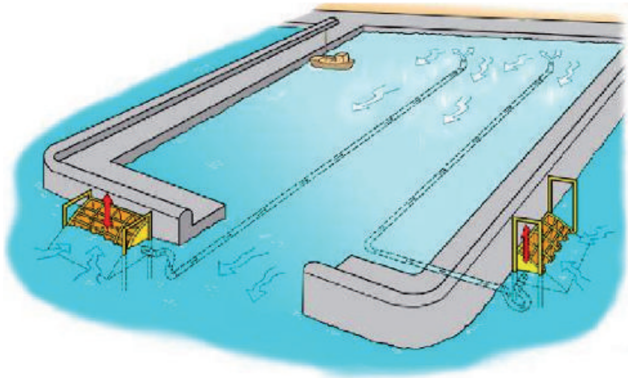

Figure 18. Harbour WavePlane System.

The WavePlane transforms the waves' shape and speed. When the waves' lower part reaches the artificial beach, speed decreases and the higher part is pushed towards the system. Water enters the lower channels moving the turbine, while water entering the upper channels moves the turbine once the wave is gone; consequently energy generation is more uniform. Tubes get narrower when they approach the turbine so that water speed, and thus kinetic energy, is higher.

This technology is used in different systems:

- WaveFlexGrid: this system anchors several WavePlanes together in a certain position to avoid them crashing into one another, and yet, allowing vertical movement. It only requires an anchoring point and a connection cable.
- Oxygen WavePlane: Oxygen WavePlane is designed to oxygenate big areas. A unique system is able to guarantee healthy oxygen conditions in a polluted environment of one hectare.
- Reverse osmosis WavePlane: consists in a desalting plant with 25 units of 100 kW grouped in 5 FlexGrid. Each WavePlane unit weighs approximately 40 Tm.
- Harbour WavePlane: is located in harbour areas to pump water into the harbour and avoid stagnant waters (Figure 18).

e. Pelamis

System developed by Ocean Power Delivery Ltd.(www.pelamiswave.com). The first prototype at a real scale was tested and approved in the European Marine Energy Centre, also known as EMEC (http://www.emec.org.uk/), located in the Orkney Islands, North Scotland. Pelamis is a cylindrical articulated and partially immersed structure. When this structure goes up waves, they induce a relative movement between those cylinders activating a hydraulic system made up of rods and pistons pumping oil at high pressure through hydraulic engines. Each articulated structure is 120 m long,

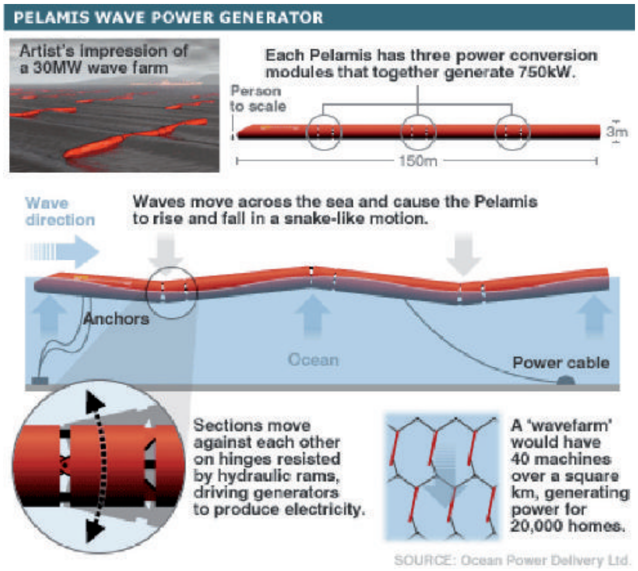

Figure 19. Pelamis System. From http://www.pelamiswave.com/index.php.

3.5 m of diameter and is able to produce 750 kW of power (Figure 19).

The first installation started operating in September 2008 in Aguçadoura (near Póvoa de Varzim, Portugal), using P-750 elements with a unitary power of 750 KW, consequently the total power of the park added up approximately 2.25 MW.

f. Archimedes Wave Swing (AWS)

System developed by AWS Ocean Energy Ltd. (http://www.awsocean.com/), a Scottish company established in Edinburgh in May 2004 to commercialize AWS. The wave energy converter AWS consists in an immersed big cylinder filled up with air located on the seabed (Figure 20).

While the wave's crest is approaching, water pressure in the cylinder increases and the upper part or floating device comprises air inside the cylinder to balance pressures. The opposite effect occurs while the wave is passing by, air expands and the cylinder goes up. The relative movement between the floating part and the lower part is directly turned into electricity by means of a lineal generator. Nevertheless, they are considering the use of a hydraulic trigger system at present. It is thought that power higher than 1 MW per unit could be generated.

A complete system has been tested in a pilot plant in the coast of Portugal, and these days, a pre-commercial model is being developed. This system has got many advantages, amongst which we would like to mention the protection against storm, as it is located underwater, what also reduces mooring costs and damages. The commissioning of these devices requires an area fairly exposed to swell, deeper than 40m and an appropriate seabed where the cabling can be installed.

g. PowerBuoy

This system was developed by Ocean Power Technologies, Inc. (OPT) (http://www.oceanpowertechnologies.com). It consists in a point buoy transforming vertical in rotating movement through actuators, pumping hydraulic fluid and

Figure 20. Archimedes Wave Swing (AWS) System. From http://www.awsocean.com/.

Figure 21. PowerBuoy System developed by Ocean Power Technologies, Inc. (OPT).

Figure 22. AquaBuoy System developed by Finavera Renewables.

profiting from the relative movement between the float and the mast. Scaling the system, power from 40 kW to 500 kW can be achieved (Figure 21). The anchoring mechanism allows locking the system so that it does not produce energy in case excessive waves caused damage.

h. AquaBuoy

Developed by Finavera Renewables (www.finavera.com), it consists in a floating structure that turns kinetic energy of the waves' vertical movement in electricity (Figure 22). This technology was planning to install several experimental models in the USA, Portugal, Canada and South Africa. However, in February 2009, the company decided to focus in the wind power sector instead of wave energy.

i. WaveBob

Wavebob Limited (www.wavebob.com) is registered in Ireland, and its subsidiary, Clearpower Technology (http://www.clearpower.ie/cleartech.html), in Belfast. They have

Figure 23. WaveBob System developed by Wavebob Limited. From www.wavebob.com.

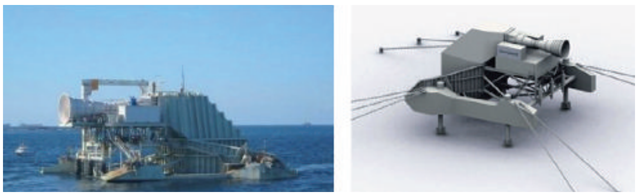

Figure 24. Parabolic OWC System developed by Oceanlinx.

developed marine WECs for six years. Their product, Wavebob, is a marine energy converter which has a 20 m diameter at real scale and is calculated to produce from 500 kW to 1 MW in highly energetic environments (Figure 23).

This system has been developing since 1998, having passed the test phase in wave tanks with 1:50 and 1:20 scale models in the Hydraulics and Maritime Research Centre (UCC, Cork) and wave channel of the German Coastal Defence Centre (Hanover University and the Technical University of Braunschweig).

j. Oceanlinx

System developed by Oceanlinx Ltd. (http://www.oceanlinx.com/), whose operation is based upon water column variations. Main innovating features are a turbine modelling adapted to the air flow variation and a design of a parabolic reflector, which concentrates wave energy to achieve a higher flow (Figure 24).

A smaller nozzle section linking the wave's surface to the turbine's entry guarantees a higher air speed as it comes into the turbine. Due to the fact that the turbine must rotate always in the same sense, no matter what the air flow direction is, a turbine operating at low revolutions with a high torque was chosen.

In October 2005, an experimental unit of 500 kW was installed in Port Kembla, Australia, and due to the good results obtained, in December 2006, the test period was extended. Beginning October 2009, Oceanlinx started commissioning their last demonstration system, the *mk3*, connected to the electricity network in Port Kembla. The station will be finished in the beginning of 2010 and is expected to produce around 2.5 MW in open sea.

5.3.2.3 Underwater Connectors

Nowadays, no underwater connection model or standard for wave energy installations has been developed. But this is bound to change, once the introduction of marine energy as a competitive alternative in the renewable energy market is a fact.

One of the solutions up to-day is an underwater connector box system, specifically designed for each project. These connection boxes are passive elements lying on the seabed where the static cable goes in and one or several dynamic cables go out.

Other proposal taken into account, in spite there are no operational data, is an underwater sub-station, where voltage generated by WECs would be transformed before being injected to the network.

5.3.2.4 Mooring

Most of offshore WECs are floating bodies on the water surface which use weights or anchors of a diverse nature to be grabbed to the seabed; those being concrete blocks, metallic structures, and anchors driving into the seabed. There are also WECs directly lying on the seabed.

Impact on seabed and its living communities caused by moorings will depend on the number of anchors and their size, and also on the type of seabed.

An added problem is how difficult and expensive it is to recover these heavy bodies, especially when they are located at depths higher than 50 m.

5.3.2.5 Marker buoys

For safety reasons to navigation and the equipment itself, the testing area for demonstration, operation, etc. of WECs will be clearly signalled with marker buoys or any other navigational support required, and must be present in nautical charts. In order to guarantee safety, the area will be declared of exclusive use for the companies involved in the installation.

The IALA (*International Association of Marine Aids to Navigation and Lighthouses*) is in charge of the publication of signalling recommendations for any kind of installation in the sea.

In offshore parks where connection boxes lie on the seabed, additional signals could be used to locate the position of these boxes.

5.3.2.6 Oceanographic Buoy

An oceanographic buoy is a very useful element when it comes to swell characterization and gaining knowledge on the exact values for relevant parameters of wave energy, such as wave height, significant height, tension, peak direction, etc. Superficial currents can also be measured together with currents at a given depth. Moreover, buoys are usually equipped with various meteorological sensors providing information on wind speed and direction, air temperature, visibility, etc. Some of this data is transmitted real time via radio or satellite, and other pieces of information are periodically taken from the buoy while maintenance tasks are developed.

5.3.2.7 Transformation Sub-Station

A sub-station is designed to transform the produced electricity voltage, and thus, facilitate its injection to the network, as well as to gather electrical data at both stages. The following elements will be usually found:

- A given voltage for the electricity network connection.
- Transformer from one voltage to another.
- Electrical protections.
- Measurement systems at each entry line.

Its location will primarily vary depending on the connection point to the electricity network granted to the installation by the electricity company. Its size, though, will depend on input and output voltage, that is, voltage coming from the electricity generated by WECs and voltage of the target line.

5.3.3 Nearshore Installations

Nearshore technologies are a minority compared to offshore technologies, although their interest lies in the fact that proximity to coast may overcome some installation and maintenance handicaps. Within this category we find floating devices and underwater devices anchored to seabed.

5.3.3.1 Cabling or Piping

A submarine cable will transport electricity inland from floating devices. Piping will take water to the plant, where a turbine will be activated to generate electricity, in those systems lying on the seabed and pumping pressurized water to land.

5.3.3.2 Sub-Station or Hydroelectric Conversion Plant

Devices producing electricity will transport it to a sub-station where it will be transformed to be injected to the network. However, pumping water will take it to a conversion plant where water will activate turbines.

5.3.3.3 WECs

Most *nearshore* converters, known to-day are located on the seabed, except the Danish prototype *WaveStar*, which is an elongated skeleton oriented parallel to the waves' direction with several legs at both sides from which hanging buoys progressively harness energy. The rest of structures are anchored to seabed, i.e., chains of buoys or shovel shaped devices, which profit from the elevation wave movement.

Within the present category, the main prototypes are described below, i.e., WaveRoller, WaveStar, FO3, CETO and Oyster.

a. WaveRoller

This system has been developed by AW-Energy Oy (Finland) (http://www.aw-energy.com). A WaveRoller is a flat modular system moored to seabed harnessing energy from swell. The plant's capacity is made up of a certain number of modules with 3-5 elements each installed in a common generator system. Each element can produce 13 kW in good swell conditions (Figure 25).

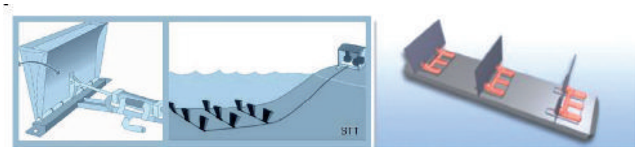

Figure 25. WaveRoller System developed by AW-Energy Oy. From http://www.aw-. energy.com/.

A 1:3 scale model was developed in 2005. Tests were carried out in the European Marine Energy Centre (EMEC) in the Orkney Islands, Scotland, and in Ecuador, proving how powerful swell is, and the feasibility of WaveRoller, both in good and bad weather conditions and with long period waves (15-20 s.). The design, manufacture and installation of the first modules were produced in a pilot plant in 2006. An additional capacity installation was developed in 2007 in the pilot plant including network connection and plant performance's measurement and analysis. They continued gathering information through real prototypes in Peniche, Portugal, in 2008.

b. WaveStar

System developed by Wave Star Energy (www.wavestarenergy.com). The main concept in *WaveStar* is different from many models, due to the fact that it does not form a barrier facing waves, but rather cuts them in right angle towards the swell propagation direction. This system is made up of semi-spherical floats linked to an anchored structure by means of pillars (Figure 26). These articulated floats are continuously moving and pumping pressurized oil to make a hydraulic engine rotate, from which electricity is obtained.

Tests were carried out in an experimental tank with a 1:40 scale prototype during 2004-2005. A 1:10 scale model was installed in the North Sea in 2006-2008. The system was made up of 40 floats of 1m diameter, and it could keep operating with only a 25 % of the total floats working. The model had a 5.5 kW generator which worked for more than 16,000 hours. A

Figure 26. WaveStar System developed by Wave Star Energy.

Figure 27 Seewec System. From http://www.seewec.org.

50-100kW prototype was installed at 7 m depth with two floats of 5 m diameter in 2009.

c. Sewed

This system was developed by a consortium of 11 members from Belgium, Netherlands, Portugal, Sweden, Norway and United Kingdom (http://www.seewec.org). It is made up of 12-21 buoy bodies attached to a floating platform (Figure 27). A 1:20 scale model was tested at the beginning of 2004 in a wave tank at average and extreme conditions. A 1:3 scale platform-laboratory was installed in the South coast of Norway in February 2005, and it is used as observatory and testing centre. The company decided to substitute the platform in favour of the point absorber model after considering the results from tests. The final real scale model was tested in 2009; dimensions: 5.15 m diameter, 1.45 m height, and 6 tons weight and 40 kW nominal power.

d. Cylindrical Energy Transfer Oscillating (CETO)

System developed by Carnegie Wave Energy Limited (http://www.carnegiecorp.com.au/), and made up of a series of anchored buoys whose circular movement after waves is transmitted to a cylinder pumping water to earth. This pressurized energy is turned into electricity in a turbine attached to a generator (Figure 28).

e. Oyster

System developed by Aquamarine Power (http://www.aquamarinepower.com/) which is located near shore at around 10 m depth and obtains energy from pumping water from sea to earth. Waves make a pendulum like motion which is transformed to pumping by means of a piston. Such pressurized water turns into electricity in a hydraulic engine and a generator which connects to the electricity network by a transformation unit (Figure 29).

Many numerical models and 1:40 and 1:20 scale experiments in wave tanks have been developed since 2003. The first trial system was built up in Nigg, Scotland, in 2008. The system has been tested on earth in the installations in Narec, Newcastle, England, in 2009. The system was installed in the EMEC in October de 2009 and at present, working parameters are being verified with operation and energy production purposes. According to the company's prevision, they will have a commercial plant by 2014.

5.3.3.4 Marker Buoys

Some projects with *nearshore* devices directly lying on or anchored to seabed must also signal underwater devices with marker buoys and/or set an exclusive area (see 5.3.2.5).

5.3.4 Spanish Technology

5.3.4.1 Oceantec

System developed by Tecnalia (www.tecnalia.info) and supported by Iberdrola, consisting in an encapsulated floating

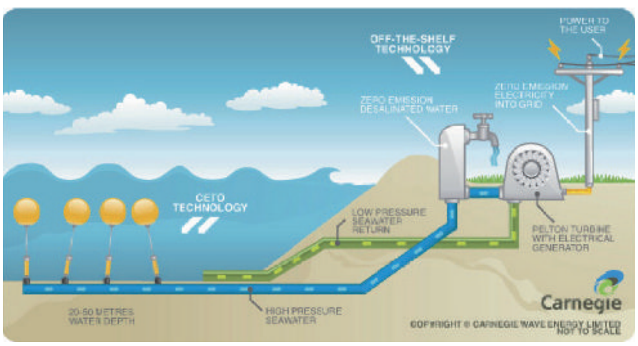

Figure 28. CETO System developed by Carnegie Wave Energy Limited. From http://www.carnegiecorp.com.au/.

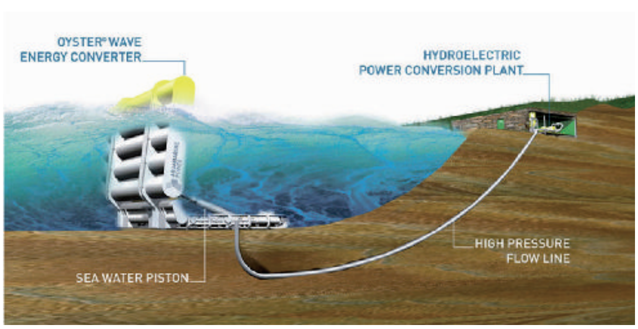

Figure 29. Oyster System developed by Aquamarine Power.

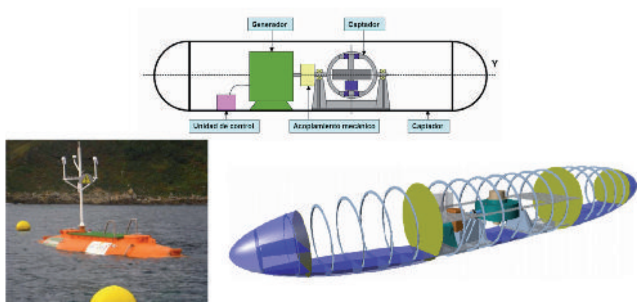

Figure 30. Oceantec System.

Figure 31. Hidroflot System.

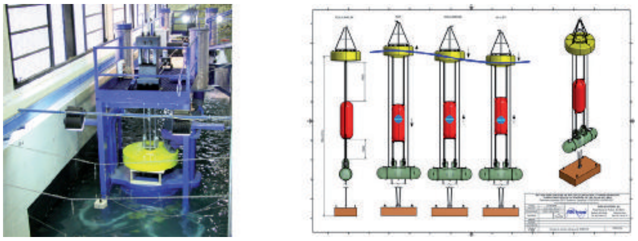

Figure 32. APC-PYSIS System.

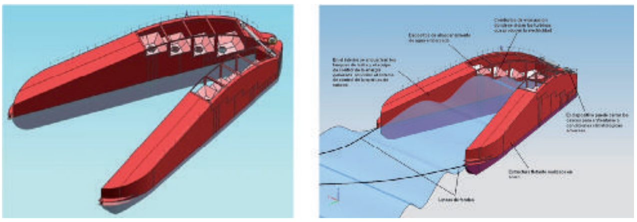

Figure 33. Wave Cat System.

system based on a gyroscope's mechanical motion from the swell undulating structure to obtain energy (Figure 30).

This system's development started in 2005 and a 1:4 scale prototype was sea tested in Pasajes, Guipuzcoa, Spain in 2008. At present, the system is being optimized to start building up a pre-commercial 1:1 scale system of 500 kW in 2010, which will be tested until 2011.

5.3.4.2 Hidroflot

Developed by Hidroflot S.L. (www.hidroflot.com) It consists in a platform made of 16 floats (Figure 31) which has got eight generation systems of 750 kW, therefore each platform is able to produce up to 6 MW. The system is protected against adverse weather by an immersing system.

5.3.4.3 APC-PISYS

This is a point absorber developed by PIPO Systems S.L. with a surface buoy and an immersed buoy. The relative motion between both buoys is mechanically transformed into unidirectional rotating motion to produce electricity (Figure 32).

A 1:10 scale system with two buoy groups was built up in 2006 and tested in the simulation channel in the Universidad Politécnica de Barcelona, Spain.

5.3.4.4 WaveCat

The system was patented by the Engineering Group of Coast and Water of the USC. Norvento Enerxia S.L., Vicus Desarrollos Tecnológicos S.L., the CIS in Ferrol and also the University of A Coruña took part in this device's development. WaveCat is a floating system to obtain energy based on the waves' side base and water storing in side tanks (Figure 33).

Then, water passes through a turbine specially designed to work at small water fall. A reduced scale system was successfully tested in the channel of University of Lugo, Spain, which has been used to validate dynamic simulations.

6. Environmental condition of the project area

This part of the study deals with a description of environmental parameters, in case they are significantly affected by positive and negative impacts associated to the project. The project's developer shall include information related to the affected environments: physical, biotic and socioeconomic (Solaun *et al.*, 2003).

The objective of such environmental inventory is establishing a "zero state" to be compared to, during the monitoring, surveillance and control programmes, including the Environmental Monitoring Programme (ESM) to see if real impacts match the predicted ones, and therefore, to be able to react and set the relevant amendment measures.

It is important to mention that monitoring all parameters and environments is not always necessary, only those in connection to a relevant possible impact on the environment (Solaun *et al.*, 2003). Table 2 shows a group of environmental variables which could be specifically and significantly affected by projects involving WECs.

On the other hand, depending on the drafting team's experience, the use will differ radically, and also their cost and value of the information gathered. Thus, the Decalogue proposed by Solaun *et al.* (2003) can be followed to determine variables:

1. They must be cheap to analyse and relevant to the object of study.
2. There must be historical references to contrast their evolution.
3. They must be comparable to legal or base levels of reference.
4. They must condition the systems' dynamic of the object of study.
5. Values must be accurate (i.e., measurable).
6. They must be quick to obtain.
7. Their meaning must be obvious.
8. They must not be redundant.
9. They must be understandable for non-qualified personnel.
10. They must be easy to use and reproduce.

In short, variables must be adequate to the case and allow identifying impacts, determining the highest variance likely to occur in the system considering available time and budget.

6.1 Physical Environment

A physical Environmental Analysis must be carried out considering how it affects the project: (i) marine dynamics and sedimentary response upon an eventual reduction in wave regime and currents; (ii) landscape, due to the presence of structures, and; (iii) hydrography, due to ocean dumping. Likewise, the physical environment must be analysed considering how the environment may affect the installations (from the safety point of view).

In this respect, an environmental inventory should involve a previous analysis of climate, current regime and swell (direction and magnitude), tides and sediment transport dynamics in the influence area of the project.

6.1.1 Climate

This parameter covers atmospheric conditions determining a region's climate, not only from an environment that can be affected, but also a factor that may affect the project.

That is why a good knowledge on winds' regime can be a key factor to efficiently determine the location of installations. Factors to be inventoried, and if necessary, carthographied might be direction and intensity of average wind, direction and intensity of the maximum gust of wind, average thermal regime, pluviometry, radiation, etc. Availability of this climatologic data will vary upon location. Available data is usually found in websites from regional and national meteorological agencies. They usually gather data from coastal land stations and open sea stations (buoys or other devices). Data is usually processed having already passed a standard quality control (based upon simple criteria of minimal and maximal values and expected peaks between consecutive values). However, using this data requires a meticulous validating process beforehand inspecting them visually and comparing each series of data.

6.1.2 Currents

Oceanic coastal currents are wind generated mainly (wind causes superficial currents affecting tens of meters in the water column), but swell also affects longitudinal currents, and tides do likewise to macrotidal regimes. Average speeds approach several tens of centimetres by second, and can even reach values of several meters per second in certain areas and/or due to specific events, such as storms. They may have a great variability at different spatial and temporal scales, and its vertical structure is not maintained constant, in general, due to friction to seabed. This is why the current profile analysis and current regime characterisation in the study area is relevant; moreover, if we are dealing with installations able to modify that significantly (e.g. those requiring the construction or modification of dikes or jetties).

The **current profile** analysis in the study area can be made with specialised systems of anchored measurement equipment, such as current meters or current profile makers. These tools can be anchored to seabed, existing structures or buoys, etc.

There are several types of current meters and profilers based upon different measurement techniques. The most popular ones are the Acoustic Doppler Current Profilers (ADCP), which are able to make accurate current measurements in the water column at different depths and ranges, depending on their characteristics and configuration. Various suppliers distribute this kind of equipment,

Table 2. Variables affected by different types of projects in relation to the marine environment (Red: highly significant impact; Yellow: significant impact; Green: non significant impact; --- non related).

		Variable	Impact
Physical Environment	Hydrography	Temperature	---
		Salinity	---
		Dissolved Oxygen	---
		Optical Properties	Green
		Nutrients	---
		Clorofile	---
		Water Clarity	Green
	Hydrodynamics	Swell	Yellow
		Currents	Green
	Sedimentology	Granulometry	Yellow
		Sediment Quality	Yellow
	Landscape	Landscape	Green
Biotic Environment	Communities/Resources	Benthos	Red
		Marine Mammals	Red
		Marine Birds	Green
		Ichthyofauna	Red
		Ecological Interactions	Yellow
Socioeconomic Environment	Socioeconomy	Fishing Resources	Red
		Archaeological Resources	Yellow
		Socioeconomy	Yellow

amongst which we can name: AANDERAA (http://www.aadi.no/default.htm), NORTEK (http://www.nortek-as.com/en) and RDI (http://www.rdinstruments.com/). Different brands offer different models with different technical specifications. Consequently, an adequate planning of the kind of sampling to be done is highly advisable before purchasing any equipment.

This kind of equipment can be programmed to collect data from currents and directional swell at a sampling frequency of 10 minutes. The anchoring position should be located in the future commissioning area for the infrastructure to make the environmental inventory and current regime characterisation at "zero" stage. And the configuration should guarantee the coverage of the water column with an appropriate spatial resolution (about 10 meters of cell width) and time frequency (at least once an hour in macro-tidal environments) from surface to seabed. The sampling length or strategy depends on the previous knowledge on hydrodynamics of the study area, and must guarantee an adequate sampling of the main processes occurring in this study area. If currents experience a high seasonal variability, it is advisable to make at least two sampling campaigns, one in summer and another in winter.

All data gathered with this equipment must be processed, using previously validated criteria and/or following the manufacturer's instructions, and the following analysis must be carried out:

- Statistical distribution of current direction and intensity.
- Spectral analysis of marine current.
- Harmonic analysis of current.
- Hodographs or progressive vectors calculation.
- Swell distribution study.

Other data from observational data bases or existing high resolution models is recommended as a complement to data collected *in-situ* with the aim to complete, in time and/or space, the local hydrodynamics description. It is important to mention that other data must be used reasonably, and being previously validated, by comparison to other groups of data o studies developed in the area.

The use of models to simulate ocean currents is especially interesting when a significant alteration in the hydrodynamic regime is expected. Such models are advisable tools when initiating an impact study of the installation on current regime, hydrodynamic characteristics and water quality. The appropriate use of numeric modelling techniques is especially necessary in case the installation is expected to generate significant retention areas and/or the study area is under a potential influence of nearby ocean dumping points, such as river mouth or emissaries. They can seriously compromise water quality. There is a great number of models that can be used at present to solve the three-dimensional dynamics in the coastal area using different physical and mathematical approaches. We do not intent to present a detailed list, but rather to name the most relevant and widely used ocean general circulation models (OGCM):

a. In Finite Differences (derivatives are substituted by approximations in finite differences on a regular mesh):
- POM. Princeton Ocean Model (http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/).
- POLCOMS. Proudman Oceanographic Laboratory Coastal-Ocean Modelling System.
- ROMS. Regional Ocean Modelling System (http://www.myroms.org/).
- MARS3D (IFREMER) (www.ifremer.fr).
- HAMSOM (Hamburg Shelf Ocean Model) (http://www.ifm.zmaw.de/forschung/modelle/hamsom/).
- MOHID. Water Modelling System (Finite Volumes) (http://www.mohid.com/what_is_mohid.htm).

b. In Finite Elements (derivatives are solved by a more complex and computationally more difficult approximation, allowing the use of non-structured mesh neither horizontally nor vertically):
- QUODDY (http://nccoos.org/models/quoddy/quoddy-model).
- SEOM. Spectral Element Ocean Model (http://marine.rutgers.edu/po/index.php?model=seom).

Most of these models are freely distributed, so they can be found in the Internet. A more detailed list of the existing models and associated bibliography can be found in http://www.ocean-modeling.org. It is worth mentioning that the use of models to simulate a real circulation, and the one resulting from different scenarios, is not trivial and requires an important level of training and qualification. Validating results is essential, what leads to the conclusion that numerical experiments must go together with field measurement experiments.

6.1.3 Astronomical Tide Measurement

With the aim of simultaneously make available current and tide measurements, current meters, such as the aforementioned, can register sea level at its anchoring point every 10 minutes. From this register, a harmonical analysis shall be made.

6.1.4 Swell

According to Gyssels *et al*. (2004), there are three ways by which information on swell characteristics of the environment can be obtained:

- Swell visual data from on-route vessels (visual data base by the *National Climatic Data Centre* in Asheville).
- Forecasts based on wind regime (WANA series).
- Data measured by buoys.

Visual data are taken by observers on board commercial ships. Information is radio transmitted to international centres in charge of data compilation, storage and distribution. Each visual data contains the following information:

- Longitude and latitude at the observation point.
- Exact date and time of the observation.
- Atmospheric pressure and air temperature.
- Wind speed and direction.
- Wave height, swell period and direction.
- Wave height, sea period and direction. (Wind is generally presumed to have the same direction).

Most of this information gathered with specialised equipment: wind speed, atmospheric pressure, ships coordinates, date and time (Gyssels *et al.*, 2004). However, information on swell depends only on the observers' training and skill. Visual data usually have the following handicaps (Gyssels *et al.*, 2004):

- Data are collected from ships on commercial routes, so information is unevenly scattered in space as these ships sail on predetermined and repeated routes.
- Visual data are not uniformly scattered in time, so several pieces of information can match the same state of the sea. Therefore, using them indiscriminately is only advisable when they are used to make average regimes and the number of independant observations is high enough.
- Captains usually vary the ship's route due to weather forecasts, avoiding big storms. This fact must be carefully considered when making extreme swell statistics.
- It usually happens that wind sea is practically impossible to be differentiated from swell, such as a great height sea combined with a lower swell.
- The wave height, period and direction pointed out by the observer are parameters of "visual" sea states, that is, they are perceptions of average characteristics of the observed wave height, period and direction. This perception is subjective and depends on the observer's training, the height of the observation point (which varies between vessels), etc. That subjectivity becomes evident in data accumulation at certain wave height thresholds, or results in a total lack of accuracy when determining wave height in exceptionally big storms. This is caused by failure of physic references which any observer uses to determine the value of each swell parameter.

In spite of these handicaps, swell visual data form a data base which, due to its extension in time, ubiquity and rendering information on swell direction, is essential in this kind of studies.

Due to its importance, there is extensive literature on the study of visual data reliability and method to combine this information to improve instrumental data bases, e.g., Hogben and Lumb (1997), Jardine (1979), Programa de Clima Marítimo (1991). Visual data for the Atlantic-European Area are compiled by the *British Meteorological Office* (BMO) in Bracknell, United Kingdom, and by the *National Climatic Data Centre* (NCDC) in Asheville, North Carolina, USA.

As far as data from buoys is concerned, the information from the Buoy Network of the Spanish Ports is fully available at (http://www.puertos.es/es/oceanografia_y_meteorologia/redes_de_medida/index.html). Swell regimes calculated from information of both sources aforementioned can be taken from "Maritime Works Recommendations" - ROM 0.3-91 of M.O.P.T. (Spanish acronym for Transport and Public Works Ministry), 1992.

Likewise, measurement platforms can be installed in open sea with the aim of evaluating the swell regime in the future area of exploitation. They can take measure of directional swell together with current and meteorology. Amongst many parameters these platforms can measure, we can name:

- Number of waves.
- Maximum, average and significant swell height.
- Maximum and average swell period.
- Energy period.
- Marine currents.
- Wind speed and direction.
- Atmospheric pressure and temperature.

Likewise, acoustic current meters or pressure sensors on seabed can be used as information source for the study of swell, as they are able to measure swell direction and magnitude. Both techniques are limited by depth. The first one has got a limitation on the acoustic beam reach and the second one on the vertical decrease of swell transmission.

6.1.5 Swell Propagation Study

The environmental inventory should include a swell propagation study in the future area for the project. This type of analysis can be carried out through a numeric simulation of the sea states which better define the average and extreme climate in open sea affecting the study area. Thus, the main characteristics of swell and their effects on sedimentary dynamics in the area will be obtained.

Amongst simulation tools, it is important to mention the MOPLA, a numeric tool belonging to tools for short-term analysis of beaches from the Coastal Modelling System (SMC by its Spanish acronym). The SMC is a computing application integrating a series of numerical models which allow implementing the methodology of study and design of littoral actions (suggested in a series of Thematic and Reference Documents). It includes both monochromatic and spectral swell models of the dynamic evolution in beaches. This tool was developed by the Oceanographic Engineering and Coasts Group (GIOC by its Spanish acronym) of the University of Cantabria (UC) and the Directorate General for Coasts of the Ministry of Environment within the research project: "Support Model for Littoral Management". Their objective is defining and unifying criteria and ways to take action when dealing with projects on coastal dynamics. The application and models together with a detailed description of this system are available at: http://www.smc.unican.es/es/index.asp. In Figure 34 an

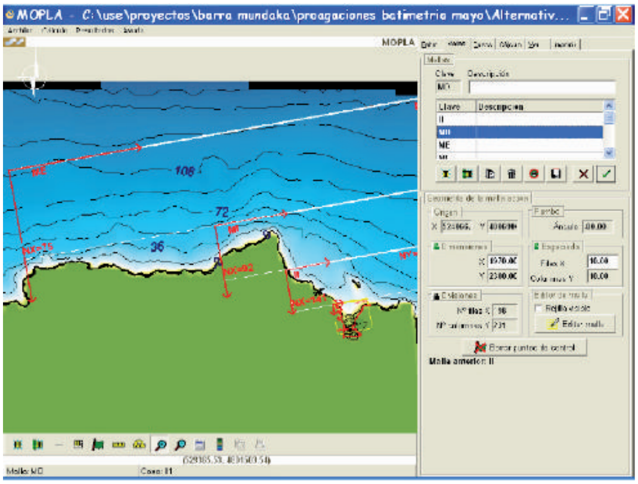

Figure 34. Swell simulation tool known as MOPLA.

access window to the program is shown from a case study made by AZTI-Tecnalia in the Oka estuary (Vizcaya).

MOPLA allows defining nested mesh of different size to adjust the level of detail to the swell variation scale at each depth, thereby optimizing the time for calculations. This model can analyse all process inducing modifications in swell shape, direction and height during propagation from deep waters to the coast. Models are adapted to study induced current along the whole water column, and also nearby seabed, therefore it is suitable for sedimentary dynamics studies. Different swell directions can be analysed through MOPLA, which had been suggested based upon the previous studies on maritime climate of the study area. MOPLA also estimates swell height in simulation conditions taking into account swells with different return periods (at least 100 and 200 years) to analyse the installation's safety against extreme weather conditions. Representative swells of the average climate of the area are also estimated.

6.1.6 Sediment Dynamics

Sedimentary dynamics and morphologic evolution of the littoral is generally a consequence of currents induced by swell. An environmental inventory should focus on understanding the relationship between swell climate and local sedimentary dynamics in a "zero state", i.e., balanced conditions when considering sedimentary dynamics. Later on, future scenarios will be likely to result from this previous knowledge with a new balanced state after the work's execution and during the operation state.

A bathymetric survey at an adequate resolution needs to be done in the environmental inventory depending on the type of installation and predicted impacts on current and swell regime. The survey must be done both in the occupation area of the installation and shady area. A bathymetry of the approximation area from open sea shall be carried out as well (minimum depths from 100 to 200 m according to marine climate characteristics), in case there are no previous data with a suitable resolution to conveniently characterise the effects of seabed topography on swell.

Different methodologies can be deployed, but it is advisable to use a multi-beam echo sounder, which is able to characterise the seabed morphology with high resolution and offer the possibility to get topographic products such as: slopes' map, digital model for shady elevation, rugosity, topographic index, etc. This information will be crucial to feed models for marine dynamics (currents, swell and coastal dynamics) and thus, simulations of different scenarios will be obtained to characterise both initial and future balance states.

Regarding modelling, the aforementioned SMC tools are advised to be used. The SMC also contains a numeric model of morphologic evolution for a cross section profile of beach called PETRA. This model solves equations on sediment flow within the breakwater area, and also bathymetric changes associated to spatial variations of sediment transport. The magnitude of sedimentary transport is a function of the morphologic characteristics of the environment (sediment and bathymetry) and hydrodynamic conditions (swell and currents induced thereby).

On the other hand, for the sedimentary dynamics analysis is required a previous characterisation of the type of substratum in the project area (occupation area where wave energy will be harnessed, together with the shady area and cable line to transport energy to land).

Several methodologies can be used with this purpose:

- Seabed characterisation with a multi-beam echo sounder. This information involves a high resolution Digital Elevation Model (DEM) and topographic products derived, such as slopes' map, shady digital elevation model, rugosity, topographic index, etc. In Figure 35 an example of a digital elevation model located between Plentzia and Arminza, Basque Country, nearby the Biscay Marine Energy Platform (bimep, http://www.eve.es/energia_marina/index_cas.htm) is shown.
- Sediment sampling in at least 7 stations where substratum is soft, using either autonomous diving suits or a Van-Veen grab. A grain-size análisis, together with organic matter and redox potencial, shall be carried out. If needed, a determination of specific pollutants such as heavy metals shall be carried out.
- Visual characterisation of the environment with ROVs or underwater operated cameras.

6.1.7 Hydrography

A description of hydrographic characteristics shall contain data on the optical properties of water: turbidity, solids suspension and transparency measured by a Secchi disk.

Data collection in relation to these variables and the determination of vision depth of the Secchi disk should be done in a minimum of 7 sampling stations as an approximation to water transparency and light extinction coefficients in superficial waters.

Surface and bottom water samples shall be taken at each station. Sampling at each depth could be carried out using oceanographic bottles, such as Niskin with 5 litres capacity. This volume guarantees enough sampling to determine turbidity and suspension solids. Samples should be split on board, distinguishing aliquots in suitable containers to be preserved until further laboratory analysis is done.

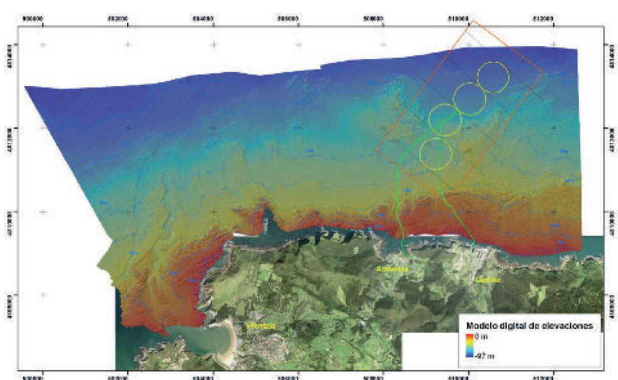

Figure 35. Example of digital elevation model.

If needed, pollutants such as heavy metals, pesticides, bacteria, organic compounds, and hydrocarbons will be analysed. As far as pesticides are concerned, it is advised to analyse filtering animals such as mussels or oysters.

6.1.8 Landscape

Landscape (in this case, seascape) is regarded hereby as an environmental parameter, a resource, unfortunately becoming scarce, difficult to substitute and easily negligible (Gómez-Orea, 1992). In any case, the study of landscape is becoming more interesting due to the growing development of assessment techniques, and for being an element which summarizes other factors (MMA, 1996). Moreover, interests are promoted by the European Landscape Agreement (from now on ELA), which came into force in Spain on 1 March 2008. The ELA is exclusively devoted to protection, management and planning of European landscapes. This agreement is intended to promote the role of landscape in all cultural, ecological, environmental and social spheres, apart from being a positive resource for economic activities. Moreover, landscape protection policies are mainly justified by their patrimonial value.

For the scope of the present report, *landscape* is defined as an area, as perceived by people, whose character is the result of action and interaction of natural and/or human factors (Article 1, European Landscape Agreement. Definitions).

A landscape study presents two different approaches. One is total landscape, which identifies landscape with environment and sees this as a synthesis indicator of relationships between inert and living elements of the environment. A second approach is visual landscape, whose consideration caters for aesthetic criteria basically: landscape is interesting as a spatial and visual expression of the environment (MMA, 1996).

In this first stage of inventory, it is necessary to identify, characterise and qualify marine landscape surrounding the infrastructure being installed in such environment. For the task of describing landscape, the National Inventory of Outstanding Landscapes (ICONA, 1975) can be used as a reference. Some Autonomous Communities have made available on-line landscape inventories at a local scale. Information on the anthropic influence degree, historic-cultural load, landscape components (earth, water, vegetation and uses, structures), conservation value, etc. can be easily obtained from these inventories. However, inventoried landscapes in Spain are only terrestrial or coastal (also known as marine influenced). That is why gathering information to characterise *marine landscape or seascape* will be necessary.

Nowadays, there is no academic definition on marine landscape. However, we can affirm in colloquial terms that marine landscape is a picture or a view of the sea. A more accurate definition would comprehend marine landscape, coastal landscape and adjacent areas of open sea including views from earth to sea, from sea to earth and along the coastline. According to the methodological guide to assess environmental impact of offshore wind power parks proposed by the Department of Trade and Industry in the United Kingdom (DTI, 2005), marine landscape is defined as a discreet area where there is an shared inter-visibility between earth and sea. This guide considers each marine landscape unit has got three components:

1. The sea component.
2. The coastline component.
3. The terrestrial component.

Therefore, a base study of marine landscape shall include:

- Definition and description of areas: consists in defining the extension of landscape units, compiling and presenting information of each of the three components of marine landscape in a systematic way.
- Characterisation: consists in carrying out an analytical study of relationships between the three components in a unit of marine landscape with a distinctive and recognisable character, which can also even classify marine landscapes in different types if needed.
- Assessment: this is the process of attributing a sensitivity or value to each landscape value based upon specific criteria.

Base information sources to assess landscape impact can be:

- Nautical Charts at a global, regional and local scale (depending the infrastructure dimensions which is planned to be built). These charts can be obtained in the Hydrographic Institute of the Navy or any other autonomic institution publishing them.
- Aerial Pictures.
- Previous landscape assessment. For now, as it has been mentioned before, there are few landscape assessments with marine influence in Spain. At a national scale, the National Inventory on Outstanding Landscapes (ICONA, 1975) can be consulted. At a regional scale, there is a proposed catalogue of outstanding landscapes in the Basque Country.
- Inventory of protected landscapes.
- Territorial planning at a local scale.
- Meteorological Data. Atmospheric conditions may affect visibility in various ways. This is important when assessing the project's visual impact. Visibility is measured by means of the atmosphere's tranmissivity, but this is turned into meters for a functional reason. Ideal data should come from an analysis of 10 years' period of time when visibility can be categorised by distance range, for example: <1 km, from 1 to 2 km, from 2 to 4 km, etc. A frequency table can be compiled providing information of the total number of observations in each category at hourly intervals for each month.
- Apart from these, other kind of information is used, such as: classification of intertidal areas and natural processes, touristic information, historical and cultural guides.

6.1.8.1 Landscape Characterisation

The characterisation process of marine landscape can be carried out in 4 stages (DTI, 2005): (i) defining each Landscape unit's area; (ii) defining each landscape unit's characteristics; (iii) defining activities, visibility and views and; (iv) presentation of landscape characterisation and base visual analysis.

a. Definition of each Landscape unit's area.

DTI (2005) suggests following 7 steps to define landscape unit's areas:

- Determining the scale of the project: the landscape characterisation scale must be determined; national, regional or local. In the case of landscape impact studies for offshore marine exploitations, the most suitable scale is regional. That can go up to 35 km further into the sea and have a terrestrial scope of approximately 10 km.
- Determining the longest extensions of capes at the given scale: this step divides the coast into a series of longitudes. In order to determine capes, a reference line for the coast must be taken. In Spanish cartography level 0 of the sea is commonly regarded as the average level in Alicante.
- Defining a sea limit representing the *limit of visual significance* in the sea: Hill *et al*. (2001), based upon other studies, developed a methodology consisting in determining how the level of detail of marine landscape with respect to earth decreases with distance. And thus, different visibility distances from sea to earth were established. For example, in wind power plants in a marine environment, Scott *et al*. (2005) recommend using a limit of 35 km to the sea as a suitable value for landscape units at a regional level.
- Defining a limit to earth representing the *limit of visual significance* in land: this limit is defined applying the same logic as the limit towards the sea.
- Establishing visual fields in each unit's boundaries: for this aim, inter-visibility analysis software must be used. The extension of visual basins is recommended to be defined taking down all available sea-earth views.
- Determining or redefining the marine landscape unit showing only land areas with inter-visibility of the sea within a limit line. Once a sea area is defined, its theoretical visual field from land can be calculated. The inter-visibility calculation is recommended to include all sites in the sea area (not only spots or lines parallel to coast). Thus, the amount of marine area visible from earth can be estimated.
- Obtaining the limit of the final marine landscape unit. In case the visibility effect extends along several areas, ignoring views under a given threshold value is advised in order to establish the final limit of the marine landscape unit.

b. Definition of each unit's characteristics

Each marine landscape unit shall have distinctive components, i.e., marine, terrestrial and coastal. Each landscape unit is described underlying differences with another area. This description can be done using acknowledged techniques on landscape assessment as described in the guide of MMA (1996). However, marine landscape characterisation needs additional information covering the coastline and sea, i.e., coastal geometry, physical processes involved and affecting the coast, different kinds of marine horizons.

Although base information on the landscape characterization of the study area had been already gathered, this information might not be enough. Occasionally, some field work is necessary to describe the three components of marine landscape (marine, terrestrial and coastline components). Hill *et al*. (2001) set an example of field work taking down visual characteristics and qualities from different observation spots (from land to sea and from sea to land) using visual perception principles such as clarity and harmony, colour and contrast, etc.

Even though they might not be necessary in all cases, aspects concerning natural and historical content of marine environment are also important to characterise marine landscapes. The separate study of historical and cultural content in an EIA is usually regarded as an independant element to be assessed. The historical and cultural study is advised to characterise marine landscape and establish possible interactions between effects on marine landscape and historical and cultural content.

c. Definition of activities, visibility and views

This stage consists in carrying out a visibility analysis of each landscape unit and in identifying observation spots from land to sea, along the coastline and from sea to land. The following steps can be followed:

- Listing activities and functions of marine landscape: to understand anthropic pressures on marine landscape and give information on whom the coast's users are and how they use it, identifying the most important visual receivers, i.e., the users of a certain marine landscape unit. These activities and functions must be spatially represented in a map.
- Identifying and describing views from land to sea. Once the theoretical visual field from sea to land is calculated, areas and/or spots with a higher concentration of observers are identified. These observation spots can be described and listed to later predict and assess the impact.
- Identifying and describing far views of the sea from the terrestrial component. Even though these views might be outside the defined marine landscape unit, special attention must be paid to those areas with scarce sea views. This might happen, for example, in a distinctive topographic spot, such as a far mountain with panoramic views over the coast.
- Identifying and describing views from sea to land. Land areas visible from the sea at different distance from coast need to be identified and visual significance limits must be established. In case a vessel is not available for this task, nautical charts can be used, where reference points appear, such as lighthouses, high buildings, or prominent peaks, to help a sailor orientate. It must be taken into account that sea views can be numerous when the coastline is concave or there are islands.
- Identifying and describing views from sea to sea. The interest of this task lies in considering as observation spots visual receivers or users of leisure or commercial activities around the area of marine WECs.

d. Presentation of landscape characterisation and base visual analysis

The results of landscape characterisation and visual analysis is presented as a map including one o several marine landscape units, showing subdivisions in areas of different landscape nature, together with a description of such nature.

6.1.8.2 Landscape Assessment

Once base information is compiled and marine landscape characterisation and visual analysis completed, next step is establishing quality values and landscape fragility based upon the described marine landscape nature. Each marine landscape unit is advised to be analysed according to the following aspects:

- Quality: depending on landscape representativity, naturality, diversity, morphologic complexity, continuity, etc.
- Fragility: depending on the quality degree, accessibility, housing, uses of the environment, historical and cultural content, etc.
- Visual fragility: depending on abundance of visual receivers, etc.

A list including each of these aspects shall be done to consider criteria to be assessed. Criteria shall be ranked into a simple scale, e.g. from 1 to 5, distinguishing from very high, high, intermediate, low and very low values.

6.1.9 Underwater Noise

Most animals living in the marine environment are sensitive to sound in one way or another. This means any anthropogenic perturbation of the acoustic environment may cause adverse consequences to marine life.

The methodology developed by Nedwell and Howell (2004) and Nedwell *et al*. (2003; 2007) can be used to characterise the sound environment in the study area. For this purpose, a design and installation of three buoys equipped with high (500 ks/s) and low (192 ks/s) frequency microphones will be carried out, apart from amplifiers and digital recording sound systems with a minimum of four channels. This installation shall be done before building the infrastructure with the aim of getting a noise control pattern to be compared with noise generated during the commissioning and operation stages.

Installing three buoys will determine directionality of the detected noise, and therefore, its origin (generated by devices, marine mammals, support vessels, etc). These buoys will be anchored and will continuously register the sound environment in different periods, during day and night, rendering the previous reference noise level to the installation.

6.2 Biotic Environment

The analysis of the biotic environment, fauna (benthic communities, birds, fish, etc.) and flora (marine phanerogams, algae, terrestrial vegetation, etc.) will be especially focused on the presence of communities, species or areas of high ecologic value or special interest, which could be protected under national, European or international law, and might be affected by the project's development (Solaun *et al.*, 2003) (see section 6.4).

In this respect, it is important to mention that fish, whales and seabird communities can be affected by noise from the WECs and electromagnetic fields generated from the cable. Benthic communities can be affected by sedimentary dynamics, as well as dragging during the devices' mooring and the installation of the cable.

Therefore, a description and illustration on suitable maps for fauna and flora habitats of the area occupied by the project and its influence area should be carried out. Identification, data from richness, abundance, biomass and diversity shall also be made available. That will allow an assessment of the possible changes generated in the environment. Likewise, both quality and fragility of these environments and presence of species with conservation problems will be reported.

6.2.1 Benthic Communities

In order to determine benthic communities, *in situ* sampling can be carried out with a Van-Veen grab or similar, in case there is soft substratum, and also with autonomous diving suits. In any case, sampling shall cover a minimum area, big enough to represent the system's complexity, and capture even uncommon species, which could be protected. If there are no previous work which can help to define this minimum area, the minimum qualitative area might need to be determined firstly (Niell, 1977).

Sampling stations must be distributed along the occupation area of the future exploitation field for wave energy, and the line of the cable's route. Regarding ESM, unless there is previous information, one o several sampling stations should be located beyond the estimated influence area of the installations, with the aim of obtaining previous data before setting up the installation, to carry out an analysis of the type *Before After Control Impact* (BACI).

A visual inspection of the whole occupation area can be carried out together with sampling, and the cable's route can be inspected with operated underwater cameras from the ship. This inspection will also be useful in those areas where it is impossible to take samples for further analysis in a laboratory, due to the presence of hard substratum and/or higher depths.

Samples obtained, both in hard and soft substratum and in subtidal and intertidal stations, shall go through a sieve with a maximum 1 mm mesh size, which is enough to retain practically all species (Viéitez, 1976; Seapy y Kitting, 1978; Andrade y Cancela Da Fonseca, 1979; Mora *et al.*, 1982). The retained sample will be fixed later on.

In the laboratory, benthic organisms from soft and hard substratum will be separated for their identification (down to species level if possible) and counting of individuals. For this purpose, a binocular magnifying glass and microscope is needed. Specific biomass in dry weight will be determined after drying up the identified microorganism in a stove for 48 h at 65ºC.

The main structural parameters of the community will be calculated from data extracted from counts, i.e., total abundance, specific abundance, specific richness and specific diversity by means of Shannon-Weaver index (1963), estimated from numeric and biomass data (Wilhm, 1968). Maximum diversity and equitability will also be calculated both from density and biomass data. Other diversity and/or dominance indexes may be estimated, e.g., the Simpson index (1949), and rarefaction index (Hurlbert, 1971).

Moreover, considering benthic organisms show great ecological requirement differences, species presence or representative taxa of several environmental quality degrees shall be determined: pollutant indicator organism, high environmental quality indicator organisms, pioneer communities (recolonisation), etc.

With the result from benthic communities' analysis in soft substratum, a classification of station according to biotic indexes should follow. That is how results will be shown in a simple way, as fluvial systems are commonly represented, where biotic indexes calculation from macro invertebrate communities' analysis is a widely used methodology.

The methodology developed by AZTI-Tecnalia to classify stations according to biotic index is important to mention (Borja *et al.*, 2003; 2004; Borja y Muxika, 2005; Muxika *et al.*, 2005; Muxika, 2007; Muxika *et al.*, 2007; Borja *et al.*, 2008). The method is based upon previous works by Majeed (1987) and Grall and Glemarec (1997), who consider the literature by Hily (1984).

Fauna composition in stations shall be considered for this purpose, giving for granted this is the result of an impact gradient caused by the environment enrichment due to organic matter. Thus, benthic macro invertebrate species are likely to be assigned to one of the five ecological groups depending on their sensitivity or tolerance to the environment alteration:

- Ecological Group I (EG I): sensitive species to enrichment and present in normal conditions.
- Ecological Group II (EG II): indifferent species to enrichment always present in low densities with scarcely significant variations in time.
- Ecological Group III (EG III): tolerant species to an excessive organic matter.
- Ecological Group IV (EG IV): second-order opportunistic species, of a small size and short life cycles, adapted to reduced sediments.
- Ecological Group V (GE V): first-order opportunistic species.

Calculations can be made using the software called AMBI, downloadable from AZTI's webpage http://ambi.azti.es, using an updated species list and following advice from Borja and Muxika (2005) and Muxika (2007).

Moreover, with the aim of determining communities present in an area, a correspondence analysis is suggested: DCA = *Detrended Correspondence Analysis* or CA=*Correspondence Analysis* (Hill, 1973; Gauch y Whittaker, 1981) and TWINSPAN=Two Way Indicator SPecies ANalysis (Hill *et al.*, 1975; Hill, 1979; Gauch y Whittaker, 1981); or nMDS = Non parametric MultiDimensional Scaling (Clarke y Warwick, 2001).

6.2.2 Ichthyofauna

There are interesting methodological references on fish community assessment, mainly in the field of marine wind power, i.e.: Stocker (2002), Girard *et al*. (2004), Gill *et al*. (2005), Hvidt *et al*. (2005), Wilhelmsson *et al*. (2006), Andersson *et al.* (2007) and Langhamer and Wilhelmsson (2007). According to these authors, a fish community assessment campaign must be carried out combining different methodologies and adapting all of them to the type of construction and environment where they are located. In general, two big groups of techniques can be distinguished as shown in Table 3: (i) capture methods and (ii) observation methods.

Combinations to be developed within all methodologies described in Table 3 involve a wide variety of possibilities: dredging and trawling to capture species in the water column, acoustics to register information on individuals from reduced populations, visual census made by divers to register species and individuals which were neither captured through trawling and dredging nor registered by acoustic systems, etc.

Planning and selecting the method or combination of methods to be used depends on the work's objective, as methods provide different kind of information, and slants associated to the method itself. In general, fishing assessments use capture methods, while ecology studies prefer observation methods (Watson, 2008). According to Kulbicki (1998), sampling in fishing grounds should use fishing arts, due to a higher level of adaptability of interest species against new conditions, and therefore the possibility of these species hiding from divers while they are developing observation techniques.

Registers obtained after sampling must be processed (data compilation and cleaning) and included in a data base specifically designed for the project. A geospatial and statistical analysis will follow, according to Tissot (2008), in a precise way regarding randomness, replication, independence and strength of used methods.

6.2.2.1 Capture Methods

a. Traps

Traps are fixed fishing gears whose characteristics vary depending on the species to be captured. This gear is used in capture and recapture studies, age studies and reproduction surveys, etc. and includes species with day and night activity. The main advantage is they can site at depths where divers cannot reach and the captured individuals can be freed alive and without serious damage once analysis has been carried out (Watson, 2008).

- According to Watson (2008) the main disadvantages are:
- Species' capture depends on the mesh size.
- Predation phenomena on the captured individuals may occur.
- Some species can go in and out of the trap.
- It is difficult to estimate the number of individuals per area unit.
- Many sampling repetitions are needed to delete differences between trap variance and low capture.

b. Seine nets and Purse seines

Seine nets and purse seines register a bigger number of captures in less time than traps or bating hooks. However, studies developed in reefs have shown abundance estimates of species with no fishing interest are not correct and captures may depend on density and fish movement (for food, migration, etc). That is why these techniques are recommended to be used together with sampling of species without commercial interest (Acosta, 1997).

c. Selective fishing with trawling and dredging gears

Trawling is used to determine school fish's species, size, age, reproduction and biomass, and also to validate results from acoustic tools and visual census made by divers and video cameras (Watson, 2008).

Dredging is an easy technique of fishing and results are comparable to capture records. On the contrary, this capture method does not discriminate any kind of organism and its bottom modality can even damage the benthic habitat (Kulbicki, 1998; Bailey *et al.*, 2007).

Selecting a suitable gear depends on the species, type of seabed (sand, mud or rock) and the environment (demersal, pelagic) and must be complemented by other sampling techniques (diving with or without video cameras, ROVs, submarines, etc) able to sample in conditions where fishing arts cannot sample, such as, areas where bottom dredging is not possible due to the presence of bedrock.

Selective fishing with angling and line fishing

The use of this type of arts, such as baited hooks and handlining have the following advantages: they are affordable, replica can be obtained quickly (increasing accurateness levels), they present a high survival index of individuals captured and they can go much deeper than divers (Willis *et al.*, 2000; Watson, 2008).

On the contrary, these fishing arts also involve disadvantages mainly due to the presence of factors affecting fish vulnerability to be captured (over-exploded gear, selectivity regarding species and sizes, etc.); consequently, a study of a community's structure or abundance estimates may not be totally accurate. Moreover, logistics and personnel involved in this kind of sampling (vessel, fishermen, technicians, etc) are also rather

Table 3. Fish sampling techniques used at present in ecology studies. Modified by Watson (2008).

	Technique	Typologies	
Capture Methods	1. Traps	a. barriers	
		b. pots	
	2. Trawling/Dredging	a. seine nets	
		b. purse seine	
		c. driff nets	
		d. semi pelagic trawling	
		v. bottom trawling	
	3. Angling and line fishing	a. vertical logline fishing	
		b. logline fishing	
		c. handlining	• hook
			• barbless hook
			• artificial baits
Observation Methods	1. Underwater Visual Census (UVC)	a. strip transects	
		b. seasonal point count	
		c. line transects	
		d. interval counts	
		e. visual census + audiovisual tools	
	2. Hydroacoustics	a. split-beam scientific fishing echo sounder	
	3. Video cameras	a. Underwater video camera	
		b. Underwater stereoscopic video camera	
		c. Underwater video camera with diver	

demanding and Captures Per Unit of Effort (CPUE) depend on fishermen's skill, so that is bound to vary considerably. Last but not least, hooks may originate damage in natatory bladders, body and gill, and also predation on species hooked may occur (Willis *et al.*, 2000; Watson, 2008).

6.2.2.2 Observation Methods

a. Visual Census with autonomous diving suit

This is a selective technique focused on size, appearance and behaviour of the objective species and community. The main advantage lies in the fact that they are not invading techniques, they can be repeated and have a low cost which allows generating data bases quickly and consequently, rendering estimate values (abundance, diversity, etc.).

After developing the first method of visual census which allow to determine reef fish abundance made by Brock in 1954 (en Watson, 2008), these days, such techniques have become the most popular in fish ecology studies, and they have been developed in such a way that it is possible to use different strategies (Kulbicki y Sarramégna, 1999). All of them belong to what is known as *distance sampling,* which is a sampling technique for both land and sea (Buckland *et al.*, 2001,2004).

Fish characteristics, such as density, distribution, size, mobility, behaviour to observers, etc, together with environmental physic factors, such as currents, swell, tide, type of habitat, etc, and diving variables, like speed, visibility changes, decision making, experience estimating number and size of fish, etc., condition sampling (Edgar *et al.*, 2004) and generate errors which need to be minimised (Lincoln-Smith, 1988; Edgar y Barrett, 1999; Kulbicki y Sarramégna, 1999; Harvey *et al.*, 2004; Stobart *et al.*, 2007; Watson, 2008).

Edgar and Barrett (1997; 1999) establish that big sized fish shall be sampled separately to small and cryptic fish. The same technique can be used, but in a smaller area. They also advice studying small and cryptic fishes together with invertebrates. According to several authors, studies with visual census can underestimate cryptic fish' density (Ackerman y Bellwood, 2000; Willis, 2001; Cappo *et al.*, 2006), slant which can be solved using complementary techniques such as anaesthesia and ictiocides (Willis, 2001) doing complementary sampling on cryptic species' habitats by divers with video cameras (Harvey *et al.*, 2004).

Methodology used in visual census offers different possibilities: line transects, strip transects, stationary method, random method, quick visual census and video recorded visual census. Such techniques are briefly explained below:

- *Line Transects*: consist in diving along a line, estimating distance and direction of observed fish with respect to such line. Through these techniques, estimates on diversity, density and biomass of fish in big areas is obtained. Width and longitude of the line transect depends on the species to be studied (big, small or cryptic fish) (Claro, 1998; Edgar *et al.*, 2004).
- *Strip Transects*: allow an observer to get estimates on density registering while swimming all individuals seen along a rectangular strip with a given length (Claro, 1998; Edgar *et al.*, 2004; Harvey *et al.*, 2004; Watson, 2008). Strips are longitudinally "marked" with a tape measure laid by a second diver swimming at a constant speed and direction. Marking up the strip length with a tape or another material (on the bottom or float, tied to buoys or vessel, etc) allows determining the sampling area more or less accurately. Fish count starts when the second diver lays the tape measure on the bottom (Samoilys y Carlos, 2000). Edgar *et al*. (2004) consider this is the most appropriate technique, as errors caused by variability in fish detection do not generate big variations in estimates, and generally, divers usually have got the same level of expertise.
- *Quick visual census*: this technique consists in registering observations within a circle with a given radius for a certain period of time (Edgar *et al.*, 2004; Harvey *et al.*, 2004).
- *Stationary method*: according to Tuya (2002), this technique is advisable in highly heterogeneous areas and generates relative frequency and abundance estimates. The method consists in selecting sampling points at random in the study area. At each point, two divers (two replicas) register the observed species, number of individuals and length of individuals within their visual field (an imaginary cylinder of radius "r" centred in the observer) for a period of time "t", after which, caves and hollows where species with cryptic habits dwell are checked in detail. Once finished, another sampling point is scrutinized. In the case of fish stock, estimate is done in units of 10, 20, 50, 100 or more than 100 (they are counted only the first time they enter the cylinder, even though only part of fish enter). Taking note of data relative to fish behaviour used to correct census and real biomass, and data on turbidity, temperature, sediments, seaweed coverage, etc. is recommended. Radius "r" and time "t" of observation are determined depending on what Bohnsack and Bannerot (1986) and Lincoln Smith (1988) establish. When obtaining data on biomass, the protocol described in Tuya (2002) on size-weight relations is followed. Several software tools can be used for this purpose (Ecocen 1.1, etc.) (Castro *et al.*, 2007).
- *Qualitative method of roaming or random census*: is the most efficient method to list representative species and their occurrence frequencies in a given area. Nevertheless, it has got many limitations regarding absolute abundance estimates. This technique consists in freely swimming for a given time in a given area taking down all species and number of individuals seen. Divers can get close to explore hollows and caves, and therefore, cryptic species are studied with this technique. As sampling can be carried out by a high number of divers, an extensive list can be generated, covering a wider spatial and temporal coverage. On the contrary, as the result do not render abundance and density estimates, this methods must serve as a complement to more precise and exhaustive ones (Schmitt y Sullivan, 1996; Claro, 1998).

- *Recorded visual census*: this method combines audio and video techniques with any other visual census techniques described above.

In case no other protocol had been established, the same technique to other occasions is recommended to use, so that obtained results can be comparable. These shall be taken in optimal conditions of luminosity, turbidity and sea state; therefore, sampling is advised to be carried out in the beginning of summer (more hours of daylight and less turbidity), in the morning (more light) and in good visibility conditions (low turbidity). Sampling should be done on a minimum of 5 transects (this value may vary depending on the study area's extension), replicas should be made and intervals of 15-20 minute (30 minute immersion) should be kept.

On the other hand, there is a lineal relationship between species detectability and the number of replicas. Thus, the greater number of replicas, the more species detected; that is, when the object of study is obtaining a representative sample of all kind of fish in a study area (including cryptic species) as many replicas as needed shall be made (MacNeil *et al.*, 2008).

b. Underwater video cameras

Thanks to technological progress, traditional visual census can be complemented or substituted using underwater video cameras in all their variety: (i) fixed on a structure anchored to the bottom; (iii) operated by a diver following some of the technical specifications set in one of the visual census techniques described above; (iv) remotely operated underwater vehicles, also known as ROV, human operated underwater vehicles, also known as HOV, or autonomous underwater vehicles, also known as AUV.

These days, the most popular sampling method is the line transect (Shortis *et al.*, 2007); however, strip transect or a combination of them both is also used. Slants caused both by the sampling method and the use of robots, cameras, etc. must be estimated by means of several procedures: quantifying the fish quantity milling around the visual field, comparing fish location between two visual fields, determining the detection probability function, etc. (MacNeil *et al.*, 2008; Stoner *et al.*, 2008; Watson, 2008; Yoklavich y O'Connell, 2008). Thus, accuracy and precision of abundance estimates, fish diversity and length both in shallow and deep waters has been proved by several authors (entre otros Willis *et al.*, 2000; Langlois *et al.*, 2006; Shortis *et al.*, 2007), while absolute density was not proved.

An advantage of video cameras is they can be used at higher depths than divers can reach, being able to record deep waters (Costa *et al.*, 2006; Heagney *et al.*, 2007; Shortis *et al.*, 2007; Stoner *et al.*, 2008; Yoklavich y O'Connell, 2008).

Furthermore, video cameras are not invasive and gather data in a permanent and standardised way, even registering fish moving to avoid human presence or escaping from fishing nets; moreover, they are slantless of immersion and diver constraints and they are not dependant on time, daylight or fishing arts' selectivity (Watson y Quinn II, 1997; Cappo *et al.*, 2006; Morrison y Carbines, 2006; Stobart *et al.*, 2007; Watson, 2008).

Some disadvantages of this method are a consequence of: (i) cryptic and small size species hide in caves and gabs that cannot be registered; (ii) visibility limitations; (iii) repeated "entries" of the same fish individual in the vision field cannot be distinguished (Watson, 2008); (iv) the equipment's initial cost is usually high and (v) density estimate generated is usually relative (maximum number of fish of a same species represented in the camera's vision field at a given time).

Presently, two types of video cameras can be used:

a. *Solitary underwater video camera*: registers all fish passing in front of the camera. They are scarcely used due to the fact that they adapt badly to marine environments and render 2D results (Shortis *et al.*, 2007)
b. *Stereoscopic underwater video camera*: using two cameras simultaneously, accuracy and preciseness of abundance, density and diversity estimates are improved, and even morphologic measures can be obtained directly (Harvey et al. 2002 en Watson, 2008). Software development and algorithms addressed to obtain in an automatic way size and other morphologic measures of detected fish is progressing quickly these days (Harvey y Shortis, 1996; Cocito *et al.*, 2003; Costa *et al.*, 2006; Rosenkranz *et al.*, 2008).

Underwater video cameras can also be used baited to attract a greater number of individuals and species. However, some slants may occur due to fish behaviour in front of bait or due to other fish milling around the bait and also as a consequence of current direction and speed in the bait (specially in pelagic sampling) (Cappo *et al.*, 2006; Heagney *et al.*, 2007; Watson, 2008).

Presently, the use of underwater devices and ROVs has spread around the world, like on the West Coast in the USA (Yoklavich y O'Connell, 2008; Laidig *et al.*, 2009), the protected marine area of Le Danois Bank, also known as "El Cachucho" within the Ecomarg (http://www.ecomarg.net/index.html) project, the exploration of Cap de Creus in Catalonia by the Marine Technologic Division of CSIC (Barcelona) (http://www.utm.csic.es/garciadelcid_diario.asp?id=%7B1AE68B5A-818C-45EC-BE3C-8D3F3C4FA98F%7D), etc.

Direct and indirect effects (attraction, repulsion or indifference to the vehicle) caused by artificial light (intensity and wave length), sound (intensity and frequency) and speed and size of the vehicle will vary according to environmental conditions and the way the vehicle operates (Trenkel *et al.*, 2004; Stoner *et al.*, 2008). According to Stoner *et al.* (2008) an added value of underwater vehicles (all versions) is they can offer the possibility of directly observing the relationship between fish behaviour within the habitat and fishing arts.

6.2.2.3 Hydroacuostic Surveillance Techniques

Hydroacuostic sampling techniques are based upon the use of split-beam scientific fishing echo sounders of the type SIMRAD EK60 or alike. Fishing echo sounders are usually made up of ceramic piezoelectric materials emitting sound pulse and receiving retro-scattered echo of such pulse interacting with diverse targets in the water column. Split-beam echo sounders are called this way because they have got a receptor split in four quadrants receiving independant signals from the environment. From phase difference in the received sound waves, the echo sounder is able to infer the target direction within the insonified volume. Thanks to which, it is able to produce abundance estimates and information on size of the detected organisms, giving for granted it is a known species.

Scientific sounders are made up of a power source, a transmitter-receiver, a laptop computer and one or several transducers operating at a different frequency: 38, 120 and 200 kHz. The most commonly used frequency in hydroacustic assessment of fishing resources is 38 kHz. However, contrasted information of different frequencies can render additional information to identify different organisms.

Identifying species is done using fishing throws, generally done through pelagic arts, although other arts can be deployed. The advantage of pelagic gear is the possibility to sample at different depths, while fencing can get a small biologic sample and release the big bulk of capture.

In case no fishing is done, the acoustic prospect biomass will lack species composition. In such case, acoustic prospection will provide relative abundance and horizontal and vertical spatial distribution of biomass split in big groups: fish, plankton and krill.

Sampling design varies according to the study area's extension. It must cover a series of parallel and regularly spaced transects; being 0.3 miles a commonly used distance for small prospect areas. The vessel used for this study shall sail at a higher speed than 6 knots (that is, a higher speed than the targets').

A far away area from the structure's occupation will be set as control area in any case.

6.2.3 Marine Mammals

Unawareness of impacts caused by cables (voltage, horizontal or vertical layout, diameter), WECs (noise, collisions, aggregation, etc.) support and maintenance vessels on cetacean communities is high; therefore, interest on this topic is growing.

In this respect, there are some methodological antecedents for the study of marine mammals' communities developed by Thomsen *et al*. (2006) and Diederichs *et al*. (2008) amongst other, suggesting two kinds of action:

1. *Visual Observation* on board a ship according to Buckland *et al*. (2001; 2004) and Hammond *et al.* (2009).
2. Register of mammals' presence using *underwater acoustic techniques*.

By means of acoustic and visual methods, information on distribution, abundance, habitat use, population's conditions, as well as affection degree of human activity on cetacean present in the area where the energy harnessing park is considered to site.

Thus, the study shall mainly account for those species included in self-made lists or from state, European or international regulations establishing any kind of protection figure on marine mammals. Amongst which we must highlight those species included in Annex II of the Habitats Directive, such as, *Tursiops truncatus* (Common Bottlenose Dolphin) and *Phocoena phocoena* (Porpoise).

On the other hand, those species swimming at great depths should also be taken into account, such as beaked whales (*Ziphiidae*) and sperm whales (*Physeter macrocephalus*), all of them vulnerable species to anthropogenic noise (Cox *et al.*, 2004).

6.2.3.1 Visual Observation

Visual prospection shall be done according to the line transect methodology, developed amongst other by Hammond (1995) and Buckland *et al*. (1993; 2001; 2004), even improvements introduced in observation and analysis techniques applied to the Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA, http://server.knosys.net/biodiversidad/kndoc?bd=BIODIV&n=1978&q=CODA&page=1) project could be incorporated. This project was focused on analysing cetaceans' distribution and abundance in the Northeast Atlantic (Hammond *et al.*, 2009).

Visual prospection can be done on board a ship or from a plane; but the whole study area must be always covered. The method consists in estimating distance and angle between animals seen and the observer calculating the perpendicular distance from the line transect.

Visual prospection shall be carried out following the specifications in the aforementioned references. The methodology applied in the project CODA, where a two platform vessel was used is described: one platform was called *primary platform*, while the other was *tracking platform*.

- *Primary Platform:* platform where two observers shall make out the space near the vessel (approximately 500 m). Observations will be done using an angulometer to estimate the angle where the spotted cetacean is located and a distance stick to estimate the radial distance between the spotter and the cetacean. Binoculars are only used in case the species needs to be verified, never to spot individuals.
- *Tracking Platform:* both observers in the tracking platform will make out the distant space from the vessel (beyond 500 m). One of the observers shall use *Big-eye* binoculars and another 7*50 binoculars. Distance will be estimated counting reticles superimposed upon the view, while angle will be estimated with a transporter sited on the base of the Big-eye and at the observer's feet in the case of 7*50 binoculars. On top of each binocular a video camera is installed to estimate real distance of the spotted individuals. Likewise, the real angle is estimated using a webcam installed below each binocular.

A *duplicate identifier* and the person who keeps in touch with observers on the primary platform and registers all observations in a computer also work on the *tracking platform*. Each observer on both platforms has got a sighting and re-sighting button located in a box on the primary platform and at both sides of the binoculars for observers on the tracking platform, which automatically registers observations when it is pressed.

Thanks to a six second data buffer continuously updating, when observers press the sighting or re-sighting button, the previous six seconds area also registered into a *firestore* equipment, likewise, data about the sighting indicated by the observer are recorded (species, distance, angle, number of individuals, etc.). This design to capture data makes images and individual or group data available for each view.

The observer registering data uses a software developed by IFAW (*International Fund for Animal Welfare,* www.ifaw.org) which integrate GPS data, handwritten, voice and image data by means of *firestores*, and saves all information in an Access data base. After the observation work, registers must be validated (data correction and relationship between sightings and audio and video registers) with the software Validate. Images are used for estimating sighting distance by means of photogrammetry techniques.

Figure 36 shows a summary scheme describing the sighting system used in the CODA campaign.

6.2.3.2 Acoustic Prospection

Simultaneously to sighting, an acoustic prospection can be done by means of a passive acoustic monitoring, PAM, which covers different sampling techniques: hydrophones line dragging, sonobuoys location, acoustic recording packages, ARP, etc.

These techniques allow detecting and monitoring cetacean population with the advantage of being independant from sea and weather conditions, time and daylight, apart from being able to register continuously; therefore, they are more economically efficient than sighting techniques. However, in spite of their high potential, equipment, applications and technicians' training need to be developed (Moore *et al.*, 2006).

In general, acoustic systems usually count on an immersed part (hydrophone line, ARP, etc.), an onboard hardware (amplifiers, analyzers and PCs) and a software for processing and analysing registered sounds.

- *Hydrophone line*

The method of a hydrophone line consists in dragging a series of hydrophones with a vessel (at stern or a side by means of a cylindrically-shaped wire-mesh framework) following the designed transects according to the line transect methodology (Figure 37). The hydrophone cable is usually made up of two pairs of hydrophones installed at a given length of the ship and away from one another. The distance between the position of the first pair of hydrophones and the ship is determined according to noise made by the ship itself, wind and swell over sea surface, in an attempt to minimize interference of noise from the ship. The distance between both hydrophones in each pair may vary between some centimetres and several meters, while depth where they are located is set by the pressure sensor installed on the dragged cable (Soldevilla *et al.*, 2006; Uriarte *et al.*, 2007).

- *Sonobuoys*

Sonobuoys are made up of one or several hydrophones located at a given depth and transmitting registered sound to an antenna built on top of them (Figure 37). This antenna is the signal transmitter (in radio frequencies VHF, WIFI or WIMAX) reporting to a ship or land station, where apart from receiving the signal, it will digitally record it to further treat it. They are also made up of amplifiers and digital recording systems with a minimum of four channels. Sonobuoys shall be anchored and will continuously register underwater noise in the study area. Installing three sonobuoys, directionality and origin of detected noise will be determined (Moore *et al.*, 2006; Soldevilla *et al.*, 2006).

- *Acoustic Recording Package (*ARP*)*

ARPs are made up of hydrophones built into a body lying on the bottom where data acquisition system, batteries, etc. are installed. Contrary to sonobuoys, ARP can register sound a few meters away from the bottom. They can be installed there for

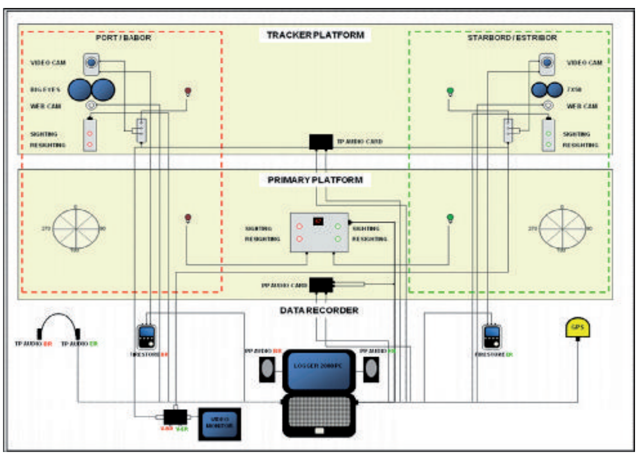

Figure 36. Cetacean sight system used in the CODA campaign.

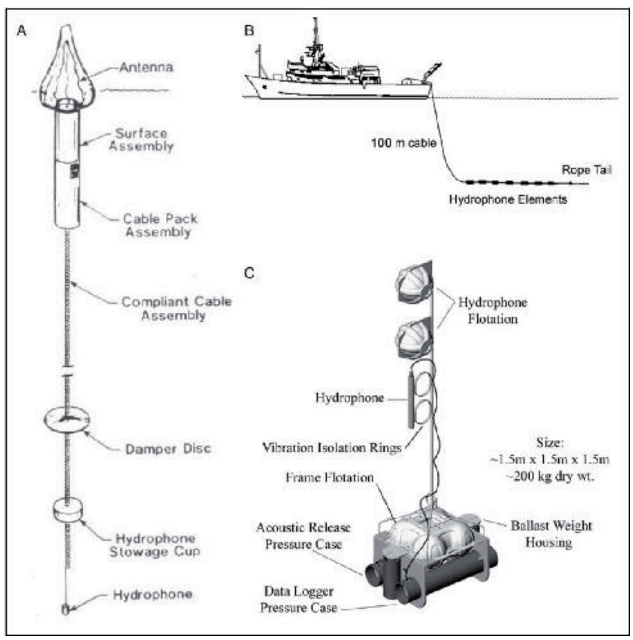

Figure 37. Representation of three PAM techniques: a) sonobuoy; b) line hydrophone dragging; c) highfrequency ARP(Soldevilla et al., 2006).

long time periods, and like the aforementioned systems, data can be digitally registered for further processing. In case high frequency sounds need to be detected, HARPs are used; they have got the same design as ARPs, but made to detect high frequencies.

After field data gathering, abundance and density estimates can be done applying different methods and software, most of them, freeware; within which PAWGuard software stands out. PAWGuard focuses on detection, localization, classification and visualization of sounds in a marine environment.

The present state of development of the application makes available navigation modules for: (i) click and whistle train detection (both of them based upon the analysis of a spectrogram image) and (ii) to estimate signal direction and distance (based upon time difference between each hydrophone in the pairs detecting the same signal) (Uriarte *et al.*, 2007).

Last but not least, information regarding environmental variables' affection on species can be obtained through *Geostatistical Spatial Modelling,* GSM (Pebesma y Wesseling, 1998; Bjørnstad, 2006; Bellier, 2007).

6.2.4 Seabirds

Seabird communities' studies must take into account nesting seabirds' census around the study area with the object of assessing possible effects of the project over this community.

In case such information is not available, studies on such census and identification of nesting seabirds in the influence area of the project shall be carried out.

6.3 Socioeconomic Environment

In this section, a description and analysis of population, including demographic, social, economic mortality and morbidity, employment levels and similar indexes should be described rendering relevant information on life quality of the affected communities; like equipment, services, infrastructure works and economic activities.

The description of national monuments, outstanding landscapes and sites with historical-archaeological, anthropologic, paleontological, religious and cultural values which may be affected by the project development need to be described. Moreover, we must not forget a possible effect on non-renewable marine resources such as arides, oil, natural gas, etc.

This economic and social analysis shall picture two main aspects:

- On the one hand, aspects related to social acceptability: all agents who may interfere in a positive or negative way in the development of the project and its future feasibility need to be identified. The project shall be presented to them, and possible benefits and advantages derived from the project development taking into account different perspectives will be explained. The objective is not only trying to neutralize possible confrontations to the implementation of this technology in the environment, but also finding out in the system potential "prescribers" of the product.
- On the other hand, analysing the direct economic consequence expected in a further implementation stage would be convenient. Dimensioning the installation will be necessary, setting up different possible scenarios to quantify the potential energy production and economic value. Moreover, the "domino effect" of this type of technology on sectors such as naval construction (which, a priori, has the best conditions to construct this type of devices) will be taken into account.

6.4 Environmental Protection

Environmental protection refers to information, relative to instruments and measures legally, established to preserve ecosystems and species. In this respect, an environmental inventory needs to include the existing environmental protected items to the projects' scope. In this section, international, European and autonomic scopes are explained according to the analysis made by Uriarte *et al*. (2009).

6.4.1 International Scope

- Convention on the conservation of migratory species of wild animals (Bonn Convention, http://www.cms.int): conservation of the listed species in the annex must be achieved by means of international or global agreements (compulsory legal treaties), memoranda (less formal instruments) or action plans. The *Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas* (ASCOBANS, http://www.ascobans.org/index0101.html), including waters in the Gulf of Biscay, has not been signed by the Spanish government, but the French homologue has.
- Pan-European Ecological and Landscape Diversity Strategy (http://www.strategyguide.org/fulltext.html): this strategy was established to cover the implementation of the Convention on Biological Diversity. The action plan of threatened species established in 1996 by the Strategy has been developed under the umbrella of the Convention on the conservation of wild life and natural environment in Europe or Bern Convention (http://conventions.coe.int/Treaty/FR/Treaties/Html/104-2.htm#Mammals/Mammifères).

6.4.2 Regional Scope

- Convention on the protection of the Northeast Atlantic (Convention OSPAR, http://www.ospar.org): *Law 42/2007 on Natural Heritage and Biodiversity* (http://www.boe.es/g/es/boe/dias/2007/12/14/seccion1.php#00000) establishes in section 1, article 53 that species which are protected and listed in any annex of Directives and international conventions, such as convention OSPAR, will be part of the List of Wild Species under a Special Protection Regime. Entering this list will be decided by the Ministry of Rural, Marine and Natural Environment

(MAMRM, by its Spanish acronym), and this involves periodically assessing the conservation state of such species (it is understood that the responsibility of this task lies on the MAMRM itself).

- Convention on the conservation of European wildlife and natural habitats (Bern Convention): these agreements are applied through the Directive 92/43/CEE of the European Council on the conservation of natural habitats and wild fauna and flora (Habitats Directive) and Directive 79/409/CEE of the Council, on the conservation of wild birds (Birds Directive).

6.4.3 European Scope

- Habitats Directive and Birds Directive: protection of the listed species in any annex by means of special protection areas for birds (SPAs) and special areas of conservation (SAC). All of them will take part in the Natura 2000 Network.
- Section 1, article 53 of Law 42/2007 on Natural Heritage and Biodiversity, establishes that species listed as protected in annexes of Directives, such as the Habitats and Birds Directive, will take part of the List of Wild Species under a Special Protection Regime. Entering this list will be decided by the Ministry of Rural, Marine and Natural Environment (MAMRM, by its Spanish acronym), and this involves periodically assessing the conservation state of such species (it is understood that the responsibility of this task lies on the MAMRM itself).

6.4.4 National Scope

- *Law 42/2007 on Natural Heritage and Biodiversity* includes, amongst many, the "List of Wild Species under a Special Protection Regime" made up of species, subspecies and populations deserving a special attention and protection according to their cultural, ecological and/or scientific value, uncommonness, singularity or threat degree, and also protected species mentioned in Directives and international conventions. Entering this list will be decided by the Ministry of Rural, Marine and Natural Environment, and this involves periodically assessing the conservation state of such species.

Autonomous Communities can establish lists on wild species under a special protection regime, and determine prohibition and complementary actions which are necessary for their preservation.

Besides, article 56 of this law establishes that the Spanish Catalogue of Threatened Species is included in the List on Wild Species under a Special Protection Regime, and such catalogue shall include two categories: "in extinction danger" and "vulnerable". In these cases, there is an obligation to write down and apply recovery action plans in a maximum term of three years for species in extinction danger (being able to assign critical areas which will be included in the list of the Spanish Catalogue of Endangered Habitats) and five years for vulnerable species. Recovery and conservation plans for threatened species will be done and approved by the Autonomous Communities.

Plans on species or population exclusively or mostly living in protected natural areas, Natura 2000 Network or internationally protected areas will be executed by the relevant planning and management institutions of such areas.

Now-days, while lists on species aforementioned are not made, it is on force the National Catalogue of Threatened Species (CNEA, by its Spanish acronym) created by Law 4/1989 on Natural Spaces and Wild Flora and Fauna (amended by Law 40/1997 and Law 41/1997) and regulated by RD 439/1990 of 30 March, regulating the National Catalogue of Threatened Species (BOE n. 82, of 05/04/1990). In this catalogue, species are classified into four categories: in extinction danger, vulnerable, sensitive to habitat alteration and of special interest. Species included in CNEA will be incorporated to regional catalogues if they inhabit totally or partially in that Autonomous Community, who will be in charge of developing the relevant recovery, conservation and management action plans.

6.4.5 Regional Scope

This section includes regulations only by Autonomous Communities in the north of Spain, i.e.: Basque Country, Cantabria, Asturias and Galicia.

- Autonomous Community of the Basque Country: *Law 16/1994 on Nature Conservation in the Basque Country* establishes the development of the *Basque Catalogue on Threatened Species of Marine and Wild Flora and Fauna*, defining the following categories "in extinction danger, vulnerable, rare and of special interest". After a thorough classification, a Management Plan shall be written down and approved to do with any existing threats on these species, promoting recovery, conservation or appropriate management of their population, together with their habitats protection and maintenance.

In case it is necessary, management plans will include a declaration as protected natural space of areas constituting a land or marine settlement for those classified species. On the other hand, article 53 establishes that Reintroduction plans will be developed for each species or subspecies that recently extinguished in the Basque Country and which are likely to occupy again Basque natural habitats, taking the necessary measures to make this introduction compatible with economical, cultural, social and ecologic conditions of the Basque Country or to modify these so that the introduction can be feasible.

- Autonomous Community of Cantabria: *Law of Cantabria 4/2006 on Nature Conservation in Cantabria* establishing the development of a *Regional Catalogue on Threatened Species*, regulated by Decree 120/2008, of 4 December, regulating the Regional Catalogue Regional of Threatened Species in Cantabria. Categories which threatened species can be classified into are the following: extinct (requiring a feasibility study for its potential reintroduction; in case this is possible, Law 42/2007 will

Table 4. Species included in different catalogues. Except for species of gobies (Pomatoschistus microps and P. minutus) and pipefish (Syngnathus abaster), the Habitats Directive lists in the annexes all species included in the Bern Agreement.

Species	Cantabria	Asturias	Galicia	Spain	Europe	Bonn	OSPAR
Charonia lampas lampas	V			V			
Nucella lapillus							X
Pinna nobilis	V			V	Annex IV		
Caretta caretta			V	IE	Annex II-IV	Annex I	X
Chelonia mydas				IE	Annex IV	Annex I	
Dermochelys coriacea			EP	IE	Annex IV	Annex I	X
Petromyzon marinus	V	V		EP	Annex II		X
Carcharodon carcharias						Annex I	
**Centroscymnus coelolepis*							X
**Centrophorus granulosus*							X
**Centrophorus squamosus*							X
**Cetorhinus maximus*						Annex I	X
**Lamna nasus*							X
Eubalaena glacialis			EP	EP	Annex IV	Annex I	X
Balaenoptera acutorostrata	V			V	Annex IV		
Balaenoptera borealis				V	Annex IV	Annex I	
Balaenoptera musculus musculus	V			V	Annex IV	Annex I	X
Balaenoptera physalus	V			V	Annex IV	Annex I	
**Raja montagui*							X
**Rostroraja alba*							X
Megaptera novaeangliae			SAH	SAH	Annex IV	Annex I	
Physeter macrocephalus	V			V	Annex IV	Annex I	
Kogia breviceps				IE	Annex IV		
Delphinus delphis				IE	Annex IV		
Lagenorhynchus acutus					Annex IV		
Lagenorhynchus albirostris					Annex IV		
Hippocampus hippocampus							X
Stenella coeruleoalba				IE	Annex IV		
Steno bredanensis					Annex IV		
Tursipos truncatus	V		V	V	Annex II-IV		
**Squatina squatina*							X

apply), in extinction danger (demanding a recovery plan), sensitive to the habitat alteration (requiring a habitat conservation plan), vulnerable (binding to write down a conservation plan and, if applicable, a habitat protection plan), and of special interest (requiring a management plan). According to Law of Cantabria 4/2006, spaces included in the Natura 2000 Network must count on suitable planning tools by 2010.

- Autonomous Community of Principado de Asturias: the *Regional Catalogue of Threatened Species of Vertebrate Fauna in the Principado de Asturias* and the *Regional Catalogue of Threatened Species of Flora in the Principado de Asturias* developed by Decree 32/1990 of 8 March, Regional Catalogue Regional of Threatened Species of Vertebrate Fauna of Principado de Asturias (BOPA n. 75 of 30/03/1990) and Decree 65/1995 of 27 April, creating the Regional Catalogue Regional of Threatened Species of Vertebrate Fauna of Principado de Asturias (BOPA n. 128, 05/06/1995) respectively, establish four categories of threat: in extinction threat (demanding a recovery plan), sensitive to habitat alteration (requiring a habitat conservation plan), vulnerable (forcing to draw up a conservation plan) and, of special interest (requiring a management plan).

The drafts deadline for habitat conservation plans, species conservation and management included in the regional catalogue is two years from approval of the *Land Planning of the Natural Resources in Asturias (Decree 38/1994, of 19 May, approving the Natural Resources Planning in Asturias, BOPA n. 152 of 02/07/1994)*, giving priority to species

Table 5 (Cont. from Table 4). Species included in different catalogues. Except for species of gobies (Pomatoschistus microps and P. minutus) and pipefish (Syngnathus abaster), the Habitats Directive lists in the annexes all species included in the Bern Agreement.

Species	Cantabria	Asturias	Galicia	Spain	Europe	Bonn	OSPAR
Orcinus orca				IE	Annex IV	Annex II	
Pseudorca crassidens					Annex IV		
Globicephala melas				IE	Annex IV		
Grampus griseus				IE	Annex IV		
Hyperoodon ampullatus					Annex IV	Annex II	
Mesoplodon bidens					Annex IV		
Mesoplodon densirostris					Annex IV		
Mesoplodon europeaeus					Annex IV		
Mesoplodon mirus					Annex IV		
Ziphius cavirostris					Annex IV		
Phocoena phocoena			V	V	Annex II-IV	Annex II	
Halichoerus grypus					Annex II-V		
Phoca vitulina					Annex V		

classified as sensitive. Any new introduction of a species in the regional catalogue will involve the obligation to develop the relevant Plan within a time period of two years.

- Autonomous Community of Galicia: the *Galician Catalogue of Threatened Species* regulated by Decree 88/2007, of 19 April, regulating the Galician Catalogue of Threatened Species (DOG n. 89 of 09/05/2007), established four categories of threat: in extinction threat (demanding a recovery plan), sensitive to habitat alteration (requiring a habitat protection plan), vulnerable (forcing to draw up a conservation plan), and of special interest (requiring a management plan). Like in Cantabria, extinguished species will require a reintroduction plan, in case natural habitats and socioeconomic and cultural conditions are suitable.

Galicia also counts on a *Register of Galician species of interest* under the Law 9/2001, of 21 August, on nature conservation (BOE 230, of 25/09/2001), where uncatalogued species, subspecies or population groups can be included; even those whose scientific, ecologic or cultural peculiarities grant them a specific attention, paying special attention to Galician endemisms.

6.4.6 Listed Species

Lack of information on biology and ecology of many marine species frequently leads to referring to fauna and flora groups which are better studied, leaving out of catalogues and lists some species which are probably in a dramatic state. Furthermore, in most of the cases, the fact that there is not enough information forces to make decisions based upon the expert's opinion. According to Uriarte *et al*. (2009), species included in catalogues and lists, up to-day, mentioned in the previous section are shown in Tables 4 and 5.

7. Impact identification and assessment

7.1 Introduction

Generally speaking, the term impact refers to an alteration of the environment caused by the execution of a project, expressed by the difference between the evolution with and without that project (Gómez-Orea, 1992) and can be represented graphically as shown in Figure 38.

The main objective of an EIS is predicting the nature and magnitude of effects caused by the development of the project studied. In order to do that, following several steps is required:

1. Identifying foreseeable impacts derived from the execution of the project. According to regulations, the focus must be on the significant impacts.
2. Estimating or assessing, in a quantitative way if possible, otherwise in a qualitative way, the incidence on environmental factors.
3. Putting them in relation to dynamic factors, what will allow predicting their evolution and determining control and amendment measures needed, to delete or minimize the impact.

According to Solaun *et al*. (2003), the project's developer

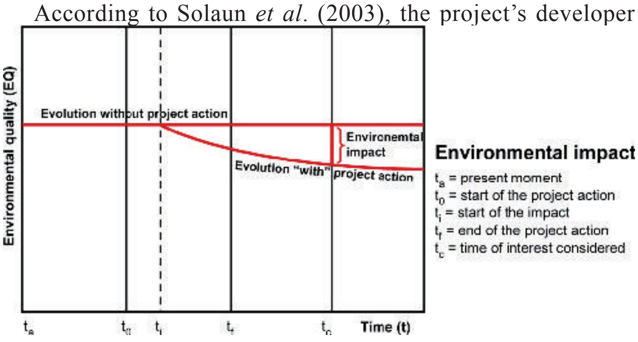

Figure 38. Graphic representation of the concept "Environmental Impact". Adapted from Gómez-Orea (1992).

shall always make sure that all techniques used in the identification, analysis, assessment and hierarchy of positive and negative impact with a relevant adverse character, derived from the project, fulfil the following requirements:

1. Analysis of the previous environmental circumstance (antecedents or baseline) compared to the expected environmental transformations.
2. Prediction of derived impacts and risks which may occur on these environmental variables.
- Suitability of methodology used according to:
- Nature of the action taken
- Affected environmental variables
3. Environmental characteristics of the influence area
4. Use of representative environmental variables to identify environmental impacts, discussing on their scale, resolution level and volume of data, replicability of the information, identification of positive and negative relevant impacts, and definition of these impacts' threshold.
5. Fulfilment of environmental national or international regulations on the matter and geographical area involved. If environmental national regulations on the matter were inexistent, regulations from other countries or those coming from international organizations, in accordance with the Responsible Authority, will apply.

7.2 Impact Identification

Identifying environmental impacts derives from the study of the relationship between actions of the project and specific characteristics of each affected environmental aspects (Solaun *et al.*, 2003).

According to this, the methodology is developed in two parallel lines, one analysing the project and leading to the identification of actions that may cause impacts, and another analysing the environment to identify factor that may be affected by those actions (Gómez-Orea, 1992); both lines lead to a specific task of identification of effects by means of several tools amongst which Solaun *et al*. (2003) name the following:

1. *Monitoring Lists:* they include a wide range from simple environmental factors, to descriptive approaches including information on measurements, prediction and interpretation of the identified impact alterations.
2. *Interaction Matrix (cause-effect):* they vary from a simple description of the project's activities and their impacts on environmental factors to structured stages showing the existing relationship between affected factors.

The Leopold's Matrix (Leopold *et al.*, 1971) was the first method established to assess environmental impact. The system is based upon a matrix where columns list human actions which may alter the environment, and rows are the environmental characteristics (environmental factors) which may be altered. Existing interactions can be defined by this column and row system.

A first step to use the Leopold Matrix consists in identifying existing interactions. All actions (columns), which may occur within the project, are firstly taken into account. Then, environmental actions (rows) for each action, which may end up being significantly affected, are represented by a diagonal in the cell belonging to the column (action) and row (factor) to be considered. Once we do likewise with all actions, marked up cells will represent interaction (or effects) to be taken into account.

Once all cells representing possible impacts are marked up, an individual assessment of the most relevant ones is done. Each cell contains two values:

- Magnitude, ranked from 1 to 10, being 10 the maximum and 1 the minimum alteration caused in the environmental factor to be considered.
- Importance (ponderation), which gives the relative importance of the environmental factor within the project compared to the possibility that alterations may occur.

Magnitude values must be proceeded by a + or – symbol respectively for positive or negative effects on the environment. Once all cells are filled in, next step consists in assessing or interpreting the numbers they contain. In order to simplify the process, a reduced matrix is recommended, using columns and rows where actually an interaction occurs.

The final reduced matrix presents a series of values showing the degree of impact that an action may have on an environmental factor. In spite of doing a ponderation or definition of the importance of such factor, according to Leopold *et al*. (1971), values in each cell of the same matrix cannot be compared or added to each other. Even though their first objective was some specialists proposing ponderation methods that may allow some kind of operation or addition in columns and rows (Gómez-Orea, 1988,2003). Nonetheless, cells belonging to matrix prepared to define different alternatives for the same project can be compared. In fact, the Leopold's Matrix is especially efficient for a previous comparison of alternatives (Estevan, 1984).

3. *Network Diagrams:* integrate cause and consequence of impacts by means of the identification of the existing relationship between actions and environmental factors that take the impact, including those representing secondary and tertiary effects.
4. *Analogy*: mainly refers to the information from other existing projects with similar characteristics and the fact that they can be used in an analogue way to identify previous impacts of the proposed project.
5. *Experts' judgement*: this method is generally used to deal with specific impacts of the proposed project on environmental factors.
6. Literature revision: involves a compilation of information from types of projects and their common impacts.

7.3 Impact Analysis

According to Gómez-Orea (1992), differentiating between *effect*, or modification of a factor and *impact*, understood as the assessment of such effect, is truly clarifying.

This section focuses on describing in a qualitative and/or quantitative way the impact characteristics (effects) which the project may cause on several environmental factors.

In order to do this analysis, a study of the project needs to be carried out to determine all possible impact sources, together with an environmental inventory to identify environmental factors likely to be altered by the project. Both data matrixes shall be crossed to define incidences, paying special attention to the parameters which can best predict the impact rather than piling up information that may blur the process of establishing cause-effect relationships.

The description of each impact generated from the relationship action-affected factor must be done according to the definitions established by the following regulations:

- COUNCIL DIRECTIVE 97/11/CEE of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.
- DIRECTIVE 2003/35/CE of the European Parliament and of the Council, of 26 May 2003, providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC.
- Legislative Royal Decree 1/2008, of 11 January, through which the revised text of the Law of the Evaluation of the Environmental impact of Projects is approved.
- LAW 62/2003, of 30 December, on fiscal, administrative and social measures.
- LAW 22/1988, of 28 July, on Coasts, and its regulations (Royal Decree 1471/1989).
- LAW 26/2007, of 23 October, on environmental responsibility.

According to legislation on force, impacts are defined as follows, some of which have been revised or extended for a better understanding:

1. According to their nature or character, impacts are divided into:
- *Positive Effect*: as understood, both by the technical and scientific community and people in general within the context of a complete analysis of costs and generic benefits and the circumstances of the action itself.
- *Negative Effect*: translates as a loss on nature, aesthetic-cultural, landscape, ecological value or as an increase of damage derived from pollution, erosion or colmatation and other environmental risks in discord with the ecologic-geographical structure, character and personality of a certain region.
2. According to their immediacy:
- *Direct Effect*: has got an immediate incidence on any environmental aspect. This also includes those effects occurring at the same time and in the same place of the causing activity (Solaun *et al.*, 2003).
- *Indirect or Secondary Effect*: involves an immediate incidence on interdependence or, in general, on the relationship between an environmental sector to another. They also refer to those impacts that may occur in a different place than were caused as a result of human action, and that usually derive from a direct or primary effect (Solaun *et al.*, 2003).
3. According to their accumulation or synergy:
- *Simple Effect*: affects only one environmental component or its action mode is individualized, without any consequence or causing new effects neither by accumulation nor by synergy.
- *Accumulative Effect*: when the action of the causing agent extends in time, it progressively becomes more serious, and it lacks any suppressing mechanisms with temporal efficiency similar to those of the agent increasing the cause of damage. They are also defined as those resulting in a proposed action which increases when adding collective or individual impacts caused by other actions. (Solaun *et al.*, 2003). Their final incidence is equal to the addition of partial incidence caused by one of the actions provoking them (Solaun *et al.*, 2003).
- *Synergic Effect*: occurs when the global effect of the simultaneous presence of several agents causes a higher environmental incidence than the addition effect of individual incidence considered in an isolated way. That is, they occur as a consequence of the global effect of several actions and their final incidence is greater that the addition of individual incidences caused by each of the actions independantly considered. Likewise, such effect whose action mode provokes in time the occurrence of other effects is also included in this typology.
4. According to duration:
- *Short, medium and long-term effect:* their incidence can occur within a year, within five years or after five years, respectively.
- *Permanent effect*: involves an indefinite alteration in time of main action factors in the structure or relationship between ecologic or environmental systems present in that particular site.
- *Temporal Effect*: involves a non permanent alteration with an occurrence term that can neither be estimated nor determined.

In the description of this effect, Spanish regulations add some brief remarks on the way the environmental effect occurs in time. And this is described as follows:

- *Periodic effect*: it occurs intermittently and continuously in time.
- *Irregular occurrence effect*: it occurs at any time and their alterations need to be assessed according to occurrence probability, especially circumstances which are neither periodical nor continuous, but exceptionally serious.
- *Continuous effect:* these alterations occur irregularly or intermittently.

5. According to their reversibility and ability to recover initial conditions:
- *Reversible effect*: their alteration can be assimilated by

Table 6. Examples of impact analysis techniques. By Solaun *et al*. (2003).

Element	Method for impact prediction
Atmosphere	• Inventory of emissions • Statistical models of the urban area • Simple or multiple models of dispersion • Box models • Indexes of air quality • Receivers' management
Superficial Water	• Distribution of dumping loads • Quantitative models • Statistical models • Studies on water usage • Indexes of water quality
Underground Water	• Study on pollution sources • Indexes of soil and/or surface water vulnerability • Indexes of pollution sources • Essay on lixiviates • Flow and transport models
Noise	• Propagation of individual sources models • Statistical model of noise based on population • Indexes of noise impact
Biological Conditions	• Essays on chronic toxicity • Methods based upon the habitat • Models of species population • Indexes of diversity • Biotic indicators and indexes • Biological assessments • Risk assessments based upon ecology
History / Archaeology	• Inventory of resources and effects • Predictive modelling • Resource planning
Visual	• Inventory of the bottom line • Control Lists • Photographic and Photoshop approximations • Computer simulation • Indexes of visual impact
Socioeconomy	• Demographic models • Econometric models • Descriptive control lists • Multiplying factors based on population or economy changes • Indexes of life quality • Risk assessment based upon health and safety

the environment in a measurable way at medium term due to the operation of natural process in ecologic evolution and environmental self-depuration mechanisms.

- *Irreversible effect*: it involves an extreme difficulty or unlikeliness to return to the previous situation before the action triggering the effect.
- *Likely to be recovered effect*: the alternation caused can be deleted, either by natural action or human action (amendment measures) and likewise, such alteration can be substituted.
- *Unlikely to be recovered effect*: the alteration or loss is not likely to be repaired nor restored neither by natural

nor human action.

6. According to environmental consequences:

- *Remarkable Effect*: it is manifested as a modification in the environment of natural resources or their fundamental process of operation which causes or may cause a remarkable effect on them.
- *Minimum Effect*: this effect is proved to be non-remarkable.

There are many useful methodologies for characterizing the environmental impact according to the attributes described below. Their application especially depends on the way data are gathered and the working scale used. In this respect, if we refer to the first aspect we can find two alternatives (Estevan, 1984; Conesa, 1997):

- Qualitative Methods: qualitative data register (presence or absence, etc.).
- Quantitative Methods: quantitative data register (numeric data use). In this case global or partial quantitative systems can be applied.

The first alternative require less effort, and can cover wider objectives, but has a disadvantage that data gathered this way cannot be statistically analysed in detail. The second, on the contrary, is more elaborate in time and effort and allow the study of less number of variables compared to the first one; however, they can be statistically treated.

The use of one or another alternative depends, obviously, on the study cost and the necessity to obtain results more or less precise and more or less immediate. Regarding this simple classification, some analysis methods can be named such as:

Simple techniques: amongst simple tools for the impact analysis we find the use of similar or analogue information about impacts from projects in other similar geographical areas.

- *Graphic techniques or cartographic systems:* like the superposition of transparency; based upon the graphic representation of impacts on a cartographic base of the affected area.
- *Experimental indexes and methods:* in this type of analysis, environmental index are taken into account (for example, quality standard, reference values, etc.) and laboratory essays (for example, lixiviate essays for dredged material, toxicity essays, etc.). The change in the index which may cause the proposed action in the project is quantified o qualitative described in these analysis. This change could be regarded as an impact measure.
- *Mathematical models:* the most sophisticated approximation in the impact analysis involves the use of quantitative models to predict transport and destination of pollutants by means of hydrodynamic simulation in 2 or 3 dimensions. When using these models, their assumptions, limitations and uncertainty must be taken into account, they must also be calibrated with field data from the place where the project is bound to be developed. That is why more sophisticated quantitative models are scarcely used.

Within this type of complex model we can also mention the Battelle method (Whitman *et al.*, 1971). This system is based upon a list of impact indicators with 78 environmental parameters representing a unit or an environmental aspect which is worth considering separately, and whose assessment is also representative of the derived environmental impact from the actions or projects under consideration.

Once a parameters list is ready, the Battelle model establishes a system where these are assessed in comparable units representing values that are a result of real measurement, whenever that is possible. In this respect, the use of curves or transformation function is proposed (Whitman *et al.*, 1971; Estevan, 1984; Canter y Sadler, 1997; Conesa, 1997; Morgan, 1998) which can achieve an approximate value for the environmental quality degree from the value of a given index. Measurement of each parameter in their characteristic units is translated to a ranking scale from 0 to 1 representing the environmental quality index of that parameter. Applying this system to the environment situation with and without project, the net impact of the project will be obtained by substraction in each parameter, component or environmental category to be considered.

A disadvantage of this method lies in the need to adapt the relationship between parameters and environmental measures originally established (developed for the USA) to the conditions in each specific environment. For example, proposals for indicator to assess geotic component in coastal areas have been made within the context of environmental impact assessments (Cendrero, 1995; Rivas *et al.*, 1995; Cendrero y Fischer, 1997; 1997; Cendrero y Panizza, 1999). The scarce application of the method in environmental impact studies presented in Spain (Español, 1998), is caused by the lack of proposals of indicators for all aspects which must be considered and due to the high cost of the application.

In this line of methodologies, another interesting system is

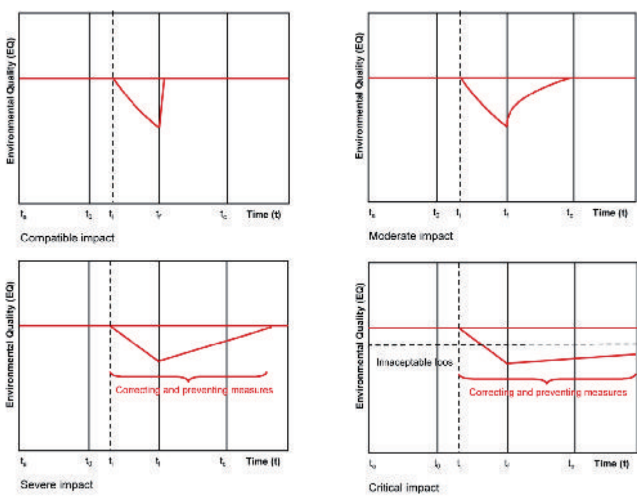

Figure 39. Graphic representation of an impact of a compatible, moderate, severe and critical nature.Key: tp = present time; to = beginning time of the action; ti = beginning time of the impact; tf =finishing time of the action; tc = time of special consideration.

Table 7. Main actions causing impact.

INSTALLATION	• Transport of material and equipment to and from the selected site. • Installation of equipment/structures: WECs, moorings and submarine cables (associated noise, marine bottom and landscape alteration) and structures along the coastline. See sections 5.3.1, 5.3.2 and 5.3.3. • Residues storage (if required). • Small hydrocarbon leaks. • Accident Risk (failure of devices, crashing, etc…).
OPERATION AND MAINTENANCE	• Presence of structures. • Operation of underwater cables (electromagnetic field). • Reduction of marine energy. • Noise. • Use of anti-fouling paints. • Hydraulic/other liquid pollutants leaking. • Presence of maintenance equipment/structures (associated noise, marine bottom and landscape alterations). • Accident Risk (failure of devices, crashing, etc…).
DESERTION	• Transport of material and equipment to and from the selected site. • Presence of dismantled equipment (associated noise, marine bottom and landscape alterations). • Final destination of dismantled structures. • Small hydrocarbon leak. • Accident Risk (failure of devices, crashing, etc…).

the one developed by Conesa (1997), which categorizes the impacts in an index which varies from -10 to +10 according to several attributes and characteristics of the impact which have been mentioned before.

In an analysis of the Spanish experience in EIS made by Español (2000), it is said that the interaction matrix model between actions and project (Leopold Matrix) is present in most of the EIS; monitoring lists, network diagrams and more elaborate methods have not succeeded in Spain; attention is brought to the defence of the Battelle method in academic contexts and the scarce application in EIS. However, technological development in Geographic Information Systems (GIS), the increase in digital cartographic information and their availability have allowed spreading the use of the originally called transparency method as the assessment system for different sites or drafts mainly in an initial phase of EIS.

Table 6 shows a list of methods for the impact analysis according to possible affected elements.

7.4 Impact Assessment

According to the present environmental legislation, the final assessment of each impact derived from the proposed activity shall be carried out in accordance with the following definitions:

- *Compatible environmental impact*: recovery is immediate after cessation of the activity and does not require any protection or amendment practice (Figure 39).
- *Moderate Environmental Impact*: recovery does not require intensive protection or amendment practice and the achievement of initial environmental conditions require some time (Figure 39).
- *Severe Environmental Impact*: recovery of the environment conditions requires an adaptation of protection or amendment measures and, even with these measures recovery needs an extended period of time (Figure 39).
- *Critical Environmental Impact*: its magnitude surpasses an acceptable threshold. A permanent loss of quality in environmental conditions occurs, and there is no possibility of recovery even taking protection or amendment measures (Figure 39).

7.5 WEC Systems

The main generating activities are summarized in Table 7, while affected environmental factors are summarized in Table 8.

Environmental factors occur in two different temporal scales: at short- and long-term. Impacts at a short-term can occur mainly during the commissioning stage of the structures, while long-term impacts, even though they tend to be less intense than the previous ones, usually occur along the whole existence of the installation (AWATEA, 2008).

Amongst short-term impacts, we must mention:

- Alteration of the substratum during mooring and installation of the submarine cable, causing a local alteration of the habitat and increase of turbidity.
- Noise during the construction (drilling, dredging, etc.).
- Increase of maritime traffic.
- Others.

Amongst impacts at a long-term, the following must be mentioned:

Table 8. Main environmental factors affected.

PHYSICAL ENVIRONMENT	• Water quality. • Hydrodynamics. • Sediments. • Landscape.
BIOTIC ENVIRONMENT	• Benthic Communities. • Ichthyofauna. • Marine mammals. • Marine Birds.
SOCIOECONOMIC ENVIRONMENT	• Fishing. • Archaeological and cultural resources. • Socioeconomy.

Table 9. Relationship between the project activities and the identified environmental factors, both at commissioning, operation and decommissioning stages.

		Hydrodynamics	Water Quality	Sediments	Benthos	Ichthyofauna	Marine Birds	Marine mammals	Fishing	Archaeological resources	Landscape	Socioeconomy
Commissioning	Structures		●	●	●	●	●	●	●	●	●	●
	Cable		●	●	●	●	●	●	●	●		●
Operation	Structures	●	●	●	●	●	●	●	●		●	●
	Cable				●	●		●	●			
Decommissioning	Structures		●	●	●	●	●	●	●	●	●	●
	Cable		●	●	●	●	●	●	●	●		●

Physical presence of structures.

- Noise and vibration caused by the installation.
- Electromagnetic fields caused by cables.
- Accidental collision with structures.
- Animals getting caught by anchors and cables.
- Others.

Table 9 summarizes the interconnection between the project activities and the identified environmental factors, both at commissioning, operation and decommissioning stages.

7.6 Structures

7.6.1 Impacts on Hydrodynamics

Impact of WECs in hydrodynamics is strongly dependant on the type of installation and, especially, on the shape and design of the immersed/emerged structure and disposition of weights and mooring elements (Michel *et al.*, 2007).

Generally, immersed structures (and floating structures to a narrower extent) may affect ocean and tidal currents, swell and sediment dynamics. An impact on ocean currents and tidal currents occurs when different elements on the installation are likely to cause significant changes in speed or flow direction. These changes in flow may generate areas of greater turbulence (water under an obstacle generates vortex or vortex tails) which, in their turn, modify mixture capabilities and interactions between deep ocean and surface layers or simply shady areas with a less energetic marine dynamics and a greater residence in water mass.

Regarding swell, installations may cause a decrease in wave height and modifications in wave climate due to direct interactions between waves and structure (reflexion, diffraction, breakage, shady areas occurrence) and also modifications on effects derived from the wave/current interaction.

In terms of the effect of these installations on the coast, we can name impacts in hydrodynamics and, therefore, in sediment transport, alterations on leisure activities, together with the reduction of the installation capability of other marine WECs. In the case of floating structures, we can say that the impact on hydrodynamics and sediment transport in general is low, especially compared to the effect of fixed harnessing structures (Wavenet, 2003; Hagerman y Bedard, 2004).

7.6.1.1 Commissioning

During the commissioning stage of floating structures, relevant impacts on water hydrodynamics are not expected (currents, swell and tides).

Cases requiring civil work, such as creating or modifying emerged dikes, jetties, coating works, longitudinal walls or scaffolding setting at a great scale, will certainly cause an important impact on hydrodynamics and sediment transport. Such an impact is progressive and reaches a peak during the operation stage. No significant additional impact is expected on the current or swell regime during the commissioning stage.

7.6.1.2 Operation

Floating structures may cause a reduction of currents in the occupation area of the installation (near the bottom, close to weights and, generally, in deep waters depending on the shape of the immersed elements), consequently, an increase in natural sedimentation rates in the area.

Therefore, interference of anchoring altering hydrodynamics in the area has been described by some authors relating that to aquiculture structures (Silvert y Sowles, 1996; Boyd y Heasman, 1998; Ogilvie *et al.*, 2000; Hartstein y Rowden, 2004), being less significant in floating elements and structures.

In a similar way, swell regime can be affected by anchored structures. Calculations made in trial installations like the ones by Wave Hub in England, estimate a reduction of 5% in wave height in the worst case (equivalent to ~10% of energy) being re-established from an approximate distance of 5 km (Halcrow_Group_Ltd, 2006).

Floating installations for energy harnessing are still quite new. There are no specific tools, as far as we known, developed to assess different affections that these structures may cause on hydrodynamics. Consequently, using tools designed for traditional (rigid) structures is recommended taking into account higher energy transmission factors (energy transmission factors show the energy percentage that stays in the sea after waves have interfered with the structure and they are usually higher in the case of floating structures than rigid/opaque ones).

A recent example of a shadow area assessment for the installation of a floating wave harnessing structure in Arminza, Basque Country (Bald *et al.*, 2008) is based on propagation of a series of waves from the most energetic directional sectors with the average direction in that sector, achieving a series of associated shady areas. The global percentage of energy decrease in each case is calculated supposing a uniform absorption of 10 % of the average annual energy flow coming from this directional sector. This value is the most commonly used in several studies on wave energy harnessing projects (Wavenet, 2003; AWATEA, 2008). Finally, a superposition of all shady areas is done resulting in an approximate map of decrease in maximum annual average energy.

It is worth mentioning that in spite of having an average value to soften energy, transmission factors of all types of floating structures remain unknown and the installation will depend on the number of devices and their relative location (complex interactions between waves can be caused by different devices depending on the distance separating each other). Therefore, it is recommended to take into account different scenarios and carry out several sensitivity tests (with different placements and supposing different transmission factors) when doing simulations.

Considering peculiarities of floating structures (and having specific tools not yet been developed), the use of analysis tools of the Coastal Modelling System (CMS), as described in section 6.1 (Environmental Inventory) is recommended. As described in that section, CMS is a computing application integrating a series of numeric models that allow the implementation of the study methodology and action design in the littoral, including monochromatic and swell propagation models together with beach dynamics evolution models.

Talking about fixed structures, a decrease in the current regime is expected during the operation stage in the inner area of occupation of the infrastructure due to the physical barrier they build up. Depending on the installations' dimension and total resistance surface, the impact might be more or less significant. In general, dikes, jetties and other fixed structures are elements that lead to shady areas in the voussoir of these structures, as they are dynamic barriers to the normal wave and current trajectory.

The modification of currents and wave regimes may cause an increase in the residence time of water mass in certain areas (leading to an effect on water quality and potential affection on benthic communities).

Besides, direct interaction between currents and swell with the structure may lead to important modifications in flow and swell climate due to the processes described in the previous section.

Last but not least, flow modifications directly affect sediment dynamics causing new accumulation or erosion areas nearby the structure or leading to changes in net longitudinal transport direction of sediments, their spread along the coastline and, in the long-term, on the coast morphology.

The use of tools and criteria for traditional fixed works is recommended when assessing this kind of impacts on structures. The Coastal Modelling System (CMS) described in section 6.1.4 of the Environmental Inventory is recommended for swell.

As far as currents are concerned, the correct use of numeric modelling techniques is especially necessary in case the installation is likely to cause significant retention areas and/or the study area is under the potential influence of nearby dumping points (river mouth or emissary) which may significantly compromise water quality. A more detailed list of available tools is provided in section 6.1 (Environmental Inventory).

Generally, it is worth pointing out that the use of models is not trivial and requires an important degree of expertise and training. Validating results is totally necessary; consequently, numeric experience must go together with field measurement experience.

7.6.1.3 Decommissioning

During the decommissioning stage of floating structures, no significant impact on water hydrodynamics is expected (currents, waves and tides). Fixed structures have similar impacts on hydrodynamics and sedimentary dynamics as described during their commissioning.

7.6.2 Impacts on Water Quality

7.6.2.1 Commissioning

During the commissioning stage, mooring and fixing structures and cables to the bottom may cause an increase in suspension material in the water column. The most immediate consequence of this increase of suspension material is loss in transparency and raise in turbidity. Sometimes, the correspondent decrease and increase depends not only on the quantity but also quality of suspension materials.

On the other hand, taking into account that thin materials put less weight on the solid concentration in suspension than thick materials, but have different optical properties (10 particles of 0.1 gr absorb or diffract more light than 1 particle of 1 gr) and thin materials suspend for a longer period of time, the affected areas' extension considering water quality would be higher with respect to these variables.

Apart from the direct effect that the increase of matter concentrations in suspension has on optical water properties with the consequent reduction in quality, other indirect effects can be mentioned considering water transparency. The most important one relates to a decrease in phytoplankton development capacity caused by a severe limitation of available light for the photosynthesis process.

In terms of fixed structures located for example on dikes, docks, etc., tasks like excavation, dredging, transport, formwork, confinement, concrete, etc. may be required and they can potentially affect water quality.

The main parameters affected will be solids concentration in suspension and turbidity which will increase, consequently reducing water transparency and causing the aforementioned effects on photosynthesis. The most important effect derives from the surface runoff of concrete and water exchanges in the contact area that transfer a significant amount of materials. Amongst these materials, thin components of cement are highlighted as causing alterations in colour and high turbidity; even though they do not cause a high concentration of solids, they show a high time of permanence in suspension what implies a negative factor in terms of the effect extension.

Effects on water quality are summarized to resuspension of some materials from the bottom, and release of thin material and other adherence which, to a smaller or greater extent, always go together with very thick materials used, even though they are origin dependant. This leads to an increase of solids in suspension and turbidity being other parameter alterations scarcely noticeable or minimum.

Another parameter in water quality, directly affected by concrete works, is pH, which will take higher values due to the alkalinity released by cement.

On the other hand, ship traffic associated to commissioning tasks may cause accidental hydrocarbon leaking from water pumps, oil or other objects.

Operation or Exploitation

Pollutants' leaking from vessels and equipment, hydraulic fluids, anode erosion and anti-fouling paints during the operation stage may affect water quality.

Some WECs have a built-in hydraulic system, where leakage may occur, even fluid dumping due to breakage after a storm or crashing of a floating object or vessel. It is important to mention this impact is exceptionally rare, as WECs are technically designed to overcome storm conditions, and navigation around the occupation area is usually prohibited. On the other hand, any immersed structure in the sea is subject to bio-fouling of marine organisms. In order to manage this effect, there are two solutions: (i) divers cleaning periodically and (ii) the use of anti-fouling substance with the less possible degree of toxicity.

Likewise, maintenance vessels of the installation may cause a punctual hydrocarbon, oil or other object leakage, so they shall be conveniently serviced to minimize hydrocarbon or other chemicals leakage into the sea.

Summing up, expect in uncommon accident, crashing or breakage situations, the structures affection on water quality can be regarded as minimum only if a contingence plan is developed to cope with the aforementioned situations together with a visual inspection of the environment to detect possible leakage and hydrocarbons presence on the water surface.

7.6.2.2 Decommissioning

During the decommissioning stage, impacts on water quality are similar to the commissioning stage.

7.6.3 Impacts on Sediments

7.6.3.1 Commissioning

During the commissioning stage, the affection on sediments is mainly associated to their re-suspension during anchoring and installation of fixed devices to the bottom, thus being an impact extremely temporal in nature and with a rapid recovery. Their assessment is similar to the one described in section 7.6.2.

Another possible impact derives from the increase of hard substratum as a consequence of moorings and WECs, being applicable remarks mentioned in section 7.6.1.

7.6.3.2 Operation

Mooring dragged after an exceptionally severe storm may affect rocky structures, making rocks and stones rotate, and also the sedimentary bottom of the installation area, if present. If moorings are properly designed and dimensioned, we can expect little impact related to dragging during a storm. In case an accident or landslide of the structure after a storm occurs, mooring can be caught in emerged or coastal areas of special interest causing a dredge and scouring effect on marine communities and habitats.

Another effect derived from moorings involves the artificialisation of substratum. If anchor points are mainly located on sedimentary bottoms, an accumulation of anchors may lead to a significant change in proportion of hard/soft substratum in the installation area.

Talking about fixed structures anchored to seabed or dikes, breakwaters, docks, etc., remarks mentioned in section 7.6.1 will apply.

7.6.3.3 Decommissioning

During the decommissioning stage, impacts on sediments are similar to the ones described during commissioning.

7.6.4 Impacts on Benthos

7.6.4.1 Commissioning

During anchoring, sediment turnover may cause an increase in turbidity of the area (ENERGI y ELSAM, 2005). The amount of sediment that may pass to the water column depends on the methodology used to anchor, the kind of sediment present in the area and hydrographic conditions when the installation is carried out. Besides, an increase in turbidity depends also on the amount of sediment turned over, size of the grain and hydrographic conditions after sediment turnover. Thus, the smaller the sediment grain size is and more severe hydrographic conditions, and the longer the increase in turbidity.

Installations requiring civil work, both turnover of sediment and construction activity, may involve an increase in turbidity in the area. This increase in turbidity would depend on both the quantity of sediment incorporating to the water column and other materials coming from the work; therefore, this will be directly related to the magnitude of the work and grain size of the particles. Likewise, the extension in time of this effect would depend mainly on how long the construction work takes.

Such increase in turbidity, apart from affecting seaweed communities due to the decrease in light reaching the bottom (as anchoring is done from 50 m depths, big seaweed areas are not expected), it has also got an effect on benthic macro invertebrate communities, as they may collapse trophic structures of filter animals, for example.

7.6.4.2 Operation

Moorings leads to a complete destruction of the fauna and flora of the bottom where it is placed (ENERGI y ELSAM, 2005). The lost surface and consequently, total affected biomass will depend on the total number of structures installed at the bottom and their sizes.

In sedimentary areas, moorings presents an artificial hard substratum surface that may promote seaweed fixation (quantity will always depend on depth where anchors are located) and sessile biota, specially sponges, cnidarians, bryozoans and polychaetes. An alteration in the proportion of hard-soft substratum in the installation area of the project could facilitate a recolonisation of the sedimentary area by fauna and flora which, in ordinary conditions, is more likely to live on hard substratum. Generally speaking, it is considered that this impact would be similar to other kinds of structures such as cages for fish aquaculture and platforms for gas or oil extraction (AWATEA, 2008).

Likewise, effects derived from a dragging action of anchors and ends are not the only sources of this impact, cables and chains are also bound to cause: on the one hand, the destruction of benthic communities around anchors and a variable radius according to the cables' looseness and anchors' stability; on the other hand, turnover of sediment and consequent decrease in transparency and increase on turbidity in the area whose conditioning and impact are similar to what was mentioned in the commissioning stage.

Finally, WECs installed shall extract a variable energy quantity from the system. In the present technological state, good performance is considered to be around a 10 %. These harnessing levels may lead to a decrease in wave height of approximately 3.0 – 3.5 %, at an average regime, in the shady area (at an extreme regime, WEC systems will usually stand by, so the loss will be reduced). This decrease in wave height may cause a narrowing of the intertidal area in case it sites in the shady area of the infrastructure, as wave and their splashes will reach lower.

Moreover, a decrease in wave energy may cause an impact on some species of interest. In this respect, Borja *et al*. (2006) determined a relationship between incident wave energy and biomass of goose barnacle in the protected biotope of *San Juan de Gaztelugatxe*. According to this relationship, the decrease in incident energy by 0.3 % in the biotope area implies a decrease in biomass from 0.015-0.021 $kg\cdot m^{-2}$.

This variation in abundance can also occur for other species, whose data are not available, but they are known to have an important dependence on swell like seaweed *Gelidium and Cystoseira*. In all cases, a decrease in structuring species abundance may involve an increase in opportunist species such as *Plocamium cartilagineum* or alike.

On the other hand, as it has been mentioned before, in case an accident or detachment of structures occur after a storm, they might be caught in emerged or coastal areas of interest, causing a dredge and scouring effect on marine communities and habitats.

Another possible effect on benthic communities derives from fouling which may occur on floating structures, ends, cables, chains and anchors. Regarding floating structures, fouling may cause a faulty operation of WECs; therefore, it must be eliminated, either by means of mechanic cleaning or anti-fouling coating. In case mechanic cleaning is carried out *in situ*, detachment of crusting species to the bottom may occur, leading to enrichment on organic matter of the seabed and possible affection of their communities. This impact's effect will strongly depend on the type of WEC and number WECs installed.

Regarding structures that require civil work, if the installed structures have a barrier splitting a habitat in two in a relative homogeneous way, changes in the current regime to the other side of the structure may involve a change in benthic communities. Thus, communities which are thought to be characteristic of areas more or less exposed will be displaced by communities typical in a protected environment. These changes can get to the extreme that sedimentary environments are created in areas that previously had a rocky substratum and a consequent adaptation of benthic communities.

On the other hand, the structure will form a new artificial substratum where seaweed and sessile macro invertebrates can adhere to (sponges, cnidarians, bryozoans, polyquetes, etc.) creating a new habitat. Such habitat would substitute the previously existent rocky substratum if construction is made on that kind of substratum or sedimentary environments, characterized by radically different benthic communities, were done with, and a consequent rock arousal will occur.

7.6.4.3 Decommissioning

Taking away anchors may have a positive effect as this will allow a recovery of these occupation areas.

Moreover, the absence of WECs would allow coastal incidence of average height waves, consequently the intertidal fringe would also recover its normal width.

7.6.5 Impacts on Ichthyofauna

7.6.5.1 Commissioning

Moorings, fixed prototypes to the bottom, dikes, docks and similar devices may cause noise and vibration, which generally scares away fish communities dwelling in this area. According to Gill (2005), noise up to 260 dB may cause hearing damage to some species in a radius of 100m.

According to this study, the impact on water quality and benthic communities during the commissioning stage will occur at a short-term; therefore, fish nurturing resources will not be significantly altered. Fish usually avoid very noisy or turbid areas, which are two factors with harmful consequences on them. Even at a short distance of 25-50 m there is no relevant problem (Mauvais *et al.*, 1991). According to this author, the quantity of solids in suspension may affect fish if it is above 500 mg.l^{-1}, and morbidity is found for 15 days with values of 6 g.l^{-1}. Higher values may cause brachial collapse in juvenile fish.

However, Dong and Vatenfall (2006) report that negative effects on species like *Hyperoplus*, *Gymnammodytes* and *Ammodytes* can be serious, as they are highly sensitive to habitat alteration, especially to changes in silt and fine sand composition.

Furthermore, Boehlert *et al.* (2008) point out that both in the commissioning and operation stage, WECs located near the coast will cause changes in the physical structures of benthic and pelagic systems.

7.6.5.2 Operation

Generally speaking, any artefact located in the sea may cause an attraction effect on fish communities, especially if it is floating. Similar effects have been observed by Morrisey *et al.* (2006) in relation to floating structures for aquaculture (fish cages, mussel mesh, etc.). Such attraction can favour changes in species composition in the study area and alter the relation predator-prey (Boehlert, 2008). However, noise and vibrations from the devices' operation could compensate this attraction effect.

On the other hand, closing down a fishing area can have a beneficial effect on certain species, which may increase their presence, creating a similar effect to a marine reservation. Thus, an increase in species such as *Epinephelus marginatus*, *Serranus cabrilla, Diplodus sargas, parapercis colias and Pagrus auratus* has been described in areas declared protected marine spaces (Reñones *et al.*, 1999; Davidson, 2001; Willis *et al.*, 2003; Claudet *et al.*, 2006). Nevertheless, the environmental surveillance plan carried out in the marine wind power park in Horns Rev in 2004 and Nysted Wind Farm in 2001 (both located in Denmark) showed that the potential effect of artificial reef was irrelevant (DEA, 2006). In any case, this potential positive effect shall be checked by means of a proper monitoring along the life of the installation (Michel *et al.*, 2007).

Finally, the installation of WECs in ecological corridors (migration routes of species) between coastal areas and the continental platform may directly affect some species in some cases, specific stages in the life cycle (Elasmobranchii, Salmonidae, etc.), leading to behavioural changes.

Even though the effect of waves' attenuation and current remains unknown, it is supposed that both the electricity transmission system, WECs and ancillary cables may cause effects to some extent (Boehlert, 2008).

7.6.5.2 Decommissioning

The impact on fish communities during the decommissioning stage is similar to the one described for the commissioning stage. In this stage, noise and vibration disturbance may reach a level of 178 dB, which can affect hearing systems of some fish around an area of 100 m (Gill, 2005). According to Boehlert (2008), potential affections generated by mooring dismantling and the infrastructure of electricity transmission can be relevant for most of species.

7.6.6 Impacts on Seabirds

7.6.6.1 Commissioning

During the construction stage, disturbance associated to noise, vibration, navigation, etc., may scare away marine bird communities. As it was mentioned regarding ichthyofauna, this effect on seabirds can be considered minimum, negative and recoverable once installation works finish. These species have got a great capability to avoid areas of major affection. In any case, nearby presence or absence of nesting birds including species of special conservation interest shall be taken into account when assessing such impacts.

Regarding fixed structures on the coast or anchored to the bottom, a possible destruction of the associated habitat must be taken into account, especially if this is a nurturing or growing area for marine birds.

7.6.6.2 Operation

In principle, no significant impact is expected in the operation stage except for some disturbance caused by noise, vibrations and lighting of the marking system of WECs. This effect may be especially disturbing during the nesting season in case there were nearby nesting birds to the infrastructure.

On the other hand, closing down an area to fishing may have a beneficial effect on marine birds given that this would lead to a higher abundance of fish. However, this is difficult to assess.

7.6.6.3 Decommissioning

Impact on marine birds communities during the decommissioning stage is similar to the one described during the commissioning stage.

7.6.7 Impacts on Marine Mammals

7.6.7.1 Commissioning

Effects on marine mammals during the commissioning stage of the structures derives from noise and vibration during mooring and installation of fixed WECs to the bottom, breakwaters, walls, dikes, etc. Both noise and vibration cause a behavioural change in cetaceans (Dong-Energy y Vattenfall-A/S, 2006; Halcrow_Group_Ltd, 2006), and even a decrease on availability of food causing cetaceans to emigrate to other areas (Dong-Energy y Vattenfall-A/S, 2006).

Noise level varies according to the structure to be anchored, the site's geology and bathymetry (Gill *et al.*, 2005). The anchor diameter and geology relate to the necessary energy to fix the anchor point, while geology and bathymetry relate to the generation and propagation of sound. In the example of piles for wind power in open sea, their affection can generate behavioural changes in a radius of 1 km from the installation area (Halcrow_Group_Ltd, 2006). According to Nedwell *et al*. (2007), the anchoring process such as anchoring pillars may generate an average noise volume of 250dB.

On the other hand, Nedwell *et al*. (2007) established a limit of 90 dB, from which a behaviour of escape from the generated noise occurs, in such a way that an exposition to this limit for 8 hours or going beyond a punctual limit of 130 dB may cause permanent damage to species of acoustic sensitivity. According to the aforementioned authors, and taking into account the aforementioned limits, a porpoise could be located at 250 m of the installations without any damage. Taking into account the spacing capacity of marine mammals, they would have to be located a hundred meters away from the acoustic source to experience damage due to the noise generated by the installation. According to Madsen *et al*. (2006), such effect might be relevant for any species nearby the installation area at a short-term, but the effects disappear once construction activities finish (Carstensen *et al.*, 2006).

In any case, we must mention that installations of this kind of mooring exceed the damage limit of 130 dB, which can be used as reference level marking a precaution area after which irreparable damage can be caused. This area, according to Nedwell *et al*. (2007) can be around 400 m. And the escape or avoidance area marked with a limit of 90dB can be around 1 km.

Likewise, the presence of vessels to execute installation works will also involve noise and disturbance that may scare away marine mammals dwelling in or passing by this area.

7.6.7.2 Operation

Table 10. Noise sources and their intensity. By Michel *et al*. (2007).

Source/Activity	dB
Hearing threshold	0
Background noise in a rural environment	20-40
Room in silence	35
Wind Farm 350 m away	35-45
Car driving at 64 km·h-1 100 m away	55
Office	60
Truck at 50 km·h-1 100 m away	65
Pneumatic Drilling 7m away	95
Plane Turbine 250 m away	105
Hearing damage threshold	140

During the operation stage, noise and vibration coming from WECs may either scare away or attract cetaceans.

However, the level of noise is likely to be remarkably less than during commissioning, and therefore, no significant impact is expected on marine mammals. According to AWATEA (2008), it is highly unlikely that WECs can generate noises louder than the environment's itself. Madsen *et al*. (2006) determined, after studying marine wind power farms, that the generated noise level depends to a great extent on the type and method of installation. Propagation levels remain unknown, but the total noise produced according to Madsen *et al*. (2006) is likely to be less than the noise of a cruising ship, and it is highly unlikely to exceed the environment noise in area of great currents. In any case, due to the initial state of development of these devices, there are no studies determining the noise level generated by this technology (Halcrow_Group_Ltd, 2006; Boehlert, 2008). As a comparison, Table 10 shows noise intensity generated by different sources, amongst which wind farms have been included.

On the other hand, fish gathering around the structures may indirectly favour marine mammals gathering around the structure looking for food.

7.6.7.3 Decommissioning

Impact during tasks to put down the structure would be similar, and yet of a less magnitude, to what was described for the commissioning stage.

7.6.8 Impacts on Fishing

Consequence for fishing is similar in all three stages of the project (commissioning, operation and decommissioning) and mainly derives from the fact that fishing activities compete for a same space in the sea.

Besides, sea energy harnessing equipment, such as WECs, establishes a peripheral security area of a variable size according to the dimensions of the installation. Considering wave energy devices, these security areas are higher than any other kind of technologies such as wind power, due to their inherent danger for navigation and fishing of mooring and ancillary ends, and also the devices themselves and their movement. Thus, the project Wave Hub (Halcrow_Group_Ltd, 2006) in England and *bimep* in Spain (Bald *et al.*, 2008) determined an area of 500 m around the installations as a security area. In the example of the project Wave Hub, the impact on fishing was considered negative with a moderate character (Halcrow_Group_Ltd, 2006), while in the case of *bimep* it was also regarded as negative but with a severe character (Bald *et al.*, 2008).

Likewise, submarine cable associated to the installation may involve a risk to dredging arts due to the possibility of getting caught especially in those areas where the cable could not be buried. This problem may lead to establishing a further security area around the cables' trajectory. The state of Oregon, USA, for example, has agreed with fishermen to develop their dredging arts in accordance with a set procedure to avoid getting trapped around cables (www.ofcc.com/procedures.htm). Likewise, a voluntary loss of the dredging net as a measure to avoid damaging the cable is economically cleared.

An assessment of the present impact should be done taking into account the capture volume, number and typology of vessels and degree of use of the area for the future installation (Michel *et al.*, 2007). Regarding leisure fishing, information concerning captures is very difficult to obtain as there are usually no registers. Regarding commercial fishing, the declaration of the activity in the future installation area is usually overestimated with the aim of getting a better economical clearance from the developer of the project.

That is why Michel and Dunagan (2007) highlight the importance of developing a previous identification of the possible conflicts with the environment's users, involving them at an early stage of the development and planning stages of the project. In this respect, Galparsoro *et al*. (2008) developed a methodological proposal to identify suitable areas to site WECs taking into account not only resource availability, but also the possible conflict with other uses of the environment.

7.6.9 Impacts on Underwater Archaeological Resources

7.6.9.1 Commissioning

The installation of structures may have a direct effect on underwater archaeological resources as a consequence of the mechanical action of anchors, weights, pillars, etc. As this is a non renewable resource, its affection is relevant and permanent.

7.6.9.2 Operation

The main affection during the operation stage derives from dragging of anchors from floating artefacts during severe storms that may affect underwater archaeological objects in a similar way as aforementioned.

7.6.9.3 Decommissioning

Remarks during this stage are the same to the commissioning stage.

7.6.10 Impacts on Landscape

7.6.10.1 Commissioning

The effects on landscape during the commissioning stage are mainly caused by the presence of floating structures, machinery and land equipment for fixed structures in the area of future occupation of the infrastructure

In order to assess the effects on marine landscape during the commissioning stage of floating structures, it is necessary to know their installation plan and to identify actions that may affect landscape units such as: length and period of time (season of the year) of the commissioning stage, location of working areas, dimension of the vessel involved in the works, people transit, dimensions of the floating structure and distance to coast of the operations.

Once these details are known, the potential effects on marine landscape during the commissioning stage can be described and identified. These effects may involve landscape as a totality and visual field. Thus, in order to predict effects on landscape during the commissioning stage, the following points are required:

a. Knowing the possible visual range of the operations. Visibility from land is usually affected by topography, vegetal cover and artificial constructions or elements. In order to define this range, a Digital Terrain Model (DTM) is commonly used and a spatial analysis software to estimate the potential Zone of Visual Influence (ZVI). Once the potential ZVI is obtained, the guide DTI (2005) recommends following these stages:
   - Stage 1: identifying visual receivers (also known as users of that environment).
   - Stage 2: identifying visual receivers within the ZVI.
   - Stage 3: selecting a representative range of observation points.
   - Stage 4: field work to locate and describe representative observation points.
   - Stage 5: Visibility analysis.
   - Stage 6: Photography from representative observation points.
   - Stage 7: Edition of Photoshop previews.
   - Stage 8: Virtual reality and video previews.
b. Carrying out simulations of the project's views from the observers' concentration points.

Once possible impacts have been identified, the magnitude of the change shall be assessed, both in landscape units and observers' concentration points. The magnitude of the visual effect can be classified as: very big, big, medium, small, very small and insignificant.

Main criteria to determine the effects' significance on the total and visual landscape are: the **receiver's fragility** (both from the landscape and visual point of view) and the **magnitude of the change**. The degree of significance is achieved through the correlation matrix between these two criteria (DTI, 2005).

7.6.10.2 Operation

During the operation stage, the impact on landscape derives from the presence of the structures themselves (both infrastructures of floating devices and marking buoys necessary in fixed structures).

In order to assess the impact on landscape during this stage, it is essential to know colours and dimensions of all infrastructures, both floating and fixed: apart from their spatial distribution. This information is spatially superposed on the ZVI to do a visibility analysis, and afterwards, to take pictures from the visual observation points potentially affected. Photoshop superposition of the design of floating structures on the sea surface is made on these pictures.

Regarding this impact it is important to mention that most of WECs are located at water surface level, therefore their visual impact is expected to be minimal. An exception is those prototypes made by multiple buoy bodies on platforms, which can get to 13 m above sea level. Studies carried out by Halcrow_Group_Ltd (2006) in relation to a device of these characteristics showed that 15 km away, the impact on landscape is minimum.

On the other hand, marking systems (buoys, lights, radar reflectors, etc.) must be added to WECs, which must be installed for navigation safety purposes to be seen one mile away.

7.6.10.3 Decommissioning

The process to identify potential effects on landscape during the decommissioning stage is very similar to the commissioning stage.

7.6.11 Impacts on socioeconomy

Once the area is selected for the installation, a socioeconomic impact analysis is required taking into account the economic activity of the environment and the industrial exploitation characteristics to install the system:

a. Attraction effect over other activities.
b. Strategic importance for the region's economy.
c. Predicted economic performance.
d. Direct and indirect employment generated.
e. Positive/negative impact on other activities.
f. Social impact: acceptability/refusal levels from different social groups and related safe and healthy issues.

Thus, socioeconomic effects of the project can be similar at all three stages (commissioning, operation and decommissioning).

At a regional scale, the project's economic impulse in the installation area can be summarized as follows:

- Significant investment in the infrastructure's construction.
- Creation of direct and indirect activity.
- Creation of a number of direct and indirect employments.
- Hotel and catering industry: possibility of local business increase.

A comparison about the predicted socioeconomic impact is the demonstration technological infrastructure Wave Hub in England (www.wavehub.com) which is going to be built in Cornwall, United Kingdom, and was estimated like this:

- 100 new direct posts.
- 730 M€ outcome in the next 25 years, and 430 M€ staying in the region.
- Creation of 1800 indirect employments in the United Kingdom in 25 years, and 1000 in the region.
- Generation of energy to supply 7500 homes.

On the other hand, the aforementioned project *bimep*, similar to Wave Hub, rendered the following figures:

- 15 M€ approximate investment in the construction of the infrastructure.
- 5 M€ annual results from direct and indirect activity.
- Creation of a research centre with more than 25 permanent researchers and able to have 15 people more coming from company with testing equipment.
- Creation of 200 new direct and indirect employments in 4 years time.

At a local scale, the socioeconomic effect occurs in an indirect way as a consequence of the need of hiring personnel and vessels for the installation, maintenance and decommissioning of the structures. Likewise, small vessel repairing workshops and nautical material suppliers, divers and tugs are likely to have an increase in their activities.

It is important to highlight that the installed equipment will inject the generated energy into the electricity network, and will consequently supply a certain number of homes.

7.6.12 Impacts on Environmental Protection

Both the construction and exploitation or operation stages are likely to affect some habitats or species of interest for preservation included in any of the protection lists described in section 6.4.

7.7 The Cable

7.7.1 Impacts on Hydrodynamics

7.7.1.1 Commissioning

During the commissioning stage, no impact caused by the submarine cable is expected on the current regime or swell in the project's area.

7.7.1.2 Operation

During the operation stage a decrease in the current regime is expected within the inner area of occupation of the infrastructure as a consequence of the physical barrier built by the umbilical cable connecting to the WECs. In any case, taking into account the total resistance surface which a submarine cable may involve, this impact is regarded as minimum.

If the main cable does not run underground, the current and flow interaction with the cable may cause a modification in the current and swell regime close to the bottom and surrounding the obstacle depending on the cable's section; consequently, a variation in natural sedimentation rates may occur. All in all, the impact can be regarded as minimum. For an eventual assessment of the impact of the cable in dynamics, the use of tools described for fixed installations in section 6.1 is recommended.

7.7.1.3 Decommissioning

During the decommissioning stage, impacts on hydrodynamics are similar to the commissioning stage.

7.7.2 Impacts on Water Quality

7.7.2.1 Commissioning

The installation of a submarine cable may require the use of different techniques which are able to re-suspend the sediment in the water column, with a subsequent impact on optical properties causing loss of transparency and increase in turbidity. In both cases, not only quantity, but also quality, of materials in suspension, affect those parameters.

Installation work of the cable in Nysted Offshore Wind in Denmark determined an average concentration during trenching tasks, and a concentration of 14 $mg \cdot l^{-1}$ and 2 $mg \cdot l^{-1}$ during jetting. Peak values were reached at 75 and 18 $mg \cdot l^{-1}$ respectively.

As it has been mentioned before, apart from the direct effect on optical properties of water with a subsequent quality reduction caused by concentrations of material in suspension, other indirect effects can be named relating to a decrease in water transparency. The most important concerns the decrease in capacity to develop phytoplankton due to a severe limitation of available light for photosynthesis processes.

In any case, the impact is considered to be limited in time and extension, ranging from 20 and 200 m to each side of the cable depending on the type of sediment and hydrodynamic characteristics of the area.

On the other hand, polluted sediments turnover during the cable installation may release related pollutants, mainly heavy metals and hydrocarbons. Therefore, previous analysis is advised in case the cable's trajectory is suspected to cross a polluted sediment area. In this respect, there are several methodological references on relevant essays in order to assess the toxicity degree of sediments, amongst which we name the work by Del Valls *et al*. (2004.), Casado Martínez *et al*. (2006a; 2006b), Borja *et al*. (2008), Garmendia *et al*. (2008), Menchaca *et al*. (2008) and Pérez *et al*. (in press).

Finally, installation tasks of a submarine cable involve using ships and a wide variety of tools and hydraulic equipment. Therefore, there is an associated risk of oil and petrol accidental leakage.

7.7.2.2 Operation

During the operation stage, the main affection may be caused by the umbilical cables connecting WECs to distribution

Figure 40. Submarine cable installation works in the coastal zone from BMH to low water mark.Source:www.ldtravocean.fr.

boxes, associated to a pre-heating caused by the electric power running through them. This heating of the cable may cause water heating; however, this impact is regarded as minimum, taking into account that future installations for floating WECs are expected to be located in exposed marine areas with a good water renovation rate.

7.7.2.2 Decommissioning

Impacts on water quality during the decommissioning stage are similar to the commissioning stage.

7.7.3 Impacts on Sediments

7.7.3.1 Commissioning

Substratum alteration occurs during previous operation to select the route and during the commissioning stage. Such impact is usually restricted to an area of 2-3 m at each side of the cable depending on the installation equipment used. In general, impact from different equipment is similar, especially those which are dragged over the substratum.

Recovery is strongly dependant on the substratum characteristics. Thus, some installation equipment used, such as ploughs, promotes a quicker recovery, as they fill back the trench with re-suspended material immediately after they pass by. Other systems, such as jetting and saws do not allow natural filling-up of the trench with the sediment extracted, consequently, impact is higher and substratum recovery is slower. Some installation techniques require the use of ships with anchoring stabilizers what extends the affected surface of substratum caused by anchors and their dredging movements.

When the trajectory of the cable is expected to be used by trawling fishing, ships moorings, etc., the cable can be protected in various ways, such as installing concrete surfaces covering an area up to 150 m^2 around the route of the cable.

In the intertidal area, impact can be inexistent in case a horizontal perforation from the point of entrance to land up to a certain depth is done. However, an important intertidal alteration may occasionally occur due to trenches digged to bury the cable. An example of how serious the alteration may be is showed in Figure 40.

7.7.3.2 Operation

Some sections of dynamic cable between the WEC and seabed may affect sediments as if they were a dragging element due to their movement induced by the swell. In any case, this impact is regarded as minimum, considering the length of these sections compared to the total length of the cable.

7.7.3.3 Decommissioning

Impacts on water quality during the decommissioning stage are similar to the commissioning stage.

7.7.4 Impacts on Benthos

7.7.4.1 Commissioning

Substratum alteration during the commissioning stage described before may affect related habitats and species.

As it has already been mentioned, the installation of a submarine cable usually requires different techniques to re-suspend sediment in the water column with a subsequent impact on optic properties causing a loss in transparency and increase in turbidity (ENERGI y ELSAM, 2005).

Other effects can be mentioned, apart from the direct effect of concentrations of suspension material on optic properties of the water column with a subsequent decrease in quality. The most important effect relates to the decrease in capacity to develop phytoplankton and seaweed communities due to a severe limitation of available light for photosynthesis processes, especially along the shallower area of the cable's trajectory, where seaweed have got their most relative importance. Apart from the increase in turbidity and the concentration of solids in suspension, such effect reaches benthic macro invertebrate communities, due to the fact that suspension material may saturate trophic structures of filtering animals.

The magnitude and significance of this impact depends on several factors:

- The nature and geology of substratum.
- Benthic communities present along the cable's trajectory (e.g. species, abundance, richness and diversity), and the value of this assemblage in the context of a wider seabed area than the strict area of affection.
- Sensitivity, importance and recoverability of the species or communities directly affected, including any seasonal activity, e.g. spawning and hibernation periods.

In shallow water and estuarine environments, where disturbance is more frequent and opportunistic species are more likely to dominate the community structure, recovery occurs rapidly, as the environment is used to a natural generation of similar impacts to those experienced by cabling; whereas in deeper water undisturbed areas the recovery to a more stable community could take many years.

Rates of recovery for invertebrate communities appear to be related with rates of recovery for characteristics of seabed sediment. Experiments undertaken to record recovery given different intensities of disturbance revealed a total recovery within 64 days for turnover sediment at a depth of 10 cm. However, when sediment was removed to 20 cm depth, recovery occurred within 208 days from the disturbance.

Due to the localised nature of cabling, whereby the area affected is generally restricted to 2-3 m width of substratum, the overall effect on the benthic communities is not likely to be significant if habitat distribution throughout a wider area is homogenous.

In case the cable passed by habitats where communities are not widely distributed or they are particularly sensitive to disturbance and of a special interest, these areas would be avoided. E.g. biogenic reefs comprising of *Sabellaria spinulosa*, the reef building honeycomb worm. They are listed as a priority habitat under the EU Habitats Directive and they are reducedly and precisely distributed. As long as these structures shelters a great diversity of species, their destruction would involve a significant impact.

On the other hand, turnover of polluted sediment during installation of the cable may cause a release of associated pollutants, mainly heavy metals and hydrocarbons which may pass to the trophic chain.

An environmental impact study carried out by Holroyd and Byng (2000) lists possible effects on benthic communities which are likely to be caused by an installation of cable on the seabed:

i. Located and temporal affections on nearby communities to the trench where the cable will be buried;
ii. Located and long-term alterations on benthic communities dwelling along the corridor and minor short-term alterations on surrounding species due to re-suspension and deposition of sediment generated by cutting disks used in the work;
iii. Significant and temporal alterations and located long-term alterations on benthic communities dwelling along the corridor, and minor short-term alterations on surrounding species due to the re-suspension of sediments generated in the ploughing stage. Located, minor and long-term alterations on species dwelling under the cable.

7.7.4.2 Operation

During the operation stage, submarine cable transporting energy may generate electromagnetic fields both in the water column and adjacent sediments, affecting associated benthic communities.

Regarding invertebrate communities, the impact of this activity remains unknown. Nonetheless, species of decapod crustaceans like *Crangon crangon*, isopods like *Idotea baltica* and amphipods like *Talorchestia martensii* and *Talitrus saltator* have been proved to be sensitive to electromagnetic fields (BERR, 2008).

In all cases, magnetic sensitivity is related to the individuals' orientation capability. Depending on the intensity of the electromagnetic field, the impact can be either a temporal and brief disorientation, or a serious impact on migration patterns, to set an example (BERR, 2008).

However, taking into account the located affection area and the mobility of potentially affected species, this impact is not expected to be significant. In this respect, studies carried out by Andrulewicz *et al.* (2003) did not detect any significant impact on zoobenthic communities a year after the installation of a submarine cable.

7.7.4.3 Decommissioning

Removing the installations can have a positive effect as the occupied area can recover naturally. However, during decommissioning tasks similar impacts to the construction stage may occur.

7.7.5 Impacts on Ichthyofauna

7.7.5.1 Commissioning

Affection on ichthyofauna during the commissioning of the cable mainly derives from noise and vibration together with an increase in turbidity caused by the re-suspension of sediments.

The impact of noise and vibration depends to a great extent upon the hearing capacity or sensitivity of the fish species concerned. Three types of fish are distinguished:

1. Sensitive species: these species, including herring and sprat, perceive sounds through the acoustico-lateralis system; a collective term for the inner ear and lateral line. Sound vibrations are also detected by a gas-filled swim bladder which is connected to the inner ear via a gas duct.
2. Mid-range sensitive species, including cod, mackerel and salmon, are also sensitive but to a lower extent due to the lack of a gas duct between the inner ear and the swim bladder.
3. Insensitive species, including flatfish and elasmobranchs, have not got a swim bladder.

Nedwell and Howell (2004) and Nedwell *et al.* (2003) investigated the sources and intensities of sound associated with offshore wind farm construction and the related impact on marine species, and concluded that some fish and mammals will show a strong avoidance reaction to sound levels of 90 dB and above.

Nedwell *et al.* (2003) have reported that cable trenching in sandy gravel produced noise at a source level of 178 dB. However, the reception capacity of studied species related to this noise level was lower than 90 dB. In this situation, significant avoidance reactions amongst fish would not be expected. The environmental surveillance programmes carried out in Horns Rev and Nysted wind farms (both in Denmark) in 2004 showed that no significant effect on the movement of fish stock occured during the commissioning and exploitation stages (DEA, 2006).

In any case, the analysis done by Nedwell *et al*. (2003) only covers one installation method in one type of substratum. Different burial tools in different substrata may produce higher levels of noise and associated impacts, so further information is required.

According to the study carried out by Bio/Consult-as (2001) bottom living fish (e.g. flounder, plaice, dab, turbot, sea scorpions, eelpout, sandeels, gobies, species of the *Hyperoplus*, *Gymnammodytes*, *Ammodytes* and Zoarcidae) have high hearing threshold levels, therefore they are estimated to hardly hear noise frequencies above 250 Hz. On the contrary, their hearing thresholds is estimated to be around 90-110 dB at lower frequencies. Moreover, some degree of habituation of this fish species to noise is plausible, therefore no behavioural change will take place.

Cod, whiting and silver eel (in phase of genetic migration) seem to have hearing thresholds around 75-100 dB at lower frequencies. They are believed to be able to detect noise at a higher frequency. Low sound frequencies from pile-driving could elicit some avoidance. This reaction would be more plausible at short distances (less than 30 meter) from the sound source.

Herring and sprat (brisling), show low hearing threshold levels and a broad hearing bandwidth (50-75 dB at 200-

3000Hz), which is probably reflected in the avoidance threshold. Some studies have provided evidence, that hearing ability can be regenerated after damage in these species.

Increased turbidity through sediment re-suspension can create a number of adverse effects:

- Decrease in hatching success of the eggs, which depends on the life cycle of the species and the season when the commissioning stage will start (Bio/consult-as, 2000).
- Decrease in low trophic levels fish, consequently the presence of superior predators will also decrease (Bio/consult-as, 2000).
- Increase in the vulnerability of flatfish fry that have recently settled on the bottom (they have a smaller swimming capacity than the adults) (Bio/consult-as, 2000).

7.7.5.2 Operation

The impact of the cable on ichthyofauna during the operation stage derives from the electromagnetic field which the cable may generate.

A magnetic field generated by a unipolar cable (B) is defined as the force acting per unit length on a wire carrying unit current (I). Thus, the magnetic flux density around a very long, straight wire can be calculated as follows:

$$B = \frac{\mu_o I}{2\pi a}$$

where,
B = magnetic flux density. Units: Tesla (T)
μ_0 = permeability of a vacuum $4\pi 10^{-7}$ Hm^{-1}
I = current carried by the wire. Units: Amperes (A).
a: perpendicular distance with from the wire to the point were the flux is being evaluated. Units: metres (m).

Thus, the value of density of the magnetic flow generated by a given cable in the environment depends on the value of electric current, as so far as the magnetic intensity increases with the electric current. Likewise, the intensity of the magnetic field decreases with increasing distance from the wire.

Electric currents of 850-1,600 A are common in submarine cables. At such current, a magnetic field of approximately 3.2 mT is generated, decreasing to 0.32 mT at 1 m distance, 0.11 mT at 4 m and similar values to terrestrial magnetic fields (0.05 mT) at a distance higher than 6 m (Bochert y Zettler, 2006). A standard submarine cable carrying 132 kV and altern current of 350 A generates a magnetic field of $1.6 \cdot 10^{-3}$ mT (AWATEA, 2008). Cables carrying continuous current around 10-15 kV from a device are not able to generate a magnetic field beyond some centimetres with respect to the cable surface (AWATEA, 2008).

According to a bibliographic revision made by Forward (2005), affected species of electromagnetic fields are, amongst other, petromizontiforms (lampreys), elasmobranchii, ascipenseriforms (sturions), siluriforms, gymnotiforms (silver eels). All of them have got receivers in their body which can detect AC/DC low frequency signals.

According to Gill *et al*. (2005) and Halcrow Group Ltd. (2006), electromagnetic fields associated to the cable affect mainly elasmobranchii (sharks and rays) as they alter this species' sensitivity to electromagnetic microfields generated by their possible preys and consequently alter their feeding capability. These authors also report that this species is attracted or repelled depending on the intensity of the electromagnetic field. Boehlert *et al*. (2008) estimate that behavioural changes in species can be serious and primarily associated to alterations in orientation and navigation, habitats alteration and fish escape.

Therefore, two possible effects are expected: (i) species of elasmobranchii dwelling in the area where the cable has been laid may experience an alteration or interruption of their feeding behaviour; (ii) an attraction to the cable and artificial gathering of individuals.

Some species of sharks show a response to magnetic fields around $2.5 \cdot 10^{-5}$ and 0.1 mT. Westerberg and Lagenfelt (2008) have recently reported the European eel (*Anguilla anguilla*) is able to detect the electromagnetic field of a non-buried 3-phase cable of 130 kV.

Elasmobranchii are attracted by electric fields generated by a continuous current between 0,005 and 1 μV cm^{-1} and they are repelled by electric fields of approximately 10 μV cm^{-1} and higher. However, no data is available about fish (in general) reacting to electric fields generated by alternating current (Gill, 2005).

Studies developed in *Thener Offshore Wind Farm* by the English environmental agency proved that the impact of electromagnetic fields on elasmobranchii populations was insignificant (English-Nature, 2006).

An environmental study by Andrulewicz *et al*. (2003) on the possible effects caused by the commissioning and operation of a high voltage line in continuous current between Polland and Sweden (along the Baltic sea) concludes that migrating fish around the cable may be altered by the magnetic field generated; such alteration ceases at a distance equal or higher than 20 m.

7.7.5.3 Decommissioning

The impact on ichthyofauna during the decommissioning stage is similar to the commissioning stage.

7.7.6 Impacts on Seabirds

7.7.6.1 Commissioning

The impact on seabirds during the installation of the cable is similar to the commissioning of the structures (see section 7.6.6).

7.7.6.2 Operation

During this stage no impact on seabirds is expected as the cable will be immersed.

7.7.6.3 Decommissioning

The impact on seabirds during the decommissioning of the cable is similar to the decommissioning of the structures (see section 7.6.6).

7.7.7 Impacts on Marine Mammals

7.7.7.1 Commissioning

Potential impacts during the installation of the cable on marine mammal communities are:

1. Collision into any of the vessels involved in the installation.
2. Disturbance associated to noise and physical presence of ships laying the cable.
3. Contact with any product dumped during the commissioning stage.
4. Interaction or entanglement with the cable or mooring during the commissioning stage.

According to Laist *et al*. (2001), there is a relationship between traffic intensity, ships' speed and the number and magnitude of collisions into marine mammals. However, there is a series of assumptions that must be pointed out:

a. Any kind of vessel of any size might collide into a marine mammal.
b. Vessels longer than 80 m may cause impacts with more severe consequences, even lethal injuries.
c. When the vessel's speed is slower than 10 knots, severe or lethal affections are rarely caused in case of collision.
d. Mammals colliding into vessels are rarely seen before collision.
e. The collision risk is higher under low visibility conditions.

The risk of collision into the ship installing the cable is very unlikely due to the low speed at which it navigates during installation of the cable together with the noise and vibration associated which is likely to repel marine mammals.

Marine mammals may be disturbed by the presence of cable laying vessels, ROVs, plough, etc., particularly in sensitive locations such as feeding and breeding areas. Such disturbance, during sensitive periods (such as the breeding), may lead to significant impacts as the abandonment of the brood (BERR, 2008).

Regarding noise as it happens with fish (see section 7.7.5), available information proves plausible affections above the level of 90 dB, considering as scarcely probable that the installation of a cable may generate noise above such level.

According to Boehlert *et al*. (2008), during the installation of cables, the electricity transmission system and navigation may considerably affect porpoise, beaked whales and some rorquals, while other species such as sperm whales, orcas and dolphins are not significantly affected.

7.7.7.2 Operation

Moored cables and those associated to the whole structure can generate an invisible wall or curtain for cetaceans, causing entanglement injuries and crashing. The "wall" of cables will depend on the quantity and space between cables and the distance between the structure and seabed. A space between cables between 50 and 100 m is recommended. On the other hand, it must be taken into account that tense cables are less dangerous (they cause less entanglement) than loose ones; and, according to depth they are located at, vertical cables are less dangerous than horizontal (Boehlert, 2008).

A further possible effect on marine mammals during the operation stage stems from the generation of magnetic fields from the cable. Thus, Gill *et al*. (2005) report amongst other species, the common bottlenose dolphin (*Tursiops truncatus*) is a sensitive species to such magnetic fields.

Therefore, according to Gill *et al*. (2005), a cable of 33 kV generates a magnetic field in the cable surface of 1.5 μTesla, what is clearly below to the terrestrial geomagnetic field of 50μTesla, therefore no significant impact is expected.

Boehlert *et al.* (2008), report a significant effect of cables and electric transmission systems on beaked whales and some rorquals during the operation stage.

In any case, the impact of electromagnetic fields is a controversial and uncertain issue, being necessary, as OWE (2008) also mentions, carrying out further studies and research.

7.7.7.3 Decommissioning

Environmental impacts on marine mammals during the decommissioning stage are similar to the commissioning stage.

7.7.8 Impacts on Fishing

7.7.8.1 Commissioning

Effects on fishing are caused by: (i) restricted navigation during the commissioning stage, (ii) temporal fish stock displacement.

For obvious safety reasons, a security area is enclosed around the vessels involved in the installation of the submarine cable and access is prohibited to any other ship unless related to the work itself.

This may involve a restricted access to certain fishing grounds for rather short periods of time. During these periods, ships fishing in such area will be forced to develop their activity in other areas.

Taking into account this is a short-term effect, its associated impact is regarded as minimum. E.g., the installation of two cables of 7.5 km between North Hoyle Wind Farm in UK and the coastline was carried out in 4 or 5 days.

Regarding the displacement of fish stock, remarks made in section 7.7.5 would apply.

7.7.8.2 Operation

A possible consequence that may negatively affect fishing vessels is snagging either of fishing arts or moorings from the vessel.

Snagging can occur where stretches of cable are exposed, due to depth or any other reason, they have not been yet buried and they are lying on the seabed.

The recovery of snagged gear is not recommended as this can lift the cable clear of the seabed and expose a longer strecht of cable. Fishing operations will be compensated by cable operators providing that fishermen were not operating within restricted fishing zones.

7.7.8.2 Decommissioning

Impact on fishing during decommissioning stage is similar to the commissioning stage.

7.7.9 Effects on Landscape

7.7.9.1 Commissioning

The impact assessment on landscape during the installation of the submarine cabling system is very similar to the commissioning of both floating and fixed structures (see section 7.6.10).

7.7.9.2 Operation

During the operation stage, no effects on landscape are expected due to the fact that the cabling system for electricity evacuation is immersed and buried in the seabed, unless the cabling system counts on a transforming station or energy receptor which is visible from any concentration point of observers. In such case, the location and design of this station needs to be described to be included in the visibility analysis in order to assess their impact on marine landscape.

7.7.9.3 Decommissioning

The impact assessment on landscape during the decommissioning stage of the submarine cabling system is very similar to the commissioning of both floating and fixed structures (see section 7.6.10).

7.7.10 Impacts on Underwater Archaeological Resources

7.7.10.1 Commissioning

The installation of the cable may cause a direct effect on archaeological resources as a consequence of the machinery activity necessary to bury the cable.

During the installation, sediments are not dredged, but rather displaced to left and right sides of the trench where the cable will be placed. This is a precious opportunity to visualize the presence of any archaeological remain of interest. Consequently, tools incorporating cutting saws for hard substratum have a greater impact compared to jetting machinery.

A change in the sedimentation pattern and sedimentary transport may indirectly lead to significant impacts on archaeological remains as they can be exposed or buried. In any case, the effect of such impact depends on the specific hydrodynamics of the area.

7.7.10.2 Operation

During the operation stage no significant impact is expected. In any case, dynamic and umbilical cables may have some friction with seabed at this stage, and connection and re-connection maintenance tasks may expose or damage undetected archaeological remains.

7.7.10.3 Decommissioning

In case installed cables are recovered, sediment turnover, dredging of the cables, mooring of support vessels, etc., may cause a direct affection on uncatalogued submarine archaeological remains.

7.7.11 Impacts on Socioeconomy

The present impact assessment is similar to what is described in section 7.6.11.

7.7.12 Impacts on Environmental Protection

Both during the construction stage and the exploitation or operation, some habitats or species of interest for conservation included in 6.4 section may be affected.

8. Impact hierarchy

Environmental regulations specify that an impact hierarchy must be done determining their relative importance. There is no particular methodology to do this, so a proposal for a quantitative impact hierarchy commonly used by AZTI-Tecnalia is described below.

Firstly, a value is given to the impact of each action in the project for all environmental aspects (physical, biological and socioeconomic) according to the following classification based upon the characteristics described in section 7.1:

- Compatible (1): impact from 0 to 25%
- Moderate (2): impact from 26 to 50%
- Severe (3): impact from 51 to 75%
- Critical (4): impact from 76 to 100%

Afterwards, a Leopold matrix is built up where such value is given to each activity causing an impact in relation to the affected environmental aspect (from 1 to 4 according to the previous classification).

Table 11 shows an example referring to the work developed by Bald *et al*. (2008), of the environmental impact of the infrastructure Biscay Marine Energy Platform (*bimep*) for the trial and demonstration of WECs in the littoral of the Basque Country (Spain).

From this point, the global percentage of impact is calculated for each activity and factor as it is described now. If there are 3 activities affecting an environmental factor, the maximum negative value which can be obtained would be 4 (critical) x 3 = 12. If the addition is 8 (a critical 4, a severe 3 and a compatible 1), the impact percentage would be 67 % (severe according to the previous description). Therefore the impact caused by each activity and suffered by each environmental factor and factor group can be calculated.

The impact caused by each activity and suffered by each environmental factor and factor group can be calculated in such a way, that the hierarchy can be done by impact activities (from the most to the least) and affected environments (from the most affected to the least affected), by factor groups (physical-chemical, biological, socioeconomic and cultural and ecologic relationships), by stages (construction and exploitation) and in a global way for the project (Solaun *et al.*, 2003).

According to the previous example, **by activities**, the impact hierarchy of the *bimep* project according to Bald *et al*. (2008) would be the following:

- **Structures**: generate 45.8 % of (moderate) impact, especially during the operation stage (50 %) as 4 of the 11 possible environmental factors are highly present.

Table 11. Activities generating impact and environmental factors affected. Each impact is assessed as significant, insignificant and unrelated. Values are given accordingly: 1: compatible, 2: moderate, 3: severe, 4: critical: does not apply. Key: a = Commissioning stage; b = Operation or exploitation stage and; c = Decommissioning stage. By Bald *et al.* (2008).

Red	Really Significant Impact
Green	Significant Impact
Yellow	Insignificant Impact
White	Unrelated

AFFECTED ENVIRONMENTAL FACTORS	ACTIVITIES GENERATING IMPACT												IMPACT (%)
	Structures			Submarine Cable			BMH			Electricity Cabling			
	a	b	c	a	b	c	a	b	c	a	b	c	
WATER COLUMN													25
Water quality	1	1	1	1	1	1							25
Hydrodynamics	1	1	1	1	1	1							25
SEDIMENTS													33.3
Sediments	1	3	1	1	1	1							33.3
BIOLOGICAL FACTORS													54.3
Changes in Benthos	2	3	2	2	2	2							54.1
Ichthyofauna	2	2	2	2	2	2							50
Marine Mammals	3	2	2	3	2	3							62.5
Seabirds	2	2	2	2		2							50
HUMAN FACTORS													43.5
Landscape	1	1	1	1		1	1	1	1	1	1	1	25
Fishing	3	3	3	1		1							50
Socio-Economy	+	+	+	+	+	+	+	+	+	3	3	2	66,6
Underwater Archaeological Resources					1	1							25
Environmental Protection	2	2	2	3	3	3							62,5
IMPACT (PERCENTAGE)	**45,0**	**50,0**	**42,5**	**45,4**	**44,4**	**43,7**	**25**	**25**	**25**	**50**	**50**	**37,5**	
	45,8			**44,5**			**25**			**45,8**			

Their impact assessment is moderate.

- **Electricity Cabling**: generates 45.8 % of (moderate) impact as it strongly affects socioeconomy.
- **Submarine Cable**: this activity generates 44.5 % of impact, especially during the commissioning and decommissioning stages, what can be regarded as moderate.
- **BMH**: generates 25 % of impact that can be regarded as compatible.

By ***environmental factors***, the impact hierarchy would be the following (Bald *et al.*, 2008):

- **Biological Factors:** they are affected at 54.3 % (severe), as structures and underwater cables impact them strongly, especially marine mammals and benthic communities.

- **Human Factors:** they are affected at 43.5 % (moderate), mainly associated to the impact on fishing in the occupation area of the infrastructure *bimep*; environmental protection and socioeconomy are affected as a consequence of land rights on private properties where the electricity cabling locates.
- **Sediments:** they are affected at 33.3 % (moderate), as they are only impacted by structures during the operation stage.

9. Proposal for protection, amendment or compensation measures

9.1 Introduction

According to the impacts which have been identified and assessed by the relevant EIS, specific protection and amendment measures shall be foreseen or proposed, that is, modifications or additions made for the project in order to:

- Avoid, decrease, modify or compensate the most significant negative effects of the project on the environment.
- Make the most of the opportunities the environment offers to achieve a more successful project.

According to Solaun *et al*. (2003), measures to be taken into account will depend on the conditions of the area it will be located and the characteristics of the project. Then, a classification of protective and amendment measures according to their character is shown:

- *Protective*: they avoid the impact modifying some key factors of the project like its location, design, materials in use, etc.
- *Mitigating*: they focus on the deletion, reduction or modification of a given effect through procedures like antipollution, depuration or generic devices of environmental protection.
- *Compensatory*: they refer to unavoidable impacts that cannot be possibly mitigated, but they may be compensated by means of other positive effects (for example: economically compensate people affected by the project, carry out a restoration of an affected area, etc.).

A further aspect to be considered about these measures is the temporal range of their application, as it is important to carry them out as soon as possible to avoid secondary impacts (Solaun *et al.*, 2003).

It is important to highlight that it is always better not to cause any impact than establishing a protective measure to amend it. This is due to the fact that, apart from the time and money investment, in most of the cases, only part of the alteration is deleted and, sometimes, nothing at all (Solaun *et al.*, 2003). Besides, the application of a measure of this typology may introduce new impact elements (Gómez-Orea, 1992).

Amongst others, the following corrective/compensatory measures can be identified:

- Selecting a site.
- Compensations to the fishing industry.
- Commissioning and decommisioning of structures.
- Installation and dismantling of submarine cable.
- Maintenance of WECs.
- Contingency plan development.

9.2 Selecting a Site

Selecting the most convenient areas for the commissioning of WECs requires a marine spatial planning with the aim of optimising the rights of management on marine spaces and keep a sustainable ecosystem management of the oceans and seas (Gill, 2005; Maes, 2008). This type of analysis must take into account a number of factors which may be classified in general terms as technical, environmental and socioeconomic (Johnstone *et al.*, 2006; Nobre *et al.*, In press). Moreover, involved users from all sectors and their opinions, information and remarks must be taken into account in order to find a consensus on the most appropriate use of each zone in the sea. A premise of this planification tool is that these sectors take part in the process, what should lead to develop procedures to solve conflict in a simple way on the use of the space taking into account and prioritising environmental peculiarities in the area of interest.

Thus, an adequate previous planification trying to avoid competence with other uses of the littoral, protected areas, zones of interest for their biological, dynamic or geomorphologic peculiarities is one of the first mitigation measures to be applied in any project dealing with wave energy exploitation.

In this respect, the work developed by Galparsoro *et al*. (2008) made the first step in the development of methodologies for spatial planning and selection of suitable areas for wave energy exploitation taking into account all the criteria aforementioned in a comprehensive way.

Apart from marine spatial planning, it is highly relevant at this stage the Environmental Strategic Assessment coming after *Directive 2001/42/CE of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment*, further transposed to the Spanish national legislation by means of *Law 9/2006, of 28 April, on the effects assessment of certain environmental plans and programs* establishing an environmental assessment system that allows integrating environmental criteria in plans and programmes which may cause significant effects on the environment during their preparation and before their approval or process by a legislative procedure.

Thus, in April 2009, the Environmental Strategic Study of the Spanish Littoral for the Installation of Marine Wind Farms[1] was published, where a map of the whole coast of the Iberian Peninsula was included pointing out exclusion zones for the installation of wind mills (either for environmental or

1. http://www.mityc.es/energia/electricidad/RegimenEspecial/eolicas_marinas/Documents/EEAL_parques_eolicos_marinos_Final.pdf

socioeconomic reasons), suitable zones for this activity and zones which may present limitations or conflict. This is a general study that must be completed for each project in an appropriate level of detail which, by no means, will exempt from the need to submit the project to an EIA if this is stipulated.

9.3 Compensations for the Fishing Industry

With the aim of minimizing the effects on fishing as a consequence of competing for the same space, professional fishermen could be economically indemnified for the damage that can be caused by the infrastructure being sited on important fishing grounds which had been traditionally exploited.

9.4 Installation and Operation of Structures

With the aim of minimizing an acoustic impact of WECs, both during the commissioning and operation stages, it is advisable to have a previous knowledge on the noise levels and frequencies these technologies generate in all different stages of the project, as well as the background noise of the installation area (AWATEA, 2008).

Therefore, amongst the possible measures to minimize this impact on ichthyofauna and marine mammals, the following can be mentioned:

1. An appropriate dimensioning of anchors and machinery needed for their installation in order to prevent the use of excessive energy.
2. Emitting alarm signals to scare away mammals present in the area and keep them at a security distance so that they cannot be affected. Carrying out a progressive installation of structures, starting by low levels of energy and progressively increasing the level.
3. Avoiding any installation work during breeding and hibernation periods of marine mammals along the coastline.
4. During the installation work, an observer must monitor together with the equipment, the presence of marine mammals in the area, in which case works must be stopped until they are surely at a minimum distance of 1 km.

With the aim of being able to apply amendment or mitigating measures associated to the impact of structures on marine dynamics (swell, currents, sediment transport), it is necessary to develop a previous modelling of the possible impact according to the methodologies described in sections 6.1 and 7.6.1. Such modelling should serve to assess the suitability of the selected location according to what is described in the previous point.

With the aim of minimizing the impact on benthic communities, it is recommended:

a. To avoid areas where species of interest for conservation are present, e.g. corals, Maerl Beds, *Posidonia* seaweeds, *etc*.
b. To minimize the use of anchors using vessels with a dynamic positioning system instead of typical ships during the commissioning stage.
c. To dimension properly moorings needed to fix the WECs, trying to design systems that allow their recovery once the activity ceases.

9.5 Installation and Dismantling of the Submarine Cable

With the aim of minimizing the acoustic impact on ichthyofauna and marine mammals when laying the cable, the following measures are suggested:

1. Making a progressive installation, starting with a drill at a low energy level and progressively increase the energy level.
2. Avoiding installation work during breeding a hibernation periods of marine mammal communities on the coastal area.
3. During the installation works, an observer will monitor both equipment and the presence of marine mammals in the area, in which case works must be stopped until they are surely at a minimum distance of 1 km.
4. Making the course and setting of the cable on the sedimentary bed, avoiding, as far as it is possible, bedrocks.

With the aim of minimizing a possible effect of electromagnetic fields created by the cable on the ichthyofauna, marine mammals and benthos, as far as technique and environment allow, it is recommended to appropriately select the course of the cable so that most of the cable can be buried under the seabed.

With the aim of minimizing impact on species or communities of interest for conservation, the course of the cable shall avoid running over areas where these species or communities dwell.

9.6 Maintenance of WECs

Some WECs are designed to do most maintenance operations in open sea. However, a maintenance plan must be defined for the whole life of the installation.

In this stage, it is important to monitor at all times WECs and to define contingency plans dealing with possible failure like loss of data, failure in connectors or cables, emergency affecting navigation security, etc. Some WECs operate pumping high pressure fluids through a hydraulic engine. They involve the hazard of these fluids accidentally pouring into the sea, which must be accounted for.

Some regulations shall be set on the use of oils, which should be biodegradable, and anti-fouling paints must fulfil the regulations of the International Convention on the Control of Harmful Anti-fouling Systems on Ships.

9.7 Hazard Prevention Plan

Law 26/2007, 23 October, on environmental responsibility, incorporates to the Spanish legal system the community directive 2004/35/CE establishing a new legal framework for prevention and amendment of environmental damages, highlighting the operators' responsibility over environmental damage they may cause, and binding them to restore such damage.

Amongst other aspects, this law binds the establishment of a guarantee fund to economically cover environmental damage. Even though no bad faith, guilt or misconduct exists, the development of hazard prevention plans takes into account possible accident in the infrastructure during the construction, operation and abandonment stages.

This plan is commonly known as *Risk Assessment*, and considers two perspectives, human health and ecological integrity of the environment (Solaun *et al.*, 2003).

This recently acquired technique to the process of EIA has got some predecessors in authors such as Barnthouse *et al*. (1986), the North-American Environmental Protection Agency (EPA) (US EPA, 1992,1994) and Parkhurst *et al*., (Parkhurst *et al.*, 1994).

According to Canter and Sadler (1997) the assessment process or risk assessment will comprehend the following steps:

1. **Hazards identification.** This consists in identifying those agents (normally associated to substances) which may cause negative effect on human health or the integrity of the ecosystem both at a biological (i.e., diversity, richness, etc.) and physical level (i.e., landscape characteristics, geology, water quality, soil, etc.). In this case, one of the possible agents would be fluids used in some prototypes of wave energy devices, pollutants' turnover associated to sediment during the installation of the cable, etc.
2. **Analysis of suitable levels.** This consists in analysing. The relationship between the dose of a given agent and the consequent effect on human health and environment. This analysis is usually carried out through epidemiologic and ecotoxicologic studies. At an ecotoxicologic level, the methodological antecedents have been mentioned in section 7.7.2 done by Del Valls *et al*. (2004.), Casado Martínez *et al*. (2006a; 2006b), Borja *et al*. (2008), Garmendia *et al*. (2008), Menchaca *et al*. (2008) and Pérez *et al*. (en prensa).
3. **Study on exposition to the agent.** This consists in estimating intensity, frequency, exposition ways, area and size of the population likely to be affected, etc., as a consequence of the exposition to the identified agent.
4. **Hazard's Characterization.** This consists in characterising the incidence of the effect on human health and the environment under different conditions described in the previous section. In this respect, some authors like Lenwood and Anderson (1999) suggest using a risk quotient based upon the concentration of a given pollutant in relation to its concentration regarded as non toxic.

9.8 Contingency Plan

With the aim of avoiding the impact on water quality as a consequence of a breakage risk of the WECs after severe storms, a contingency plan is advised to be developed containing all responsibilities and tasks to carry out in case such emergency situation occurs. This plan should include all kinds of possible accidents, and it should also deal with the worst possible situation.

According to Solaun *et al*. (2003), contingency plans shall be supported by a special equipment, maintained in good conditions, to guarantee an efficient response, and a detailed account of the procedure to follow must be explained, together with a good supply of products for treatment and trained personnel to cope with the emergency.

Thus, when developing a contingency plan, the following criteria should be born in mind:

- Look into all available resources (including local, regional, national and international groups which can be contacted) and emergency service of the area (fire-fighters, ambulance, etc.)
- Study the best location and deployment for available equipment (fire extinguishers, absorbent materials, etc).
- Identifying the best means of dumping possible polluted materials.
- Defining special equipment and necessary products, and prepare for their acquisition, deployment and maintenance.
- Specific training of personnel.
- Establishing the person in charge and each individual responsibility in case an emergency occurs (individual actions of personnel, emergency personnel and/or management actions, informing local emergency service and authorities).
- Establishing safety regulations.

Therefore, according to Solaun *et al*. (2003), the minimum content of a contingency plan would be the following:

- Objective of the plan.
- Execution mode.
- Extension in time.
- Estimated cost.
- Necessary resources.
- Event triggering the contingency plan.
- People in charge of developing the plan and their responsibilities. The expertise of the contingency team and their part taking in test which can assess the real impact of a potential problem, are key to spot possible deficiency of the plan.

Finally, it must be clear that this plan is not aimed at solving the cause of the problem, but rather assure the continuity of the tasks to be developed.

10. Environmental monitoring program

The Environmental Monitoring Program (EMP) must establish a system that guarantees the fulfilment of mitigating measures proposed in the EIS, together with the efficiency of these measures (Solaun *et al.*, 2003). According to (Solaun *et al.*, 2003) an EMP must have the following functions:

- Check the quantity of impacts which are difficult to predict and articulate new mitigating measures in case the ones applied are not enough.
- Obtaining data to improve future EIA, as predictions can be assessed to be right or wrong.
- Detecting unforeseen alterations, because a surveillance of such alterations, once a reasonable period of time has passed, will allow to do an "exposed" assessment and check to what extent previsions are fulfilled and is necessary to adopt mitigating measures towards the future (Gómez-Orea, 1992).

In this respect, the protection of the environment and natural resources of the areas which might be affected by the construction and operation of the works or installations of the study is guaranteed (Solaun *et al.*, 2003).

According to (Solaun *et al.*, 2003), the basic stages of a monitoring, surveillance and control program are these:

1. **Defining objectives** in such a way that affected systems, types of impact and selected indicators are identified. For the program to be efficient, indicators should be few, easily measurable and representative of the affected system.
2. **Gathering and analysis data**, whose temporal frequency depends on the variable which needs to be monitored. Only those variables and matrixes relevant for monitoring must be taken into account assessing the relationship acquisition cost/value provided, understood as useful information for surveillance (Borja, 2002).
3. **Interpretation** has to be done by experts in the marine environment. To interpret possible changes caused by a specific project, a data base with a significant length in time can be used before the work had been done, or instead, witness areas can serve as control items.
4. **Results' feedback,** which will be used to modify initial aspects. That is why the monitoring, surveillance and control program must be flexible and find a balance point between the convenience of no intervention and the necessity to modify the program with the aim of reflecting the environmental issue in the most suitable way.

According to Borja (2002), the EMP must focus only on impacts which are thought to produce a significant alteration. However, given the diverse technologic state and new technologies on wave energy devices, and consequently, the uncertainty related to some impacts, the EMP proposed below covers more aspects than necessary "a priory" which should be subject to the assessment done by the EIS for each specific project.

Therefore, a surveillance programme should focus on monitoring:

- Submarine cable and moorings.
- Benthic communities.
- Ichthyofauna.
- Underwater noise.
- Marine mammals.
- Fishing activities.
- Underwater archaeological resources.
- Visual inspections.
- Electromagnetic fields.

10.1 Submarine Cable and Moorings

With the object of verifying a correct disposition of the submarine cable and moorings and their impact on sediments and benthic communities, a seabed characterisation should be carried out by a high resolution bathymetry before, during and after setting these structures. For this purpose a suitable vessel equipped with a high resolution multi-beam echo sounder should be used. An example is RESON's SeaBat7125 which has got the following specifications:

- 256 pulses.
- 130º angular sector
- Operation frequency at 400 kHz (expansible in 200 kHz).
- Pulse shape: along the transect (0.5º) and wide perpendicularly towards the transect (1º).
- Vertical resolution 6 mm.
- Fulfils the IHO Special Regulation.

Likewise, a visual inspection of the course of the cable and moorings should be done before, during and after being set by means of an underwater camera fitted to a ROV and connected to a support vessel with a cable. This camera could incorporate a square of a given area with the aim of carrying out quantitative census of bioturbation, presence of structures, etc., being able to record videos and take pictures in a 360º angle.

10.2 Benthic Communities

With the aim of monitoring the evolution of benthic communities relating to moorings and cable setting, before and during the commissioning and operation stages of the project, and also during the decommissioning, a routine monitoring of benthic communities shall be developed according to the methodology described in the section accounting for the environmental characterization of the project area (6.2.1).

Samples should be taken in the occupation area of the installation and along its influence area. The number of samples must be enough to cover different types of affected habitats and the minimum surface must be enough to analyse relationships between species, trophic groups, ecological groups, etc. This type of minimum area is known as the minimum structural area (Niell, 1977) and, is usually smaller than the minimum qualitative area necessary to develop an environmental inventory.

Besides, in case elements of interest (due to their rareness, in case they are protected, etc.) are detected in the environmental inventory, a specific surveillance plan must be developed for a suitable monitoring of such element, unless the routine surveillance plan is enough.

Once real information on the effects of the installation becomes available, the area covered by the surveillance plan could be reduced or extended according to the affection area being smaller or bigger than expected.

Sampling periodicity must be variable. Thus, during the commissioning stage and first stages of operation it is recommended that surveillance is more intense than during the maturity of the project.

Therefore, in the commissioning stage and first stages of operation, a compromise between the need to react against unforeseen impacts and the capacity to manage samples is required. It is worthless taking monthly samples if their analysis is going to take more than a month. Therefore, it is recommended to adjust periodicity at an initial stage to 4 or 5 samples per month.

Once the commissioning stage is finished, if during the first stages of operation, no unforeseen impacts are detected, periodicity can be decreased gradually up to a minimum of one sample campaign each three years, given that surveillance results show benthic communities are not having a variability which cannot be explained by ocean-metereologic conditions.

Regarding the decommissioning stage, periodicity should be increased during the works and should be extended afterwards with an annual periodicity, at least until the predicted stage is reached. Such final state does not have to be the same to the previous to the commissioning of infrastructures. In case the predicted objective is not achieved, suitable amendment measures must be taken.

10.3 Ichthyofauna

With the object of controlling the evolution of fish communities during the commissioning and operation stages reacting to acoustic impacts, sediments resuspension, etc., an assessment of present communities and their evolution in time before, during and after the execution of the project should be carried out. It is recommended to continue with the same monitoring protocol as in the commissioning, operation and decommissioning stages so that obtained results from all stages can be comparable.

In this respect, there are methodological references of interest, mainly within the field of marine wind power, e.g.: Stocker (2002), Girard *et al*. (2004; 2005), Hvidt *et al*. (2005), Wilhelmsson *et al*. (2006), Langhamer and Wilhelmsson (2007) and Boehlert (2008) amongst many.

Before starting any operation, reference information of the study area must be obtained consulting previous work, fishing data bases and/or *ex-profeso* sampling.

During the operation period of the installation, an assessment campaign of fish communities should be carried out annually consisting in doing a minimum of 5 transects with techniques of visual census with autonomous diving suit and video cameras (beyond the diving limit, ROVs or underwater devices should be deployed) to determine, amongst other parameters, abundance and density of fish stocks. The use of other complementary techniques (ictiocides and fishing arts) will be determined by their feasibility to be used in the installation area of WECs.

In any case, a distant zone from the occupation area of the infrastructures shall be selected as control zone.

Likewise, in order to do a continuous monitoring of fish stock present in the area, three buoys with a hydroacoustic object could be designed and installed with the aim of getting a continuous register of the presence of fish. These buoys would be anchored in the surroundings of the project and will be operational for one year at least.

In case behavioural changes are detected in migrating fish, an in-depth study is recommended including, if necessary, the use of telemetry and marking techniques.

10.4 Underwater Noise

Regarding noise generated by the project, a characterisation should be carried out using the same noise measuring techniques as described for the previous characterisation of background noise belonging to the environmental inventory (see section 6.1.9).

Noise levels obtained will be compared to previous registers to the installation in order to check their sonic incidence. Besides, their sources shall be spotted thanks to the directional disposition of the receiver system. The spectrum in frequencies of the registered noise shall be analysed to assess their impact according to the hearing capacity and sensible thresholds of the present marine species.

10.5 Marine Mammals

As it was the case for ichthyofauna, before initiating any operation, reference information from the study area shall be obtained either consulting works developed before and/or “ex-profeso” sampling. This information could be compared to the obtained results from sampling done during the different stages of the project, thereby being able to determine the affection degree generated before and during the commissioning and operation stages.

According to antecedents developed by Thomsen *et al*. (2006), Boehlert *et al*. (2008) and Diederichs *et al*. (2008), amongst others, short-term studies are recommended along all different stages of the project (anthropogenic impact detection and assessment, behaviour when exposed to noise, etc.) and also long-term studies (abundance estimates, habitat use, population dynamics, etc.) combining acoustic and visual techniques (see section 6.2.3). Thus, the following tasks could be carried out:

1. Visual observation every three months.
2. Presence/absence register of marine mammals by means of underwater acoustic techniques that shall involve:

i. A noise characterisation (frequency, intensity, period, amplitude, etc.) and environmental parameters in the study area, together with an influence analysis of these environmental parameters on noise propagation characteristics.

ii. The development of techniques to detect vocalizations.

iii. The development of methodologies that integrate the obtained results from visual and acoustic techniques.

iv. The study and analysis of cetacean behaviour to the presence of noise and the identification and characterisation of anthropogenic noise associated to stranding events. Estimate of the levels of noise received by animals just before stranding.

3. Photogrammetry, telemetry and marking studies in case changes are detected in migration routes.

10.6 Seabirds

Results from census of nesting seabirds around the study area must be taken into account with the aim of assessing possible effects of the project on this community.

10.7 Marine Dynamics

With the aim of determining a possible attenuation in the current and swell regime and modification in sedimentary dynamics in the shady area of the infrastructure during the operation stage, taking measurement of swell is recommended. Techniques of measurement to be used are described in section 6.1.6. Ideally, defining at least two sample points is interesting to take data simultaneously (with two equipments), one in the affected area, and another upstream, in order to better understand the effects of the installation in local hydrodynamics. Sampling should be done at least during a month in summer and winter as there might be a great seasonal variability and it should also be repeated for several years if the installation involves important changes in the hydrodynamics and/or sedimentary dynamics of the area.

Likewise, in case a significant effect of structures is estimated on the sedimentary dynamics of the area, a bathymetry with a multi-beam echo sounder from the affected area is recommended at least once a year (always during the same season summer/winter) in order to monitor such alteration or changes in sediment transport (see section 6.1.6).

Finally, only if the structure might generate an important modification of the current regime creating retention areas, it is also recommended to measure the current profile. For this purpose, as it is described in section 6.1.6., different types of devices allow taking measurement at a suitable spatial and temporal resolution. These devices must be set up at a nominal depth to allow sampling of the whole water column depending on the area's bathymetry and the location of the structure. As for swell, at least two simultaneous sampling points must be defined (with two instruments), one in the affected structure and another upstream. Sampling should be done for at least one month in summer and winter and be repeated at least two or three years.

10.8 Fishing Activity

Captures and fishing activity of ships working in the area shall be monitored in order to assess the degree of affection derived from the cessation of this activity in the occupation area of the project. Such assessment shall be carried out taking data from discharges done by the fleet or by any other methodology.

10.9 Underwater Archaeological Resources

A characterisation of possible archaeological remains should be carried out before the installation throughout the influence area of the project, doing cartographic campaigns and visual inspections with remotely operated underwater cameras, according to the methodology described in section 10.1.

Likewise, once the location of possible remains has been geo-referenced and once they have been characterised, the aforementioned campaign shall be repeated during the commissioning and operation stages in order to assess a possible damage on the identified remains during those stages.

10.10 Visual Inspections

During the commissioning and operation stages, visual inspections should be carried out annually by the personnel in charge of setting up and maintenance of energy devices with the aim of spotting accidental hydrocarbon leakage which could occur in the form of surface irisations and smell.

10.11 Electromagnetic Fields

According to the methodology developed by CMACS (2003), an *in situ* analysis of electromagnetic fields generated by the underwater cable could be carried out. This study would involve several stages:

1. Cable modellisation and their electromagnetic fields.
2. Design of suitable field sensors to determine the magnetic and electric field.
3. Measurement of electromagnetic fields generated by the submarine cable in an area where it is buried, another where it is lying on the seabed and in the water mass surrounding umbilical cables. Likewise, the electromagnetic field generated by other elements of the underwater cable such as connection boxes and connectors will be measured.

10.12 Landscape

With the object of assessing the possible impact on landscape by the infrastructure, an analysis of such impact should be carried out beforehand according to the described methodology in the chapter 6.

11. Synthesis document

According to Solaun *et al*. (2003), the synthesis document consists in a summary that allows ample understanding of the results obtained in the EIS for a given project. The developer of the project must make sure this summary can be easily understood by non experts in technical matters, and it is in accordance with the EIS' content in general, being written in a language that avoids technical terminology, detailed data and a deep scientific desertion and never exceeding 25 pages. This summary, according to Solaun *et al*. (2003) should cover the following content:

1. A brief, precise, and yet exhaustive description of the project.
2. Conclusions from the examination and selection amongst the different alternatives suggested.
3. A synthesis of the antecedents on the influence area of the project.
4. The most relevant information on significant environmental issues caused by the project and a brief description of positive and negative impacts generated.
5. A description of the effects, characteristics or circumstances (human health, flora and fauna, quantity and quality of natural resources, protected areas or landscapes, society and cultural patrimony) which are affected by those impacts.
6. A brief description of the protection and amendment measures together with the environmental surveillance plan both at the execution and operation stages of the projected activity.

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List of acronyms used in this contribution

ADCP	Acoustic Doppler Current Profilers
AMBI	AZTI Marine Biotic Index
ARP	Acoustic Recording Package
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
ASFA	Aquatic Sciences and Fisheries Abstracts
AUV	Autonomous underwater vehicles
AWS	Archimedes Wave Swing
BACI	Before After Control Impact
BIMEP	Biscay Marine Energy Platform
BMH	Beach Man Hole
BMO	British Meteorological Office
BOE	Boletín Oficial del Estado
BOPA	Boletín Oficial del Principado de Asturias
CA	Correspondence Analysis
CETO	Cylindrical Energy Transfer Oscillating
CMS	Coastal Modelling System
CNEA	National Catalogue of Threatened Species, by its Spanish acronym
CODA	Cetacean Offshore Distribution and Abundance in the European Atlantic
CPUE	Captures Per Unit of Effort
CSIC	Spanish National Research Council, by its Spanish acronym
DCA	Detrended Correspondence Analysis
DEM	Digital Elevation Model
DOG	Diario Oficial de Galicia
DTM	Digital Terrain Model
EEC	European Economic Community
EG	Ecological Group
EIA	Environmental Impact Assessment
EIS	Environmental Impact Study
EISt	Environmental Impact Statement
ELA	European Landscape Agreement
EMEC	European Marine Energy Centre
EMP	Environmental Monitoring Program
ESEOO	Establecimiento de un Sistema Español de Oceanografía Operacional
EU	European Union
EVE	Basque Entity of the Energy, by its Spanish acronym
FIS	Fisheries Information and Services
GIOC	Oceanographic Engineering and Coasts Group, by its Spanish acronym
GIS	Geographic Information Systems
HAMSOM	Hamburg Shelf Ocean Model
HARP	High Frequency Acoustic Recording Package
HDD	Horizontal Directional Drilling
HMRC	Hydraulics and Maritime Research Centre
HOV	Human operated underwater vehicles
IALA	International Association of Marine Aids to Navigation and Lighthouses
IFAW	International Fund for Animal Welfare
LIMPET	Land Installed Marine Powered Energy Transformer
MAMRM	Ministry of Rural, Marine and Natural Environment, by its Spanish acronym
MOPT	Transport and Public Works Ministry, by its Spanish acronym
MRC	Multiple Resonant Chambers
MTPD	Maritime-Terrestrial Public Domain
MW	Mega Watt
NCDC	National Climatic Data Centre
NEPA	National Environmental Policy Act
nMDS	Non parametric Multi Dimensional Scaling
OE Buoy	Ocean Energy Buoy
OGCM	Ocean general circulation models
OPT	Ocean Power Technologies
PAM	Passive acoustic monitoring
POLCOMS	Proudman Oceanographic Laboratory Coastal-Ocean Modelling System
POM	Princeton Ocean Model
RD	Royal Decree
REP	Spanish Renewable Energy Plan
ROMS	Regional Ocean Modelling System
ROV	Remotely Operated Vehicle
SAC	Special Areas of Conservation
SEOM	Spectral Element Ocean Model
SPAs	Special Protection Areas for Birds
SSG	Seawave Slot-Cone Generator
SWEP	Siadar Wave Energy Project
TW	Tera Watt
TWINSPAN	Two Way Indicator Species Analysis
UC	University of Cantabria
WEC	Wave Energy Converter
ZVI	Zone of Visual Influence

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