IUCN French Committee

Renewable energies

- VOLUME 2 -

Development of marine renewable energies and the preservation of biodiversity

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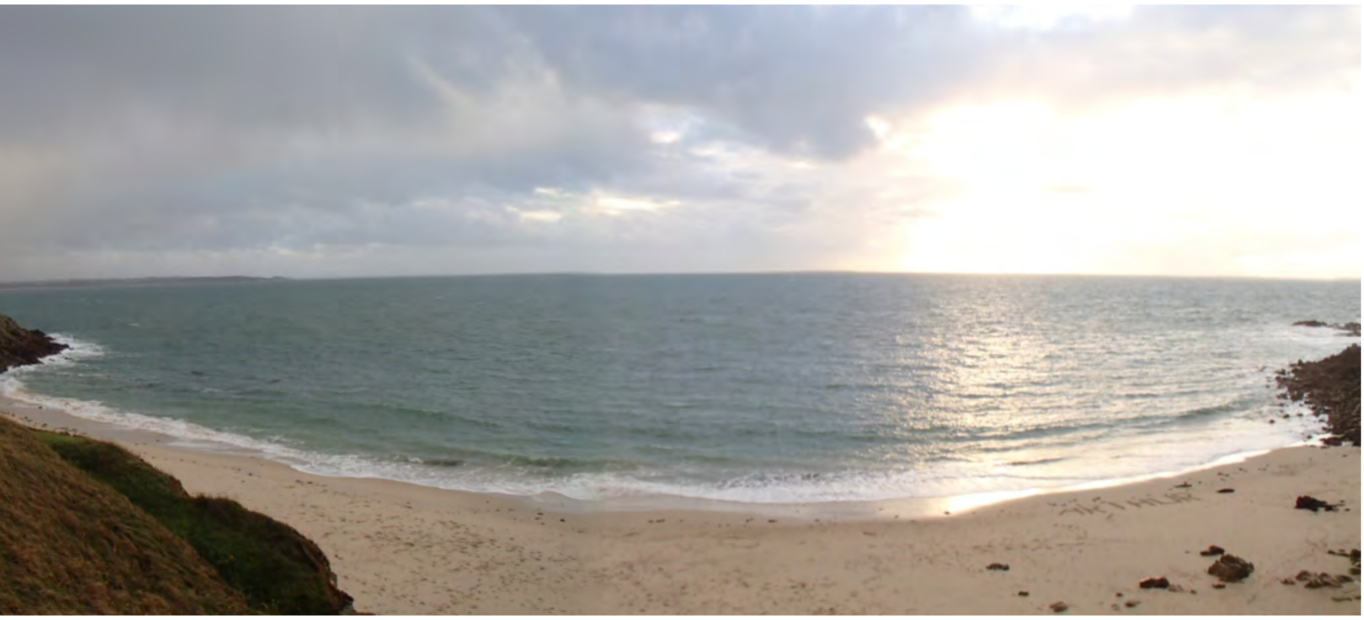

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Introduction

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"Conventional" (coal, oil, gas) or "non-conventional" (tar sands, oil shale, shale gas) fossil fuels, as well as nuclear energy, currently represent more than 80% of the total energy used worldwide (excluding unmarketed wood).

The use of fossil fuels is harmful to the environment. Indeed, their combustion contributes massively to global warming due to the carbon dioxide emissions and their exploitation is often characterized by severe impacts to ecosystems. Offshore oil and gas operations in particular have growing impacts (noise, pollution, etc.).

Nuclear energy has a minor impact on global warming, but major concerns remain over the safety of power plants, the disposal of radioactive waste and its dependence on uranium resources. Insecurity of fossil fuel supplies is linked both to the geopolitical issues of the main oil-producing countries and to the (inevitable in the long term) depletion of fossil fuel reserves.

In response to this situation, a variety of renewable energy types are increasingly being used to ensure a realignment of production methods. This offers better protection to the environment, by contributing to the reduction of greenhouse gas emissions (even if, due to their intermittent nature, some of these technologies require the complementarity of other energy sources, including fossil and nuclear energy). In addition, renewable energies are produced locally, thus limiting dependence on imports from other countries, and creating jobs.

To achieve this goal, the use of renewable energies must be combined with energy saving policies focused on energy efficiency and reduced consumption.

Reducing dependence on non-renewable resources and limiting GHG emissions has become a priority in the fight against climate change. It should be noted that this poses a threat to biodiversity, with the IPCC report stating that an increase of + 2°C risks the extinction of 30% of species. Among the many existing options for mitigating climate change, renewable energy sources can play an important role.

These energy sources depend on natural eco-systems such as forests, oceans and rivers and their functioning. The exploitation of these resources impacts each exploited ecosystem. Energy choices must be made with a holistic view of the broader issues so that the impacts are local, can be offset, and are as low as possible. Indeed, the reduction of greenhouse gas emissions must not be achieved at the expense of biodiversity.

France has therefore undertaken, within the framework of the law establishing the guidelines for energy policy (POPE Law of 13 July 2005), to reduce its greenhouse gas emissions by a factor of four by 2050.

It has also made commitments at European and international levels: as part of the adoption, under the French Presidency, of the “energy-climate” legislative package, France has committed to a 14% reduction in greenhouse gas emissions from sectors not subject to the Emissions Trading Directive (SCE-QE Directive) between 2005 and 2020. This commitment contributes to the European objective of a 20% reduction over 1990 levels for the second commitment period under the Kyoto Protocol (2013-2020). Today, France is actively participating in international negotiations on the post-2020 regime, and supports the process launched following the Cancun Conference of the Parties (COP 16), which has the objective of limiting the warming of temperatures to 2°C by the end of the century[1] compared with the pre-industrial era. France's objective is to reach an ambitious global climate agreement at the 2015 Conference of the Parties, which it will host in Paris.

In addition to these targets, France plans to develop renewable energies (RE) in order to reach the RE target of 23% of overall energy consumption by 2020. This means on the one hand controlling its consumption, and on the other hand drastically increasing production from renewable sources - from 20.6 Mtoe in 2011 to 37 Mtoe by 2020.

France has placed particular emphasis on the development of marine renewable energies (MRE), due to its national legal framework on large maritime areas and the many forms in which such energy is available. France has the second largest exclusive economic zone in the world, covering an area of 11 million km², spread over the world's four oceans, and with a considerable and diverse energy potential. But these areas contain many marine and coastal ecosystems with high heritage value (including 10% of the world's reef-lagoon ecosystems, 20% of the world's atolls and 50% of the world's marine mammal biodiversity) and these ecosystems are fragile. As a result, the challenges facing France are complex.

The French Committee of IUCN is advocating for a rapid transition to sustainable energy sources. It also seeks to disseminate existing knowledge on the ecosystem impacts of the various alternatives to fossil fuels and on how these impacts can be limited, from the very first stages of strategy design (policies, plans and programmes).

The question of environmental offsets[2] is not addressed at this stage; indeed, in Europe, few environmental offsets have so far been implemented offshore in the context of MRE projects. This subject is currently undergoing significant research.

This project particularly aims to:

- provide a baseline overview of the interactions between renewable marine energy and sensitive marine and coastal ecosystems within French territory (an overview of pressures, threats and opportunities),
- provide a sound basis on which to guide policy decisions for ecosystem protection and/or energy development,
- help raise awareness among energy stakeholders and decision-makers of the importance of marine biodiversity and its potential threats.

The study focuses on 5 types of marine renewable energy technology: offshore wind (fixed and floating), hydrokinetic energy, wave energy, ocean thermal energy and tidal energy. There are other types of energy from the sea (osmotic energy, for example) but, due to the immature stage of their development, we have chosen not to include them in this report.

This study concerns both Metropolitan and French Overseas territories.
For each energy type, a description of the operating principles will be provided, as well as its known or potential negative and positive impacts on marine biodiversity. The impacts are based on a study carried out by MEDDE[3], a study conducted by IUCN[4] and other partners, as well as discussions with French researchers. However, it should be pointed out that knowledge in this field is still deficient; it is partly based on experience from other countries with particular ecosystems that are sometimes very different from those in French waters, thus limiting the direct transfer of all of the findings.

Attention will also be given to differentiating between the construction, operation, and decommissioning phases, which have differing impacts on different components of biodiversity. The objective is to provide a global and strategic vision of each type of MRE system, and to compare their energy performance with their environmental impact.

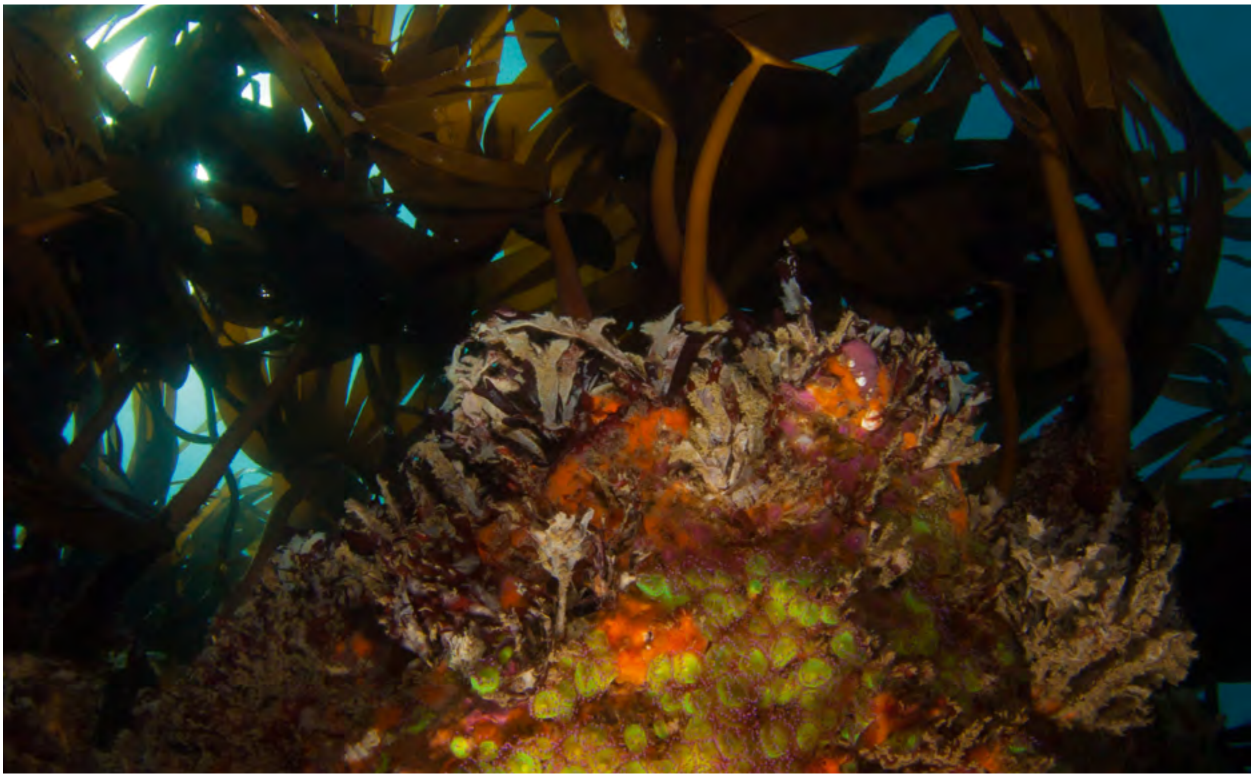
In the "Recommendations" section, therefore, this study is able to inform decision-makers about MRE development strategies that would have the least possible impact on marine biodiversity. ■

1 http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf
2 In Belgium, the Seal Action Plan aims to indirectly offset the impacts of wind turbines in the North Sea: Plan d'action PHOQUE : d'une politique environnementale défensive à une politique environnementale offensive en mer du Nord. In addition, compensatory measures have already been implemented for port developments (e.g., Port 2000 au Havre).
3 MEDDE, 2012, Energies Marines Renouvelables, Etude méthodologique des impacts environnementaux et socio-économiques. Lien : https://www.ecologique-solidaire.gouv.fr/sites/default/files/guide_etude_impact_eolien_mer_2017_complet.pdf
4 IUCN, 2010, Greening Blue Energy: Identifying and managing the biodiversity risks and opportunities of off shore renewable energy

Summary of the issues

Flock of Eurasian oystercatchers (Haematopus ostralegus) in flight © Benoît Dumeau / Marine Protected Areas Agency

Energy challenges



Anemones & kelp © Frédéric Lechat

Global warming and the biodiversity crisis

On a global scale, our energy needs are constantly increasing. Currently, 81%[5] of it is met by the combustion of fossil fuels (oil, coal, gas and nuclear [uranium and plutonium]). However, these fuels are limited: at the current rate of consumption, oil reserves could be depleted in the coming decades and gas in two to three centuries. In addition, the use of these fossil fuels is the main contributor[6] to the phenomenon of climate change, which is linked to the release of greenhouse gases into the atmosphere.

The impacts of climate change are already being felt, with an increase of 0.85°C in the global average surface temperature between 1880 and 2012[7] (GIEC, 2013). The various models of the Intergovernmental Panel on Climate Change (IPCC) predict an increase ranging from 1.5 to over 4°C for the end of the 21st century compared to the pre-industrial era[7]. The increase in global temperatures across the globe will lead to multiple, difficult-to-estimate impacts, especially because of its rapid nature. The impacts on some ecosystems can already be seen (coral bleaching, ocean-surface warming, ocean acidification, decline of forest ecosystems, melting glaciers, changes in the ranges of certain species, increases in invasive alien species, etc.), but it is currently difficult, despite the various scenarios that have been developed, to estimate the extent of the impacts this may have on biodiversity, ecosystems and the services they provide. However, the IPCC report estimates that a 2°C increase would put 30% of the world's species at risk, making climate change one of the main threats to biodiversity in the coming decades. This impact will be much greater on ecosystems with limited adaptive capacity, such as coral reefs.

Humans will also be directly affected: according to IPCC forecasts, the average sea level could rise by 26 to 82 cm by 2100[8]. This increase could exceed one metre by the beginning of the 22nd century and could reach 3 m in 2300 (which could affect 270 million people living in coastal areas[9]). Already, it is possible to link certain human migrations to global warming. This phenomenon often affects populations already vulnerable from other natural disasters.

Climate change is likely [10] to lead to an increase in both the intensity and frequency of extreme weather events, resulting in severe environmental, human and economic disasters.

Two types of response are possible (not necessarily exclusive of each other):

- Mitigation: this primarily involves reducing the greenhouse gas emissions affecting the climate. This requires limiting energy use as well as energy efficiency. The development of marine renewable energies also represents a significant mitigation measure.
- Adaptation: this concept involves reducing vulnerability and improving the resilience of natural and human systems to the consequences of climate change. The nature-based solutions promoted by IUCN are one such response. The preservation of mangroves, for example, helps to limit the impact of storms.

These approaches help to limit the effects and risks associated with climate change.

THE ISSUE IS DISCUSSED AT THE INTERNATIONAL LEVEL, AND THEN AT NATIONAL LEVELS

In the face of climate change and the predicted depletion of fossil resources, there is a global-level need for energy transition. This is even more urgent for countries that, like France, have few exploitable fossil fuel resources. This realization is not new, with many political and scientific protagonists sounding the alarm bells as early as the first oil crisis in 1973.

The Programming Law establishing the Guidelines for Energy Policy (POPE Law of 13 July 2005) had already confirmed, as well as the importance of the rational use of energy, interest in the development of renewable energies. It responds to a dual challenge:

› Reducing France's energy dependence: in the medium term, renewable energy sources are valuable strategic alternatives in our choice of energy options (it should be noted that uranium is also imported).

› Contributing to meeting France's international commitments to reduce greenhouse gas emissions (the Kyoto agreement, signed in 2002, committed France to reduce its greenhouse gas emissions by a factor of four between 1990 and 2050, in order to reduce its annual emissions to a level below 140 million tonnes of CO^2 equivalent) but also to meeting European commitments.

Indeed, France is contributing to the achievement of the European Union's objective of a 20% improvement in energy efficiency (European Energy-Climate Package adopted in 2008) and is committed to increasing the share of renewable energies to at least 23% of its final energy consumption by 2020 (Grenelle Law 1, 2009).

In this scheme, it is expected that 3% of total national electricity consumption will come from marine renewable energies by 2020. It should be noted that the installed capacity of French MRE represents only 0.1% of total consumption as of 2013 (mainly by the Rance tidal power plant).

DIFFERENT SCENARIOS FOR THE DEVELOPMENT OF OFFSHORE RENEWABLE ENERGIES

Faced with these challenges, the French government investigated its potential to achieve its objectives. The early 2010s saw the emergence of various scenarios, such as the NegaWatt model[11] and the WWF model[12].

These models are based primarily on a reduction in our consumption while proposing a renewable energies production mix, mainly based on biomass and wind power for Negawatt, and solar energy for WWF. Marine renewable energies, excluding offshore wind, occupy only a very modest place in these scenarios; this is explained by the authors' desire to only focus on technologies already validated at a large-scale industrial level.

In March 2007, Ifremer[13] initiated a prospective study on these energy sources until 2030. With the support of the Futuribles organisation, around twenty French partners representing the main sectoral stakeholders participated. Their objectives were to identify technologies, predict the socio-economic preconditions for their emergence and competitiveness, and estimate their respective impacts on energy supply and the environment. Contrary to the preferred models of NegaWatt and WWF, the Ifremer study focused on technologies that were still far from mature, such as algal biofuels, but appeared to underestimate the evolution of floating wind power.

These models have been noted, and have provided valuable input into this study.

The French strategy for the development of MREs has since been developed in a CGEDD/CGEIET report from March 2013[14]. We will return to this topic later in the report. ■

> "The IPCC report estimates that a 2°C increase globally would put 30% of species at risk.

5 International Energy Agency, 2011.
6 5th IPCC report, Summary for decision-makers
7 5th IPCC report, Summary for decision-makers
8 5th IPCC report, Summary for decision-makers
9 2010 estimate, a sharply-rising figure with a 95% increase between 1970 and 2010.
10 From unlikely to very likely, depending on the type of extreme events considered.
11 NégaWatt, 2011, Scénario NégaWatt 2011 : Dossier de synthèse
12 WWF, ECOFYS, OMA, 2011, The Energy Report: 100% renewable energy by 2050
13 Ifremer 2009. Marine Renewable Energies: Prospective Foresight Study for 2030. Collective publication, coords. Paillard, M., Lacroix, D., Lamblin, V. 336 p.
14 MEDDE (Conseil général de l'environnement et du développement durable - CGEDD)/ Ministère de l'économie et des finances - Ministère du redressement productif (Conseil général de l'économie, de l'industrie, de l'énergie et des technologies - CGEIET), March 2013. Rapport de la mission d'étude sur les énergies marines renouvelables, 104p.

Marine conservation issues

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General overview of marine and coastal habitats

France's marine and coastal habitats are highly diverse, providing France with immense resources, but also important responsibilities. France is represented in four of the five world oceans through its overseas territories, and has the second largest exclusive economic zone in the world (97% of which is located in the Overseas Territories).

The metropolitan coastline comprises numerous different ecosystems, including approx. 1950 km of sandy coastlines (35.2% of the total length), 1300 km of marshlands and mudflats (23.7%) and 2,250 km of rocky coasts (41%, of which 13% are cliffs)[15].

To these figures, 1,180 km must be added for the overseas departments and more than 3,800 km for the overseas territories.

Composed of benthic, pelagic, intertidal and aerial compartments, the marine environment offers a multitude of habitats ranging from shallow coastal waters to abyssal depths. Depending on the depth,

Seabream © Frédéric Lechat

the nature of the seabed, the penetration of light into the water column (limited to a maximum of a few dozen metres) and the presence of nutrients, organisms will be distributed in the environment according to the conditions necessary for their development.

Marine biodiversity, however, is clearly less well known than terrestrial and freshwater biodiversity. It is now estimated that less than 10% of marine species have been described. The anthropogenic pressures on these environments are increasing and studies show that many are now experiencing degradation, some of which may be irreversible. These include acidification linked to climate change, pollution, destruction of rare habitats etc.

Coastal areas are in demand, whether in mainland or French overseas territories, and therefore at risk. Factors include demographic pressure (within mainland France, coastal areas have a density 2.5

times higher than non-coastal areas) tourism, increasing urbanisation, disappearance of particularly important and sensitive natural environments, and pollution. These areas require special protection, provided by some regularly-challenged regulations (in particular the Coastal Law and certain categories of marine protected areas, including gaps in the Coast Conservatory, biotope protection orders, etc.).

Some marine habitats of heritage interest[16]

COLD-WATER CORAL REEFS

Less well known than tropical corals, cold-water coral reefs are found in all oceans, from 50 to 6,000 m deep. They are especially prevalent in the North Atlantic, in waters with a temperature between 4 and 8°C. Off French coasts, they are similarly found around drop-offs on the edge of the continental shelf, mainly in the northern Bay of Biscay and the Celtic Sea, but also in the Mediterranean (in some canyons, for example).

As important biodiversity hotspots, reefs can contain three times as many species as surrounding soft sediment zones[17]. They provide shelter for fish, and many types of invertebrates inhabit them, including crustaceans, molluscs, sponges, echinoderms and worms.

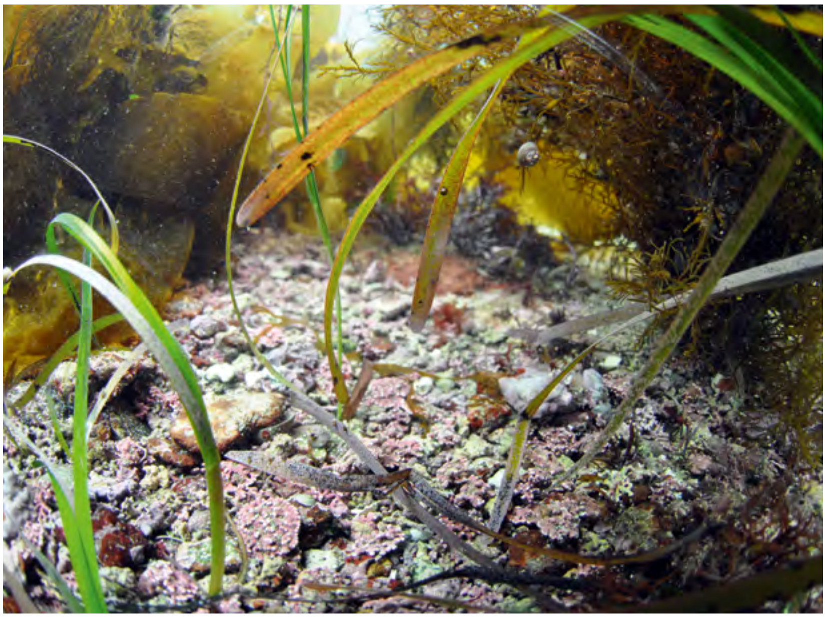
KELP FORESTS[18]

Kelp form huge underwater forests. They are stratified in the same manner as terrestrial forests, where each stratum contributes to providing food, shelter and attachment to a wide variety of fauna and flora.

These forests represent, from a natural heritage perspective, the temperate to cold equivalent of mangroves or coral reefs.

They are likely to be present on rocky bottoms from the intertidal to depths of more than 30 m. Symbolic of Breton waters, these represent some of the most significant kelp areas of Europe.

Kelp are very sensitive to disturbances. They do not tolerate changes in temperature or salinity (Birkett et al. 1998) or increased turbidity. At the European scale, they have been selected as an indicator of the ecological quality of coastal waters, as part of the Water Framework Directive (WFD).



Herbier de zostère marine (Zostera marina) et maërl (Phymatolithon calcareum) en Iroise
© Yannis Turpin / Agence des aires marines protégées

MAERL BEDS

The term maerl refers to calcified red algae that live on sediments without being fixed to them. Accumulations can range from a few centimetres to several metres in thickness, and form beds of which only the surface algae are alive, while those at depth die and bleach. Depending on environmental conditions, maerl beds are located from the foreshore to a depth of 30 m in the English Channel, Atlantic coastline, and in front of points and headlands. In the Mediterranean, they can occur as deep as 100 m.

The complex architecture of the beds creates many ecological niches, thus resulting in high diversity. The University of Western Brittany already lists 1,500 species found within the maerl beds along the Breton coast[19] (although the total number of species is estimated at between 1,800 and 2,000). There are significant concentrations of commercially important mollusc (e.g. king- and others scallops, and venus- and other clams) as well as fish (e.g. sea bass, sea bream).

There are also very large banks in the Mediterranean, Corsica, Spain, Malta, Italy etc.

15 IGN, BD Carto®, 2006, Traitements : SOeS / Occupation du sol sur le littoral
16 Commissariat général au développement durable - Service de l'observation et des statistiques, May 2011, Références : Environnement littoral et marin, Chapitre II : biodiversité et espaces protégés
17 Bajjouk T., Derrien S., Gentil, F., Hily C. & Grall J., 2010, Typologie d'habitats marins benthiques : analyse de l'existant et propositions pour la cartographie. Habitats côtiers de la région Bretagne - Synthethis note No. 2, Habitats du circalittoral. Projets REBENT-Bretagne and Natura 2000-Bretagne.
18 IFREMER/DIREN-Bretagne, Apri 2009, Fiche de synthèse d'habitat « Laminaires » – REBENT
19 Source: Jacques Grall, researcher in charge of coordinating the Fauna and Flora data at the Brest Marine Observatory (IUEM)

Close-up of a Saint-Jacques scallop (Pecten maximus) © Yannis Turpin / Marine Protected Areas Agency

EELGRASS BEDS

Eelgrass refers to the only two flowering plants living in the marine environment on the Channel, North Sea and Atlantic coasts. *Zostera noltii* grows in the intertidal zone while *Zostera marina*, which is larger, grows from the base of the foreshore to some ten[20] metres below the surface.

They are found on sandy to sandy-silty sheltered foreshores, most notably in large bays, gulfs and estuaries, from the western Cherbourg Peninsula to Arcachon. The two most significant areas are the Arcachon basin (at almost 7,000 ha, it is the largest site in Western Europe although it has significantly decreased in extent in recent years) and the Gulf of Morbihan (800 ha of common eelgrass and 530 ha of dwarf eelgrass). It is also found, mostly in lagoons, in the Mediterranean. Equipped with powerful rhizomes that provide structure to the sediment, these plants support invertebrates and algae that would not be found on soft substrates in their absence. As complex ecosystems, eelgrass beds and associated invertebrate communities represent an important food resource for many juvenile fish and crustaceans and also serve as breeding grounds. Many of these species are of significant economic value, for example flounder, red mullet and shrimp.

In addition, many birds such as the Eurasian wigeon and the Brent goose feed on eelgrass.

NEPTUNE GRASS BEDS

Neptune grass (*Posidonia oceanica*) is a flowering plant that forms vast meadows on the Mediterranean coast, and has been protected since 1988. Its ecological functions are similar to those of eelgrass and it is found from 0 to 30-40 m deep.

They bind the sediments through their rhizomes and have high primary productivity. The detached leaves enrich and stabilize the sediments, and are a source of carbon for other ecosystems such as canyons. Many species, including some of high economic value, use the meadows as a refuge, spawning ground and nursery. It is estimated that 20 to 25% of Mediterranean animal species are found there.

Posidonie oceanica. © Boris Daniel / Marine Protected Areas Agency

SEAGRASS, MANGROVES AND CORAL REEFS IN THE OVERSEAS TERRITORIES

Within the French Overseas Territories, seagrass beds, mangroves and coral reefs are valuable ecosystems that provide numerous ecological services to neighbouring communities.

These three environments are uniquely interconnected. Mangroves and seagrass beds filter the water, which provides favourable conditions for coral development. Seagrass beds and mangroves are also nurseries for many fish species that inhabit the reef complex. For their part, reefs act as physical barriers to the force of waves and currents, and create the calm waters necessary for the development of seagrass beds and mangroves. It also means that when one of these environments comes under stress, the entire local marine ecosystem is vulnerable.

Goods and services provided by marine and coastal ecosystems

The Millennium Ecosystem Assessment report[21] (MEA) of 2005 refers to ecological goods and services, or ecosystem services, as "goods and services that people can obtain from ecosystems, directly or indirectly, to ensure their well-being". Broadly speaking, four main types of ecological services can be distinguished: supporting services (the basic ecological functions), regulating services (direct services from ecological functions) and provisioning and cultural services (indirect services from ecological functions)[22].

Marine and coastal environments provide an invaluable range of goods and services in terms of food, aesthetics, and air and water quality, etc. We will provide just a few examples below[23].

REGULATING SERVICES

Marine organisms perform self-purification functions, thus contributing to the maintenance of water quality by retaining, recycling or breaking down harmful or excess substances through their metabolic processes. Other molluscs (such as oysters, cockles, mussels, etc.), for example, can filter up to several litres of water per hour. These organisms are water bio-purifiers because they concentrate pollutants in their flesh. Some marine microorganisms (fungi and bacteria) can also break down pollutants[24]. By providing some of these detoxification and degradation functions, marine and coastal areas contribute to good water quality. But it should be remembered that the ecosystem must remain healthy to provide these services.

PROVISIONING SERVICES

Marine and coastal areas are the source of many food products, thanks to the abundance of plankton that underlies the food chains, as well as the diversity of the habitats that they support. Nearly a billion people depend on fish as their only source of animal protein. Approximately 85 million tonnes of fish are caught each year worldwide.

Fishermen on board of a trawler in the English Channel (Marine Natural Park of the Picardy Estuary and Opale coast) © Marie-Dominique Monbrun / Marine Protected Areas Agency

In 2009, French commercial fishing comprised[25] 7305 active vessels and employed more than 23,090 people, 88% of them in mainland France[26].

Due to the richness and diversity of species found in the marine environment, it contains numerous resources useful for human activities (agriculture, industry, medicine). Algae are currently of growing interest as biotechnological components in food processing, cosmetology and pharmacology, as well as in biofuel production (although this would require very extensive cultivation). For example, additives used as stabilizers, thickeners and gelling agents can be obtained. Marine ecosystems are home to a wealth of natural resources that we are just beginning to discover and whose genetic diversity is of interest in the search for resistant genes, drugs, etc. The pharmaceutical industry has discovered multiple substances with anti-cancer, anti-inflammatory and anticoagulant properties in sea grass, sponges, molluscs and corals reefs.

CULTURAL AND RECREATIONAL SERVICES

Marine and coastal areas are popular recreational areas, and provide a variety of opportunities for leisure and tourism activities, such as swimming, fishing, sailing, scuba diving, sand yachting, walking, and wildlife viewing. The French coast is a major destination for vacationers, due to the beauty of the landscapes and favourable climate. In summer, in metropolitan France, 13 million tourists vacation by the sea every year[27]. The most notable sites (Pointe du Raz, Mont Saint-Michel, Dune du Pilat, and Porquerolles Island) are among the most visited natural heritage features. Scuba diving and recreational fishing are important income-generating activities.

High-quality sites can generate significant economic benefits for the local economy. Lagoons and coral reefs are very popular for tourists; with 55,000 dives per year in the coral reefs of New Caledonia alone.

The ocean and its marine species also play a key role in the religion of some traditional communities. Even in contemporary societies, the sea remains a source of spirituality, relaxation and inspiration for many artists.

Preserving these ecosystems is therefore essential if they are to continue to fulfil their functions. To this end, it is necessary to minimize human impacts on these environments and to manage them sustainably. ■

> **"Marine and coastal environments provide an invaluable range of goods and services in terms of food, aesthetics, and air and water quality.**

20 http://doris.ffessm.fr/fiche2.asp?fiche_numero=695
21 Millennium Ecosystem Assessment (MEA), 2005, Ecosystem Wealth and Human Well-Being, Island Press
22 UICN France (2012), Panorama des services écologiques fournis par les milieux naturels en France – volume 1 : contexte et enjeux. Paris, France
23 UICN France (2013) - Panorama des services écologiques fournis par les milieux naturels en France - Volume 2.2: les écosystèmes marins et côtiers. Paris, France. Also noteworthy is the VALMER project, a European project involving 11 partners, with the objective of determining how an integrated assessment of marine ecosystem services can contribute to the sound management of the marine environment. The project, led by the University of Plymouth, extrapolates from six study sites located in the western English Channel. This will lead to a better understanding of the links between ecosystem services, their valuation, and effective management of the marine environment. It was implemented from 1/9/2012 to 31/3/2015. http://www.valmer.eu/?lang=fr
24 Biodegradation is a degradation of organic matter carried out by living organisms due to the abundance and variety of microorganisms in the particular environment. The attack on a chemical molecule by microorganisms results in its mineralization and the production of metabolites of low molecular weights.
25 Ministère de l'Alimentation, de l'Agriculture et de la Pêche.
26 Ministère de l'Alimentation, de l'Agriculture et de la Pêche, 2011
27 Jean-Claude Jacob, 2009, Tourisme littoral (cf. « Le Tourisme de A à Z » : https://www.veilleinfotourisme.fr/thematiques/juridique/abecedaire-du-droit-du-tourisme)

Regulatory context

© Martin

Ocean resources are limited. Therefore, comprehensive integrated approaches are essential for the management of human activities. Large-scale marine renewable energy installations represent a relatively new challenge for integrated coastal management strategies and marine spatial planning. The development of parks in territorial waters must form a component of Integrated Coastal Zone Management (ICZM) approaches, together with spatial planning instruments, where appropriate.

Many instruments have been created at the international, European and national levels for the management of marine areas and uses such as navigation and overflight, resource exploration and exploitation, the conservation of living resources, the protection and preservation of the marine environment and marine scientific research.

MRE and the International Law of the Sea[28]

The United Nations Convention on the Law of the Sea, signed in 1982 in Montego Bay, codifies the Law of the Sea, including rules on the use of the sea and the exploitation of its resources, to ensure their conservation and preservation. These rules, along with the resulting rights and responsibilities of States, vary according to the different maritime areas over which they exercise their jurisdiction.

A coastal state has a sovereign right to develop renewable marine energy only in areas near its coasts (territorial waters) and in areas known as "under national jurisdiction" (exclusive economic zone).

With regard to inland and territorial waters, state sovereignty implies the right to exploit energy resources in these areas. Territorial waters extend a maximum of 12 nautical miles from the coastline.

Article 56.1.a of the convention refers to the sovereign rights of the coastal state within its exclusive economic zone, concerning "the production of energy from water, currents and winds". The EEZ is an area of up to 200 miles in width calculated from the coastline of the coastal state. The state must also ensure the protection of the environment. The corresponding powers can be shared with or transferred to the EU.

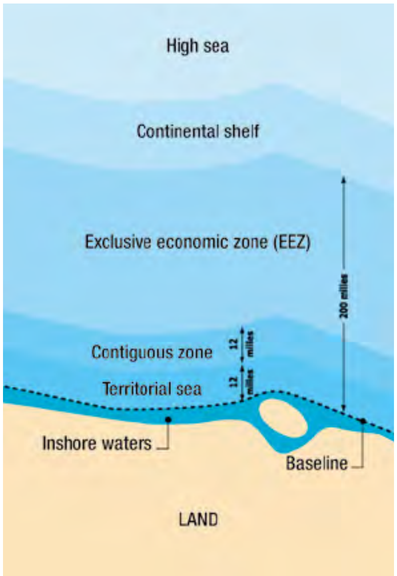


Figure 1. Maritime areas as defined by the International Law of the Sea

Regarding the continental shelf, Article 77 of the convention, which lists exploitable resources, does not mention MRE.

It is not intended to regulate pelagic areas nor airspace. Installations located on the continental shelf are mainly governed by the article 80, which introduces, all other things being equal, an extension of the regime applicable in the EEZ (Article 60).

Finally, on the high seas, there is no provision in the Convention on the Law of the Sea that refers to the right of exploitation of MRE. By contrast, the exploitation of the seabed and its mineral resources, which have been designated by the international community as "common property of humanity", is subject to a regime regulated and supervised by the International Seabed Authority under the United Nations Convention on the Law of the Sea.

European legislation[29]

European Union (EU) environmental assessment legislation describes the minimum conditions that a Member State must meet when drawing up a plan or programme, and which it may require from a developer throughout the life cycle of a project. The information it must provide is specifically defined by national laws and by the conventions to which the country is a signatory.

The EU has several relevant laws concerning:

› the achievement of sound ecological conditions in all marine waters by 2020 (Marine Strategy Framework Directive - MSFD n°2008/56/EC),

› the conservation of nature and the protection of specific species and habitats (Habitats Directive n°92/43/CEE),

› strategic environmental assessments / SEA (Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment). This Directive requires authorities establishing a plan or programme to prepare an environmental impact assessment (indicating likely significant environmental impacts and suitable alternatives) and to conduct consultations (with the public, environmental authorities and other member states in the event of significant cross-border impacts). The environmental impact report and the results of the consultations are taken into account before the plan or programme is adopted. Once adopted, the authorities, the public and any consulted member state shall be informed, with relevant information made available to them.

› and environmental impact assessments / EIA (Directive No. 85/337/EEC, repealed and replaced by Directive 2011/92/EU of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment). This directive notably states that "projects likely to have significant environmental impacts, in particular because of their nature, size or location, are subject to a permit application procedure and an assessment of their impact". This EU legislation is transposed in France through the provisions of the Environmental Code on impact assessments. In order to identify unforeseen adverse effects as early as possible and to assess the intensity of the predicted effects, significant environmental impacts should be monitored at all scales.

In January 2014, the European Commission presented a two-stage action plan to increase the development of marine energy and remove the major known obstacles by 2020.
Between 2014 and 2016, a forum bringing together all marine energy stakeholders (industry, governments, researchers, EU, NGOs) should be set up to improve coordination between policy and industry and to collectively find viable solutions. The Commission will play a facilitation and coordination role. This collaborative process will result in the drafting of a strategic roadmap. A second forum will address administrative and financial issues. A working group will also be set up to work on environmental impact assessments of existing and future installations, also to review the environmental directives applying to marine energies and their possible shortcomings. In a second phase (2017-2020), a European industrial initiative could be developed based on a public-private partnership, to set clear and shared objectives for the industrial deployment of marine energy in Europe. Simultaneously, guidelines could be published to facilitate the granting of permits and reduce the administrative burden for authorities and project proponents. A review of this action plan is planned for 2020 at the latest.

28 Beer-Gabel (J.), *Droit international et informatique juridique : dialogue sur le droit de la mer*, Paris : CNRS, 1995, 434 p.
29 IUCN, 2010, Greening Blue Energy, Ibid.

National legislation

Various laws relate to this subject.

THE NATIONAL STRATEGY FOR THE SEA AND COAST - APPLICATION OF THEMARITIME SPTIAL PLANNING (MSP) DIRECTIVE

The transposition of the MSP Directive under French law is achieved by the establishment of Marine Environment Action Plans (PAMMs) (article L 219-9 of the Environment Code enacted on 12 July 2010). These form the environmental component of future strategic coastline documents (DSF) resulting from art. L 219-3 of the same code and which themselves define the objectives of the National Strategy for the Sea and the Coast on the scale of each DSF coastline (art L 219-1).

Developed under the responsibility of the maritime and regional prefects, these marine action plans must include the following elements: (i) an initial assessment of the state of the marine sub-region, (ii) a definition of the healthy ecological state for the sub-region, to be achieved by 2020, (iii) the setting of environmental objectives, (iv) monitoring and action programmes.

These Marine Environment Action Plans (PAMMs) notably include:

› an analysis of the distinctiveness, essential characteristics, and ecological condition of these waters,

› an analysis of the major impacts and pressures, particularly due to human activity, on the ecological status of these waters,

› an economic and social analysis of the use of these waters and the costs of degradation of this environment.

The PAMM must be developed on the basis of broad consultation with maritime and coastal stakeholders. This consultation is carried out in particular within the Council of the Sea and Coastlines (CMF), which also integrates public institutions in charge of the sea and the coast, nature protection associations, and users of the environment. It is followed by a public consultation open to all citizens.

In French overseas territories , local authorities work with the state and with regard to each other's powers to develop a strategy for each overseas maritime basin (if necessary cross-border), known as a sea basin strategic document. An overseas maritime council is created at the level of each maritime basin.

IMPLEMENTATION OF THE HABITATS DIRECTIVE IN FRANCE

The Natura 2000 marine network in France currently covers an area of 4.1 million hectares with 207 sites (148 mixed and 59 fully marine). It aims to create a coherent network in order to protect the territory's biodiversity, as required by European legislation. In particular, it must include the designation of offshore sites.

APPLICATION OF THE "SEA" DIRECTIVE IN FRANCE

The Directive has been transposed into French law in various codes. For example, for the environment, Articles L. 122-4 to L. 122-11 and R. 122-17 to R. 122-24 of the Environment Code and, for town planning, Articles L. 121-12 to L. 121-15 and R. 121-14 to R. 121-17 of the Town Plan-

Seahorse © Frédéric Lechat

ning Code, and L. 4424-13, L. 4433-7, R. 4424-6-1, R. 4433-1-1 and R. 4433-1-1 of the General Code for local Authorities.

The environmental assessment of the plan or programme shall include an environmental report which, in accordance with Article L. 122-6 of the Environmental Code, identifies, describes and assesses the significant effects that the implementation of the plan or document may have on the environment. This report presents the measures planned to reduce and, as far as possible, compensate for the significant negative effects that the application of the project may have on the environment. It sets out alternative solutions that were considered and the reasons why, particularly with regard to environmental protection, the project was selected.

The development of marine renewable energies has been the subject of two CRE calls for tenders for offshore wind power (launched under the Energy Code), coupled with calls for expressions of interest for demonstration projects. The calls for tenders were not subject to the Strategic Environmental Assessment required for national plans and programmes. The initial assessments planned under the MSFD were not available at the time of the first two wind power tenders. In the future, the link between these strategic documents and the development of renewable energies at sea will be strengthened.

APPLICATION OF THE EIA DIRECTIVE IN FRANCE - IMPACT ASSESSMENT REGULATIONS

This Directive is transposed into French law in Article R122-2 of the Environmental Code, created by Decree No. 2011-2019 of 29 December 2011, which specifies that any project categorized as "development, structures and works relating to energy" and subcategory No. 27 "Offshore energy production facilities" is subject to this impact assessment.

In the event of significant negative impacts on marine biodiversity, IUCN France stresses the importance of adhering to the "avoid/ reduce/compensate"[30] approach in order to design projects that have the least impact on the environment. Implementation of the approach is hierarchical. Priority is given to avoiding impacts; if they cannot be avoided, measures are taken to reduce them, and as a last resort, any significant residual impacts that could not be avoided or reduced must be compensated for.

The "avoid/reduce/compensate" approach is described in the EIA Directive, which requires developers to describe the proposed measures to avoid, reduce and, if possible, compensate for significant adverse environmental effects of the project when assessing its environmental impacts (e. g. in the Environmental Impact Assessment report).

In October 2013, the Ministry of Ecology published guidelines to clarify the use of the "avoid/reduce/compensate" process[31].

THE COASTAL LAW

According to Articles L. 321-2 and R. 321-1 of the Environment Code, coastal municipalities are considered to be "municipalities in metropolitan and overseas France bordering seas and oceans, salt ponds, inland water bodies with an area of more than 1000 hectares" as well as those listed in Article R. 321-1 of the Code.

Faced with the increasing concentration of activities and urban development of coastal regions, the Coastal Law (1986) establishes four objectives:

› Preserve rare, sensitive areas and maintain ecological stability;

› Economically manage the use of space for urbanization and tourism development;

› Increase public access to the coastline;

› Prioritise coastal activities whose development is linked to the sea.

THE REGULATIONS APPLICABLE TO INSTALLATIONS IN THE EXCLUSIVE ECONOMIC ZONE

As part of the preparation of the Biodiversity Law (marine component), the Ministry of Ecology is required to draft proposals that clarify, complement and safeguard the legal framework permitting the development of economic activities in the exclusive economic zone while respecting biodiversity.

30 UICN France, 2011, La compensation écologique : État des lieux et recommandations. Paris, France

31 MEDDE, Octobre 2013, Lignes directrices nationales sur la séquence éviter, réduire et compenser les impacts sur les milieux naturels. Links: http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0079/Temis-0079094/20917.pdf

The Molène archipelago from the air ©Julien Courtel / Marine Protected Areas Agency

Indeed, it has become necessary to provide a framework for the future establishment of MRE installations in these areas and, more generally, for the development of economic activities (other than mining, other mineral and hydrocarbon extraction, and fisheries and aquaculture activities, which are already covered by other regulations).

This instrument will therefore fill a legal void in the regulations, and will strengthen France's capacity to protect its interests and fulfil its commitments under international law[32] (United Nations Convention on the Law of the Sea, Convention on Biological Diversity, OSPAR Convention, Barcelona Convention, Cartagena, Nairobi, Nouméa and Apia Conventions, CCAMLR Convention) and European law.

SPECIFIC CHARACTERISTICS OF OVERSEAS TERRITORIES[33]

Overseas French coasts are not governed by the same rules as those of mainland France, and the relevant regulations differ between overseas Departments (DOM) and overseas Collectivities (COM).

In the Overseas Departments, the Coastal Law is applicable but with specific requirements. The Constitution allows for adaptations of the law in the French overseas departments.

Public land in the French Overseas Departments differs from that of metropolitan France: the 50 geometric steps zone remains within a particular regime. In Guadeloupe and Martinique, the law allows for the transfer of land parcels in these areas for the benefit of municipalities, social housing organisations or for squatters.

However, the acceleration of title formalisation and occupation of the coastline is leading to the threat of privatisation of access to the coastline and the sea.

In Overseas territories, environmental authority is local (except in Saint-Martin), after transfer by an enabling law. The principle of legislative specialisation, whereby national laws apply to COMs only when they expressly provide for it, has excluded these communities from much environmental legislation. When the "Urbanism" authority has been transferred, the Coastal Act does not apply to it. However local laws still frequently lack the necessary provisions to preserve the coastal environment.

Moreover, EU law does not apply everywhere in the French Overseas Communities (differences between the outermost regions [ORs] of the EU which are covered by Article 349 of the Lisbon Treaty and the overseas countries and territories [OCTs] which are covered by Part IV of the same Treaty).

In overall terms, a development strategy adapted to these territories is now necessary.

STANDARDISING DOCUMENTS[34]

Documents that set standards have been produced by governments. They provide specific guidance on assessment processes and methods for monitoring environmental impacts. Some examples are as follows:

› Nature Conservation Guidance on Offshore Windfarm Development - United Kingdom - DEFRA 2005
› Guidance on Environmental Considerations for Offshore Wind Farm Development - OSPAR 2008
› Guidelines on wind energy development and nature conservation requirements in the EU - European Commission 2010

In France, several supporting documents have also been produced:

› MEDDE (DGEC) released a methodological study in 2012 (361p.) on the environmental and socio-economic impacts of marine renewable energies.[35]
› France Energies Marines is currently coordinating a guide for assessing environmental impacts of offshore wind turbine technologies (GHYDRO project)[36]
› The MERiFIC Project has produced a literature review of the environmental impacts of renewable marine energy, September 2012 (98p.)[37]
› Ifremer has published a protocol for conducting impact studies and monitoring of offshore renewable energy projects, with numerous recommendations[38].
› EU initiative: The Atlantic Power Cluster rings together stakeholders from Ireland, Spain, France, Portugal and the United Kingdom to develop the renewable energy potential of the marine and coastal environment of these regions in a sustainable manner. ■

> "In the Overseas Departments, the Coastal Law applies, but with specific features. The Constitution allows for adaptations of the law in the French overseas departments.

Mangroves © Ji-Elle

32 Link: http://www.aires-marines.fr/Partager/Cooperation-regionale
33 Link: https://uicn.fr/wp-content/uploads/2016/06/rapport_UICN_France_loi_Littoral-2.pdf
34 IUCN, 2010. Greening Blue Energy. Ibid.
35 Link: https://www.ecologique-solidaire.gouv.fr/sites/default/files/guide_etude_impact_eolien_mer_2017_complet.pdf
36 Link: https://www.france-energies-marines.org/R-D/Projets-acheves/GHYDRO
37 Link : http://www.merific.eu/
38 Link: https://wwz.ifremer.fr/Innovation/Filieres/Filiere-energie/Energies-marines-renouvelables

Description of the different MRE systems

© Sylvain Michel

Research and development status

Abalone © Frédéric Lechat

This study concerns 5 types of marine renewable energy technology: offshore wind turbines (fixed and floating), marine current turbines, wave energy converters, ocean thermal energy converters and tidal barrages.

Although still in its infancy in France, offshore wind energy is currently, after tidal energy[39], the most developed and mature marine renewable energy technology, compared, for example, to wave and current energy. The associated environmental problems are therefore better documented.

Academic research on environmental and ecological issues related to the development of offshore wind energy is mainly conducted in Denmark, Germany, the United Kingdom and Sweden[40], and more recently in the Netherlands and Belgium[41]. However, most research programmes have only recently begun, and many outputs are limited to the development of impact analysis methods. In addition, most studies to date have focused on specific species rather than entire ecosystems. Consequently, there is little information available on the effects on the latter.

This report highlights the need for further research on specific topics, such as the effects of noise and electromagnetic fields on different species, or the mechanisms underlying avoidance behaviour, with a view to developing appropriate mitigation strategies.

In addition, the study of the potential benefits associated with the management and growth of other activities in MRE sites, and the provision of artificial habitats, should be pursued.

Finally, it will also be necessary to develop analytical tools for assessing the cascading effects on ecosystems and the cumulative effects of MRE with other maritime activities.

The application of results obtained for onshore wind farms to the marine environment is inappropriate. The marine environment differs fundamentally from terrestrial environments, not only in the types of organisms likely to be affected, but also in physical (e. g. sound propagation) and biological (e. g. regulation of food and energy flows and dispersal of young) factors. Nor is it possible to simply transpose studies carried out for other maritime activities, as marine wind farms differ from other marine engineering industries in terms of installation methods, the areas covered and their disturbance factors. However, it is possible to find, for example in the oil and gas or seabed aggregate mining sectors, information on potential environmental disturbances as well as possible avenues for mitigation and restoration efforts.

Techniques, essential conditions and potential in France

© Martin

The energy potential of the oceans is significant. Indeed, on a global scale, the oceans cover 71% of the planet and receive a large proportion of the sun's energy. The latter, by far the principal source of energy in the oceans, is the source of winds, waves and swells, thermohaline currents and temperature and salinity gradients. The oceans also contain tidal and geothermal energy.

Various systems have been developed to harness this energy. Some techniques are currently in use, others are still being investigated or tested. As each of these systems requires very specific physical conditions, they do not have the same development potential in all waters under French jurisdiction.

Offshore wind turbines (fixed and floating)

BRIEF TECHNICAL DESCRIPTION

Currently, fixed wind turbines are the most advanced marine renewable energy technologies and the only industrial-scale system deployed in France since the construction of the Rance tidal power plant.

Offshore wind energy, like land-based wind energy, uses the kinetic energy of the wind for electricity production. Wind turbines consist of a mast that can be fixed to the bottom (currently used) or to a floating support (under development) which supports a turbine equipped with a rotor with 2 or more (often 3) blades.

The electricity is then carried to the terrestrial network via submarine cables.

The stronger and less disrupted marine winds are more suitable for wind energy development than those on land. However, significant technical challenges exist, relating to the marine environment, maintenance, transport, logistics and construction challenges.

The size and performance of wind turbines are constantly improving: some machines will soon reach 8 MW. In France, future wind farms will have an installed

39 In fact, tidal energy has been exploited in France since 1966 (Rance plant), so it is more developed than offshore wind energy, and the environmental impact is well documented.
40 IUCN, 2010, Greening Blue Energy. Ibid.
41 https://odnature.naturalsciences.be/winmonbe2013/report

capacity ranging from 450 to 500 MW and will each consist of around 100 wind turbines. In comparison, future wind farm projects could have a total installed capacity of 9 GW in the United Kingdom by 2020[42]. For aerodynamic reasons, the spacing of wind turbines in these wind farms is about one kilometre, which corresponds to an installed capacity of about 5 MW per km²; that is, about 100 km² for a 500 MW wind farm, of which less than 1% is actually occupied by the foundations[43]. In France, on the other hand, planned French wind farms will occupy 50 km² (Courseulles-sur-mer with 75 turbines), 65 km² (Courseulles-sur-mer with 75 turbines), (Fécamp with 83 turbines), 77 km2 (Saint-Brieuc with 100 turbines) and 78 km² (Saint-Nazaire with 80 turbines).

Figure 2a: Different types of wind turbines[44]: 1) three-bladed horizontal axis wind turbine, 2) two-bladed horizontal axis wind turbine, 3) vertical axis wind turbine.

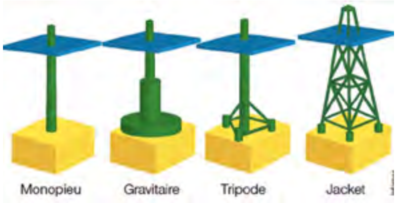


Figure 2b: Different foundation types *© Infomer*

The floating wind turbine, still at the experimental stage, is a technology that should eventually make it possible to exploit large marine areas at greater depths (from 50 m to over 200 m), thus limiting conflicts of use in the already highly-coveted coastal areas. Several flotation concepts are under development (spar, tension legs, semi-submerged, damping pool) and the associated turbines could differ radically from the fixed wind turbine designs (vertical axis turbines).

DEVELOPMENT POTENTIAL

Within the European Union, offshore wind farms currently supply 0.3% of total electricity demand: according to the European Wind Energy Association's (EWEA) Oceans of Opportunity report, this could reach 12% to 16% by 2030. The development potential is therefore enormous.

Ifremer estimates in its prospective study[45] that the potential offshore wind energy output in metropolitan France is 150 TWh (4,000 MW).

In September 2013, the Wind Committee of the French Renewable Energies Association (SER) proposed a roadmap[46], based on assumptions that consider the usable sea potential, the industrial capacity of the sector's stakeholders, and the crucial consultation between all sea users. On this basis, and using a conservative approach that considers the difficulties that other offshore wind projects around the world have encountered, the commission concluded that there was a realistic possibility of reaching 15 GW by 2030 (not including floating windfarms, which have the greatest potential).

Notably, the Wind Energy Association (FEE), published an action plan in July 2013 2013 aimed at a similar objective for fixed wind turbines and a target of 6 GW by 2030 for floating wind turbines. On this occasion, the FEE identified a technically exploitable potential of 80 GW for installed wind turbines and 122 GW for floating wind turbines[47].

France's advantages in terms of offshore wind power are particularly significant, including huge maritime areas, industrial and energy expertise, maritime expertise and harbour capacity. Mainland France benefits from strong marine winds and shallow sea beds, which are favourable to the exploitation of this energy.

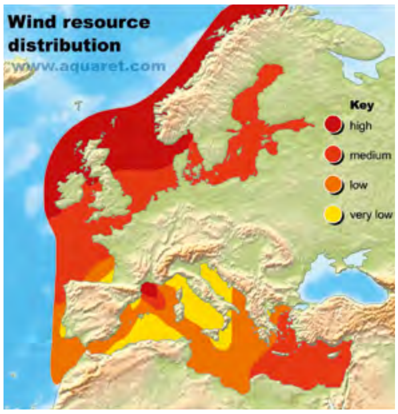


Figure 3: Map of marine wind resource as a function of wind speed at an elevation of 40 m a.s.l.[48].

The call for tenders launched by the Government in July 2011 was a first step. It will allow the installation of nearly 2,000 MW of offshore wind turbines on four sites: Courseulles-sur-Mer, Fécamp, Saint-Brieuc, and Saint-Nazaire. The commissioning of the farms is planned from 2018 to 2020 under the terms of the call for tenders[49]. This first call has paved the way for a new industrial sector; indeed, several plants are currently under construction in France.

A second call for tenders was launched in March 2013, covering two areas (Tréport, Yeu and Noirmoutier islands). The commissioning of these wind farms, with a maximum capacity of 1,000 MW, is planned between 2021 and 2023.

In overseas France, the development potential of the offshore wind energy sector is low, particularly due to bathymetry, but also due to seismic and cyclonic issues. However, the usable potential is nevertheless significant in relation to local needs (although it is unlikely that the technically usable potential alone will provide self-sufficiency for these islands).

Technical advances in the field of floating wind turbines might allow the exploitation of areas located much further offshore, where winds are strong and depth is a limiting factor for fixed wind turbine installation (particularly in the Mediterranean). This technology also has benefits in the reduction of impacts on marine ecosystems.

As part of the Investments of the Future programme, AMI Marine Energies, led by ADEME, has financed two demonstration projects in the floating offshore wind energy sector:

- The first prototype from the WINFLO project will be tested from 2015 off the French coast (Groix) and the first pre-production run could be manufactured in 2016, depending on the results of these tests.
- The floating wind turbine developed as part of the VERTIWIND project has a vertical axis to increase its stability. The wind turbine will thus have a buoyancy system requiring a draught of only around 10 m. The prototype will be tested in the Mediterranean off Fos-sur-mer, where an experimental farm of 13 units is already being studied with the support of the European NER300 fund.

The SEMREV experimental research project (École Centrale de Nantes) should also be installed soon offshore from Croisic.

Marine Current Turbines[50]

BRIEF TECHNICAL DESCRIPTION

Current turbines are submerged or semi-submerged turbines that are moved by the kinetic energy of marine currents. Structures using the kinetic energy of currents can take different forms: vertical or horizontal axis turbines, but also "paddle wheels" or oscillating devices. As with wind turbines, current turbines can be installed on supports fixed to the seabed or floating on the surface. The fixed systems may be entirely underwater or have an emerging pylon.

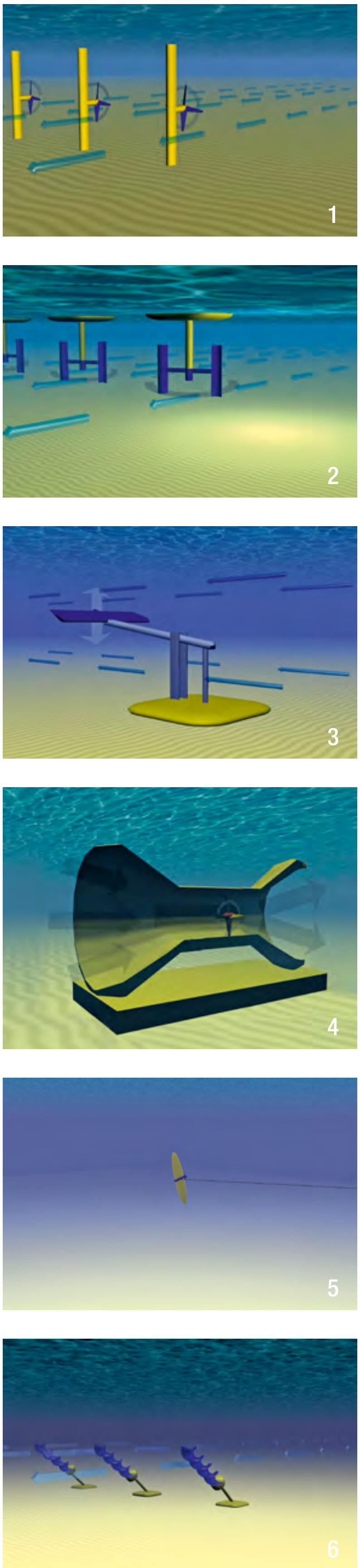


Figure 4: Diagram of the different current turbine designs[51]: 1) horizontal axis turbines, 2) vertical axis turbines, 3) oscillating hydrofoils, 4) venturi effect devices, 5) tidal kite, 6) Archimedes' screw.

> "Within the European Union, offshore wind farms currently supply 0.3% of the total electricity demand.

42 BBC article "New UK offshore wind farm licences are announced".
43 However, the graded area around the foundations, protection against scouring, and cable routing must be considered.
44 www.aquaret.com
45 IFREMER, 2009, Ibid.
46 French Renewable Energy Association, 2013, "A roadmap for offshore wind energy: 15,000 MW by 2030".
47 Link: http://fee.asso.fr/politique-de-leolien/eolien-en-mer/
48 www.aquaret.com
49 The contract specifications require 20% operational power in April 2018, 80% in April 2019 and 100% in April 2020.
50 We only deal here with turbines using tidal currents; not offshore thermohaline currents.
51 www.aquaret.com

Since tidal currents are predictable, the associated electricity production can be accurately predicted. Since the density of water is 800 times higher than that of air, turbines installed in high-current areas are smaller in size than wind turbines of the same power.

Marine current turbine OpenHydro © EDF / TOMA

DEVELOPMENT POTENTIAL

Located in an area where tides are among the highest in the world, France has the second highest marine hydropower potential in Europe, just behind the United Kingdom. Ifremer estimates in a prospective study[52] that the potential of marine hydropower in metropolitan France is 10 TWh (400 MW), which is 15 times less than the potential of floating wind energy.

The potential in metropolitan France is found in tidal areas where the average current speed is greater than 1.5 m/s, such as on headlands or in bottlenecks between islands and the mainland, mainly in the English Channel. In French overseas territories the development potential of this energy sector is low. Favourable areas are limited (e.g. lagoon passes, where currents are permanent and often very strong) but would allow decentralised production (which may be of interest to some French overseas territories).

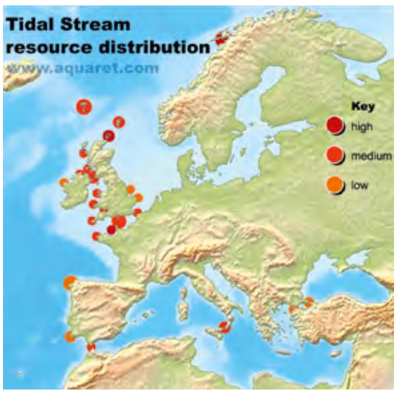


Figure 5: Map of tidal current resources, expressed in terms of current velocity[53].

In France, there are currently no operational turbines for commercial production. However, in the coming years, the blades of dozens of turbines could rotate off the French coast. On 30 September 2013, the government issued a call for expressions of interest (EOI) to support the establishment of four pilot parks. Two sites have been selected: Raz Blanchard, at the north-western tip of the Cotentin and the passage du Fromveur off the coast of Finistère (these two areas account for 80% of the energy potential of marine currents in France).

The Paimpol Bréhat site, off Ploubazlanec in the Côtes d'Armor region of Brittany, has been undergoing field tests since the summer of 2012.

Tidal barrages

BRIEF TECHNICAL DESCRIPTION

In the tradition of the tidal mills spread along the Breton coast, tidal power plants such as the one at Rance take the form of a dam that creates a basin. Tidal energy uses the difference in water level between the basin and the sea, a function of the tide. Installations can use the entire cycle (rising and falling tide), or only part of the cycle. This type of system requires very specific conditions, since it requires both high amplitude tides and a bay or estuary favourable to the creation of a dam delimiting a sufficiently large basin surface.

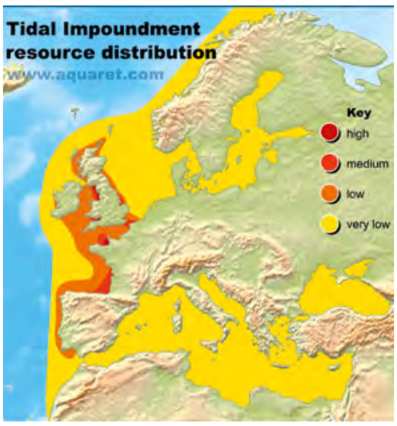


Figure 6: Map of tidal power resources as a function of tidal amplitude[54].

DEVELOPMENT POTENTIAL

The Rance plant is the oldest in the world and the only one in France, with a capacity of 240 MW. Installed in 1966, it has provided significant feedback regarding this technology. Currently, no other tidal power plant project appears to be developing in France, as the lack of suitable sites and the environmental impacts of the watercourses and marine environments involved discourage the development of further projects along the French coast.

It is been suggested that tidal basins be developed adjacent to the coast[55], in large bays rather than in estuaries: alternatively, these huge basins could channel the flow of the tide towards hydropower plants distributed along seawalls. These projects have yet to be subjected to environmental studies to date, would require very significant construction work, and would also impact on marine environments (extraction of aggregates for the seawalls, etc.).

Finally, tidal energy projects involving artificial lagoons of a more limited size (port basins, etc.) are also being considered.

Wave energy converters

BRIEF TECHNICAL DESCRIPTION

Wave energy converters use the energy of waves and swells to produce electricity. A large number of techniques have been developed to exploit this energy resource: floating structures (such as Pelamis, which uses the movement by the swell of an articulated structure), oscillating water columns (which use the compression of air due to the variation of the water level in a compartment to operate a turbine), overtopping devices, immersed systems on the seabed, and articulated systems (EMACOP project[56] led by CETMEF is a system attached to a seawall and equipped with a articulated arm attached to a floating element), etc.

Most of these devices are intended for offshore installation, except those with overtopping, oscillating water columns and articulated arms, which can also be installed on the coast.

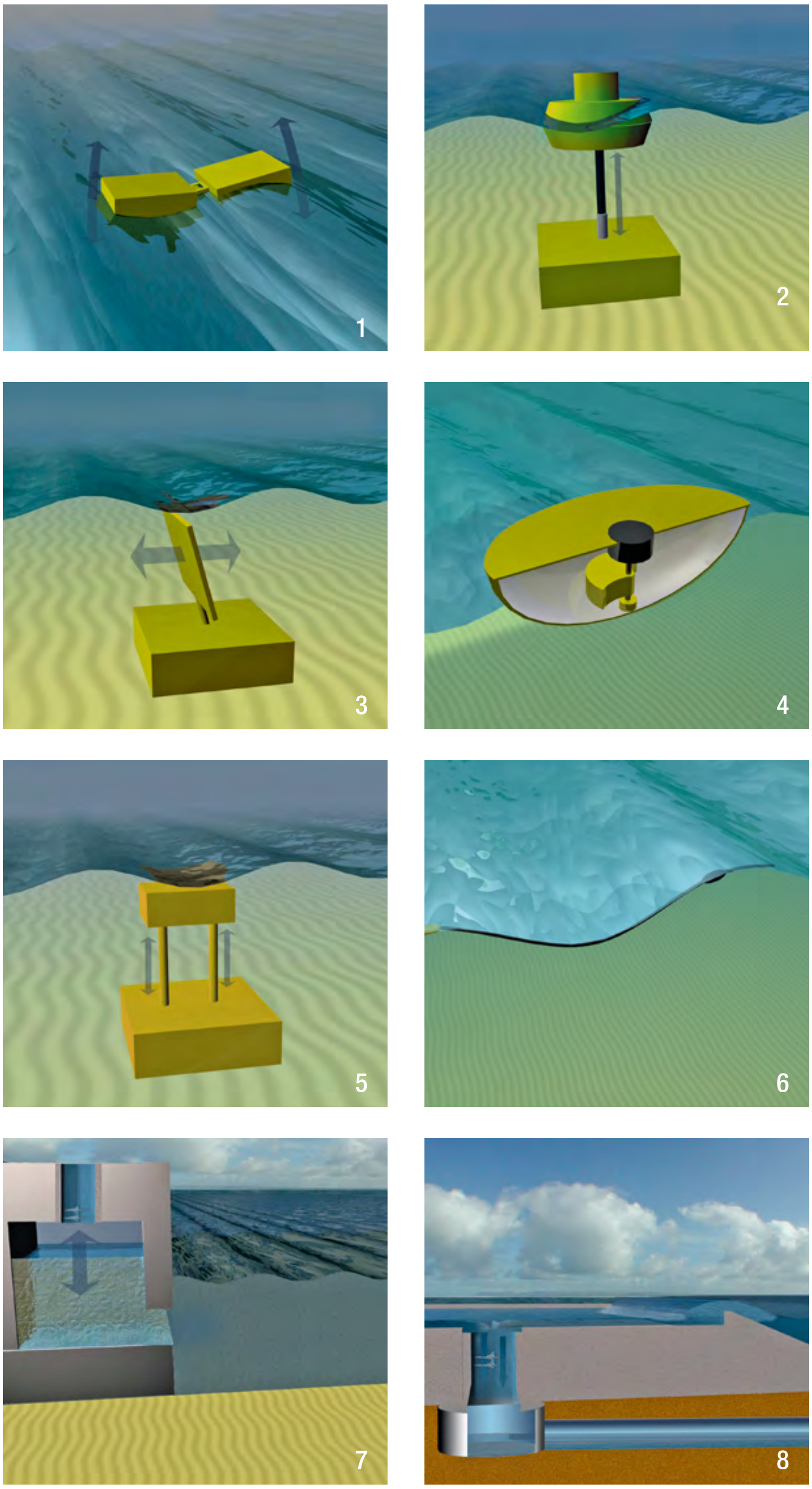


Figure 7: Diagrams of the different wave power concepts[57]: 1) attenuator, 2) point absorber, 3) oscillating wave surge converter, 4) rotating mass, 5) submerged pressure differential device, 6) bulge wave device, 7) oscillating water column, 8) overtopping device.

> France has the second highest marine hydropower potential in Europe, just behind the United Kingdom.

DEVELOPMENT POTENTIAL

Ifremer estimates, in its prospective study[58] , the potential wave energy in metropolitan? France to be 40 TWh (200 MW), while ADEME, in its roadmap, estimates that the technically exploitable potential in France is 10 to 15 GW[59], mainly on the Atlantic coast.

52 IFREMER, 2009, Ibid.
53 www.aquaret.com
54 www.aquaret.com
55 Speech by F. Lempérière (Hydrocoop) at the SHF conference "EMR 2013". Link to the Hydrocoop website: http://www.hydrocoop.org/

56 Link: http://www.letelegramme.fr/iggenerales regions/finistere/energies-marines-le finistere-a-la-pointe-de-la-houle 10-12-2013-2332304.php?utm_source=rss_telegramme&utm_medium=rss&utm_campaign=rss&xtor=RSS-24
57 www.aquaret.com
58 IFREMER, 2009, Ibid.
59 ADEME, 2010. Roadmap for renewable marine energy.

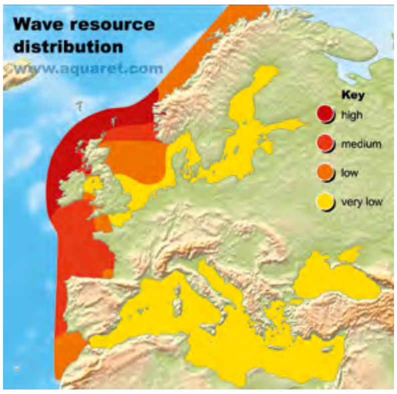


Figure 8: Map of wave resources as a function of swell size and waves generated by the wind[60].

To date, no wave power systems have been installed on the French coast, but various projects are being developed in mainland and French overseas territories. These include the SEA-REV project of the Ecole Centrale de Nantes, which involves a floating system with a weighted section that is set in motion by the swell in the manner of a pendulum. DCNS and Fortum are also planning a pilot installation based on the Wave Roller system to be installed in Audierne Bay, in southern Finistère. CETMEF is working to identify suitable sites for wave power devices integrated into port dikes, using the concept of an oscillating water column or articulated float.

In overseas France, the potential for wave energy use is significant, particularly in islands exposed to ocean swells. Projects using the Pelamis and CETO systems (submerged buoy system set in motion by the swell) could be developed on the coast of Reunion Island. A full-scale CETO prototype is being installed and tests will be carried out in 2014.

"Houles Southern" project (EDF EN) © Energies Reunion

There is also significant potential in Polynesia and New Caledonia and, more locally, in Guadeloupe and Martinique.

Ocean thermal energy Conversion (OTEC)

The thermal energy of the ocean is associated with the direct absorption of solar radiation by the surface waters of the oceans. The European Union uses the term hydrothermal energy for "energy stored in the form of heat in surface water".

BRIEF TECHNICAL DESCRIPTION

The ocean is thermally stratified, with the upper layers reaching higher temperatures, especially in intertropical areas (above 24°C and up to 30°C), while the temperature is low in deep water (about 5°C at around 1000 m depth).

Pelamis © Ocean Power Delivery

Therefore, we can exploit:

- the heat from the upper layers: heat pumps for heating;
- the cold of the lower layers: "Sea Water Air Conditioning (SWAC)" for cooling;
- the temperature differential between surface and deep water: the "ETM" (énergie thermique des mers) or "OTEC" (Ocean Thermal Energy Conversion), is a thermal system (surface-to-deep water pump, exchanger and turbine generator) and is designed to produce electricity.

Unlike most other MREs, OTEC production is stable, predictable and continuous on a 24-hour basis and could thus directly replace thermal power stations in isolated insular areas.

OTEC power plants can be of three types: open cycle, closed cycle, or hybrid cycle. In an open cycle, the water pumped from the surface passes through an evaporator where the pressure is low in order to lower the evaporation threshold of the fluid. The water vapour drives a turbine coupled to an alternator, then condenses on contact with the cold water pumped from deep below the surface. A closed cycle system (the most common and the only fully developed type), uses a heat transfer fluid (e.g. ammonia) which is evaporated by the heat from the surface water. After driving a turbine, the vapour passes through condenser cooled by cold deep water and returns to its liquid state, and the cycle is repeated (circulation pump).

The hybrid cycle combines the two principles to produce fresh water by condensing seawater vapour.

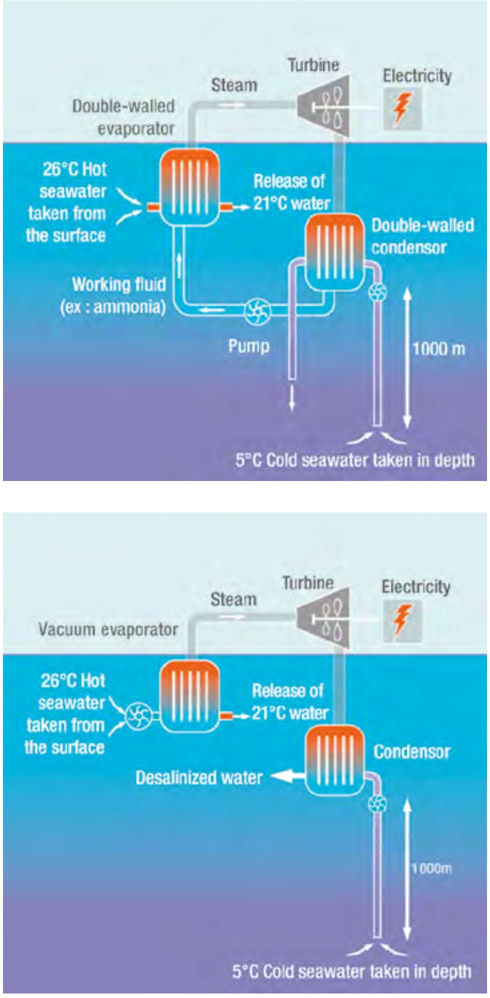


Figure 9: Operating principle of the MTE 1) closed and 2) open cycle[61].

This technique requires the pumping of large volumes of water, using pipes with a diameter of several metres.

DEVELOPMENT POTENTIAL

The technique of using the thermal gradient is not new, having been first tested in 1930. In metropolitan France, where surface temperatures are low, MTE cannot be used because a temperature gradient close to 20°C is required to obtain sufficient output.

Tropical regions, on the other hand, are particularly favourable to the development of the MTE sector as well as SWAC for air-conditioning, as surface water temperatures can reach about 25°C, compared to 5°C at 1,000 m depth. On Reunion Island, a scaled-down onshore prototype has been built at the University technologic instituelUT in Saint Pierre, and a major urban SWAC project is under way to air-condition several buildings in Saint-Denis. Various types of projects are underway off Reunion Island, Tahiti and Martinique (a full-scale demonstrator is planned by DCNS).

Some small-scale seawater air conditioning systems have been developed or are under study (and heating in Seyne sur Mer and Monaco). A well-known sea water air conditioning project is in place in Bora-Bora and another is already operating in Saint-Denis in Reunion Island.

According to the report of a study on marine renewable energies[62], SWAC is expanding in France; there is a significant demand in tropical areas but also in parts of metropolitan France where air conditioning is widely used. MTE is expensive but is progressing, with a significant niche market in islands.

Finally, coastal projects with marine heat pumps (PAC) using seawater already exist for air conditioning and heating of buildings by the coast. They share some common issues with the SWACs with regard to impacts, and a synergy needs to be developed for issues related to the adaptation of techniques from terrestrial to marine environments. ■

> "The technique of exploiting the thermal gradient is not new, as the process was first tested in 1930.

60 www.aquaret.com
61 http://www.connaissancedesenergies.org/fiche-pedagogique/energie-thermique-des-mers-etm
62 CGEDD/CGEIET, March 2013, Ibid.

Focus: Development of "Marine renewable energies" projects in Reunion Island

Prototype Onshore Marine Thermal Energy plant (PAT ETM) - DCNS © Energies Reunion

■ Reunion Island has been engaged for many years in the development of Marine Renewable Energies as it aims to be energy self-sufficient by 2030, i.e. 100% renewable energy. To date, 35% of electricity comes from local renewable sources and several Marine Energy projects are in the testing phase.

As regards thermal projects, two SWACs are under review, one for a hospital in the south and the other an urban air conditioning network in the capital Saint-Denis. An onshore OTEC prototype (PAT) has been operational since mid-2012 to facilitate R&D on the energy system. In addition, two wave energy projects are being launched, with a prototype based on CETO technology currently in the installation phase, and a project based on PELAMIS technology with a storage system, which is currently undergoing trials. Of note is that Reunion Island is unsuitable for hydropower turbines due to weak tidal currents. Reunion Island is therefore ineligible for the state aid offered to support this technology.

Among the two most advanced projects, the PAT system was the product of an agreement between the Reunion Island Region and DCNS, and was financed by the French government via a stimulus package and by the co-owners, Région Réunion and DCNS (the system's designer). A previous agreement had enabled a feasibility study to be carried out for an offshore power plant. The University of La Réunion is also involved in the project as operator of the installation (since the PAT is located within ITU facilities) and university researchers are working in collaboration with DCNS to carry out tests. This research aims to find an optimal energy system that will be used in future offshore plants. Particular attention has been paid to safety and local, environmental and regulatory acceptability. Consultation with government departments was carried out in advance in order to set up processes that were endorsed by all stakeholders.

The other well-advanced project is the Southern Houles (Houles Australes) project based on CETO technology and led by EDF EN. The other well-advanced project is the Southern Houles (Houles Australes) project based on CETO technology and led by EDF EN. Again, the Region of Reunion Island has taken on the role of co-owner and funds from the stimulus package have financed the project. The full-scale prototype currently being developed will provide data throughout 2014; it will thus enable the system's performance to be monitored and the environmental impacts assessed. The latter is a point of great concern to the co-owners, even though the relevant regulations are still unclear. Marine mammals, which are common in the area, are monitored before work is carried out, during tests and after dismantling. In addition, hydrophones will be used to accurately measure the noise generated by the prototype during the test phase.

Through these projects and experience gained in the field, in 2014 Reunion Island will become the tropical hub of the national project "France Energies Marines". ■

*Golden perch or striated emperor (*Gnathodentex aurolineatus*) in front of corals and sponges © Jérôme Paillet / Marine Protected Areas Agency*

Evaluation of the impacts of different MRE systems, and recommendations

In the caves of Crozon, at Cap de la Chèvre © Yannis Turpin / Marine Protected Areas Agency

In examining the impacts of marine energy development, it is important to place local impacts in the context of larger-scale, or even global, impacts. Climate change is a growing threat to biodiversity, but the use of marine renewable energies can substantially reduce greenhouse gas emissions and limit the effects of climate change.

Also, through the development of these energy sources, it would be possible to avoid, for example, toxic pollutants related to the extraction, transport and refining of fossil fuels (oil, natural gas, oil shale and shale gas) and local environmental impacts due to large hydropower installations etc.

These global and local benefits (positive impacts) must, however, be balanced against the specific negative effects that these technologies can have on marine life.

Some prior comments…

› To date, no offshore wind turbines, hydropower turbines or wave systems have been installed in France for commercial production.

› In the case of fixed wind turbines, we can draw on the experience of our European neighbours, in particular the studies carried out on Danish (the oldest are Horns Rev and Nysted), Dutch (e.g. Egmond aan zee), Belgian (e.g. Thorntonbank) and German (Alpha Ventus experimental park) wind farms. As the "fixed wind" technology is more mature, the knowledge of impacts is also more detailed than for other technologies.

› It should be noted that this report only highlights the impacts (positive or negative) identified during the construction and operation phases. The issue of decommissioning is the subject of a separate, in-depth section. In addition, cumulative impacts are not discussed in detail. The question of synergies/conflicts between uses is also the subject of a specific detailed section.

Velvet crab © Frédéric Lechat

Threat: Noise and vibration

© Alstom – Nicolas Job

Offshore wind turbines

POTENTIAL IMPACTS DURING THE CONSTRUCTION PHASE

The construction phase of wind farms will inevitably generate noise during seabed preparation (e. g. levelling, which may include the use of explosives), foundation installation and ship traffic.

The type of foundation (monopiles, tripods, jackets, and gravity for fixed wind turbines) has a significant influence on the type and degree of disturbance, as does the installation technique (e.g. driving, drilling, vibratory sinking). The construction of gravity foundations is therefore less noisy than pile driving of foundations, which can cause significant acoustic disturbances. The installation of foundations by drilling is also, at first glance, less noise-generating underwater than pile driving. The resulting effects, however, depend on a number of other factors, such as the topography and composition of the seabed, the diameter of the piles, the existing environmental noise and the marine species present.

Generally, the impacts of noise should be temporary. But the noise caused by pile driving can kill or injure fish (especially those with swim bladders), mammals and sea turtles, cause behavioural disturbances or cause them to temporarily abandon or leave an area that can extend for tens of kilometres from the construction site[63]. The displacement of species is likely to seriously affect the use of spawning and nursery grounds if appropriate seasonal bans are not applied. Marine turtles can be particularly sensitive to any habitat loss, even temporarily, as they appear to be highly inflexible in terms of their spatial distribution patterns. Fish larvae and juveniles could be particularly vulnerable to significant noise exposure. Studies on a few species have not shown any evidence of direct mortality, but the long-term effects on individual growth remain unknown. Similarly, areas harbouring resident marine mammals (seal colonies, sedentary mammal populations, etc.) are a major issue for this type of project.

63 IUCN, 2010, Greening Blue Energy. Ibid.

C-Power wind farm on the Thornton Bank (Belgium) © Sylvain Michel

The installation of the anchors used for the floating wind turbines could result in lower noise impacts, although precise comparative studies are currently lacking. However, in this case, seabed preparation may also require dredging operations that produce noise, which is nevertheless lower than pile driving, but which causes the materials to be resuspended.

The impact on marine organisms of noise and vibration caused by various marine activities (transport, fishing, oil exploration, and civil and military sonar) is relatively unknown. Although studies[64] have been conducted on the subject, they have not yet led to definitive conclusions. This particularly applies to the noise tolerance threshold of each species and their behaviour in the face of these disturbances. The studies were conducted mainly on mammals (pinnipeds and small cetaceans), whose behaviour is easier to observe.

Further research is therefore essential to assess the full effects of MRE.

In addition, the structures must be transported by ships from the port where they are stored to the installation site. Furthermore, there are other boats needed to prepare the area and install the structures. All of these vessels are a source of noise and disturbance for organisms, in addition to pre-existing traffic.

POTENTIAL IMPACTS DURING OPERATION

Noise and vibrations from the rotation of the blades travel through the water. During the operating phase, the overall noise intensity is lower than during construction (and generally lower than that of noise caused by other marine activities such as transportation or associated with natural surface movement) and does not appear to cause injury to any organisms. From a behavioural perspective, the effects on marine mammals and fish appear to be low. However, the results of experiments are still incomplete, and as certain species may be more sensitive to them, additional studies could help to better establish the sensitivity thresholds for the different species. Available information suggests that the impact of airborne noise on birds and bats is low, but these effects are poorly understood. Bats are mainly affected by sudden pressure variations in the vicinity of the blades.

C-Power wind farm on the Thornton Bank (Belgium) © Sylvain Michel

Marine Current Turbines

POTENTIAL IMPACTS DURING CONSTRUCTION

The presence of ships and the preparation of the substrate to accommodate current turbines generate noise. Depending on the particular project, mechanical operations may be necessary, such as pile driving or drilling in the case of a pole-mounted turbine. In comparison, a turbine fixed with ballast that requires no pile driving or drilling could generate less noise during installation.

POTENTIAL IMPACTS DURING OPERATION

The rotation of the turbine by marine currents induces vibrations that travel through the water. However, as this sector is still in its infancy, we know little about the noise associated with the operation of these turbines.

It is worth mentioning the study of the Sabella D3 prototype turbine in the Odet

Estuary in South Finistere, which has not demonstrated significant impacts on the behaviour of fish using the estuary. It should be remembered that even in the absence of hydro turbines, high-current areas already experience intense hydrodynamic noise.

Wave Energy Converters

POTENTIAL IMPACTS DURING CONSTRUCTION

As with wind and hydro power turbines, floating installations can be transported from the port of storage to the installation site by vessels. This source of noise (lower than that of commercial vessels operating at high speed) is in principle not a cause of injury or death.

POTENTIAL IMPACTS DURING OPERATION

The mechanical noise generated by wave energy converters is probably no greater than the noise emitted by boats during installation, or the natural hydrodynamic noise that increases significantly in the presence of waves.

However, the moving parts of the device can produce noise over a very different frequency range than natural noise, and its intensity may increase with system wear or the development of fouling. Anchor chains can vibrate, but his impact is poorly known and the potential consequences on organisms have not yet been identified.

Tidal barrage

POTENTIAL IMPACTS DURING CONSTRUCTION

Tidal power plants do not require structures to be installed deep within the seabed or estuary, so their construction is theoretically less likely to generate underwater noise than other energy systems. However, the construction of the barrage and temporary structures requires a large number of lifting devices and specialized vessels that move large quantities of materials, resulting in a significant increase in noise throughout the construction site.

POTENTIAL IMPACTS DURING OPERATION

Hydroelectric turbines can produce significant noise when rotating, especially if, as with other technologies, the mechanical parts are worn, dirty, or insufficiently lubricated. These sounds can propagate through the water for several kilometres, but if the plant is located in an estuary, its topography limits this propagation to a relatively narrow area.

However, actual monitoring at the Rance site did not reveal any changes in animal behaviour related to noise.

> Additional research is therefore essential to assess the full effects of MRE.

Power Oyster 800 wave converter developed by Aquamarine Power at the EMEC test site at Bilia Croo, Orkney Islands (Scotland) © Sylvain Michel

64 Studies relevant to MREs include (among others): Cowrie july 2010, acoustic mitigation devices (amds) to deter marine mammals from pile driving areas at sea: audibility & behavioural response of a harbour porpoise & harbour seals.

Ocean Thermal Energy Conversion (OTEC)

POTENTIAL IMPACTS DURING CONSTRUCTION

Acoustic impacts during the construction of a floating plant will be similar to those of any floating devices (wind, hydroelectric or wave), except that their source will be located at a single site, rather than dispersed over multiple points. Underwater noise generation can be likened to that of the installation of a floating oil platform, with the difference being that the ETM plant will probably be closer to the coast, and therefore to the coastal ecosystems. The acoustic impact of an onshore MTE plant would be similar to the laying of an underwater pipeline, but at a far greater depth (1,000 m) than discharge (wastewater, industrial effluents) or pumping (cooling, desalination) pipelines.

POTENTIAL IMPACTS DURING OPERATION

Two types of underwater noise would be generated by an plant. Firstly, noise and vibration would come from the operation of heat exchangers and electrical transformers in the plant (inside the floating platform), and secondly, grinding noise from submerged pipes up to 1,000 m long, which would increase during periods of high surface disturbance (cyclones). DCNS is conducting a noise modelling study of a floating plant for its project in Martinique. However, the effects of these disturbances on marine wildlife as yet remain unknown (particularly for marine mammals in the AGOA sanctuary).

Recommendations for the protection of biodiversity[65]

For the preservation of marine and coastal biodiversity, we recommend, in particular:

› the development of knowledge on the potential impacts of seismic surveys during the exploration phase (geotechnical surveys).

Sound waves (especially low frequencies) can propagate through water for more than a hundred kilometres. This type of noise pollution is potentially harmful to aquatic fauna, in the same manner as the noise pollution generated by an MRE site.

However, high-resolution seismic waves associated with geotechnical engineering use low energy compared to the high-penetration seismic waves used for oil exploration, which have been associated with mass marine mammal stranding. The former use higher frequencies that propagate little; however, they may still have significant effects on wildlife, and these effects need to be studied in order to be minimised.

› the consideration of habitat use and migration patterns of sensitive species when developing MRE systems.

Common bottlenose dolphin (Tursiops truncatus) © NASA

Firstly, the choice of construction period can help to minimize some negative impacts.

By avoiding the migratory times of marine mammals or the breeding periods of noise-sensitive species, we can reduce the number of affected individuals, or the degree of disturbance during the most crucial life history stages for the maintenance of populations.

This measure is difficult to implement: the main breeding season for many species in temperate regions extends from spring to early summer, which corresponds to the favourable conditions for carrying out off-shore operations. It will therefore be necessary to target, on a case-by-case basis, the critical periods for the most sensitive species or species at risk, in order to minimize the overall impacts of operations. Nevertheless, it should be kept in mind that an excessive reduction of work windows can lead to delays in the construction schedule, which will then extend over longer periods of time and ultimately have a more prolonged impact on the species and habitats.

› the development and systematic implementation of proven techniques to reduce the noise impacts of projects, such as:

When several options are possible, depending on the geological characteristics of the seabed, the choice of foundation type can help to reduce the acoustic impacts of construction.

It is also possible to reduce sound propagation by forming a curtain of bubbles around the pylons, or by wrapping the latter in acoustic insulation. However, these technologies are unproven in areas with strong tides, such as in the English Channel and on the French Atlantic coast, and their efficacy is strongly dependent on the currents.

Other measures can be taken to encourage organisms to move away from the source of the noise and avoid injury. For example, the 'pinger' device emits sounds that encourage individuals to move away before the commencement of pile-driving. However, the effectiveness of acoustic deterrents must be carefully verified as suitable for the species present under the environmental conditions of the site,

Leaping Common bottlenose dolphins (Tursiops truncatus) in the Iroise Marine Natural Park © Sylvain Dromzée / Marine Protected Areas Agency

as their effect may be negligible or even adverse depending on the species. For example, the Ping-Iroise project (PNMI) showed no significant repulsion of porpoises and dolphins by pingers attached to fishing trawlers, with similar numbers of incidental captures with or without pingers. Furthermore, where repulsion is effective, it must also be ensured that it does not lead to a prolonged loss of functional area for affected species (e. g. abandonment of a feeding area).

A gradual increase in pile driving force (soft start) is a way to allow time for organisms (mammals, large pelagics and marine turtles in particular) to leave the area before maximum noise emission is achieved. However, the evidence of its effectiveness is unclear. Individuals may become habituated to the noise as the increase occurs, and thus fail to demonstrate avoidance behaviour.

› ensuring visual (and acoustic) monitoring of construction zones during each operation likely to cause disturbance or harm to pelagic organisms (presence of observers and operators of passive acoustic devices on board construction vessels, implementation of mitigation protocols), as is practised on seismic surveys or oil exploration, for example.

› Finally, the "acoustic barrier" effect caused by underwater noise can be reduced by gradually phasing in the construction of several MRE parks located in the same marine region.

By staggering the noisiest activities in the various projects over time, animals escaping the disturbance would be able to move to a refuge area. This would require consultation between the various project leaders, and for them to agree to modify their work schedules, despite generally very tight operational constraints. ■

I 65 IUCN, 2010, Greening Blue Energy. Ibid.

Opportunities and Threats: Habitat Modification

Torpedo ray © Frédéric Lechat

Offshore wind turbines

POTENTIAL IMPACTS DURING THE CONSTRUCTION PHASE

**> Permanent:
Modification of the seabed**

Locally, the natural substrate is completely destroyed by drilling, dredging during levelling, laying anti-scouring materials, and the footprint of the wind turbine foundations. Excavation of the seabed for the foundations (approximately 8 m in diameter by 20 to 30 m deep) and trenches for cable burial (several hundred kilometres in total) can, locally, destroy the benthos[66], and will produce quantities of sediment that will impact habitats.

These impacts, however, will vary depending on the type of foundation: a gravity-based wind turbine is likely to have a larger footprint than an anchored floating wind turbine.

However, this destruction may be followed by recolonisation, particularly on soft substrates with high resilience. But if artificial structures have replaced the loose substrate, they will be colonized by species typical of hard substrates, resulting in an ecosystem very different from its original state.

Resilience is much lower in rocky reef type habitats. We emphasize in particular the role and importance of macroalgae, in particular kelp forests[67] described as some of the most dynamic and biodiverse habitats on the planet (Brikett et al., 1998) (Noderhaug et al., 2007).

**> Temporary:
Resuspension of materials: fish, benthos, plankton, filter feeders**

The remodelling of the substrate, necessary to accommodate wind turbines or for cable burial, results in the temporary, localized resuspension of materials, which can impact various biological components of the area.

This phenomenon increases turbidity, and thus prevents the light from penetrating the water body. Light is essential for phytoplankton development, and the decrease in photosynthesis can slow their development.

Turbidity also affects the development of macroalgae, especially when construction takes place in the spring when they are growing.

High turbidity can also lead to blockage in fish gills.

Filtering organisms are also affected: in particular, the digestive tract of hydroids and bryozoans can be affected by the absorption of these particles. In addition, the deposition of these materials on the seabed can cover organisms that live there. It should be noted that the area impacted by the resuspension of materials, as well as their deposition, depends significantly on the effects of the swell, the strength and direction of the currents in the area, as well as the nature of the materials.

Resuspended sediments can contain various pollutants (heavy metals, hydrocarbon derivatives such as PAHs, pesticides, etc.), which can disperse in water and contaminate living organisms. This risk is particularly high if the site is located near an estuary, a large port or a port sediment disposal area.

POTENTIAL IMPACTS DURING OPERATION

> Permanent: Disruption of hydro-sedimentary regimes

The installation of structures in the water column can locally modify currents. In soft substrate, there is a risk of upstream erosion and downstream deposition due to slowing currents. Installing boulders at the base of the fixed wind turbines protects against erosion around the foundations, but the decrease in current velocity downstream of the structures favours the deposition of particles that the device does not protect. These deposits pose a risk to the recovery of habitats around foundations.

In addition, the accumulation of organic matter (and possibly the associated decrease in oxygen) is due to the significant development of biofouling on the foundations. This generates (through filtration by fixed organisms) a transfer of organic matter from the water column to the benthos, but this impact will only occur in low-hydrodynamic areas. Research shows that this impact may be quite localized (depending on currents), but further research is needed to better understand the extent of these impacts beyond wind farms.

> Permanent or temporary: Chemical inputs

Antifouling paints (paints that limit the development of marine organisms) have a strongly negative impact on the surrounding fauna: as their purpose is to limit the colonisation of marine organisms, they are highly toxic to them. However, new generation coatings (e. g. silicone based) are much less toxic than earlier ones.

It should be noted that these biocides are also used on ships and, more generally, on many artificial marine structures, and that their use is regulated. Research is underway to develop the use of naturally occurring compounds from marine organisms in these coatings.

Also notable are the risks of pollution with the use of chemical lubricants (oils), particularly in the event of accidental system rupture, although their use is regulated and they must readily biodegrade. Risks also arise during maintenance operations. This oil typically must be recovered and destroyed by facilities specializing in the treatment of highly polluting materials.

> Resilience is much lower in rocky reef-type habitats.

Lobster © Frédéric Lechat

66 Burial is primarily to protect the cables from fishing activities such as dredging and trawling, but which in turn potentially impacts the benthos.

67 Brikett et al.,1998 et Noderhaug et al., 2007; data synthesized by J.C. Ménard, Loire Vilaine Estuaries

Anti-corrosion devices (cathodic protection) release oxides from metal anodes (copper, zinc, aluminium, etc.). It is possible that the accumulation of these substances in sediment and water may affect benthic animals, but no studies have yet been conducted to confirm this.

Chemicals can also be released into the environment through accidental pollution, from improper handling during maintenance operations, or from collisions between ships or a ship and a wind turbine.

> Permanent: Electromagnetic fields (EMF)

EMFs are generated by the cables between generators and electrical junction boxes, by the electrical transformer station (especially if it is submerged), and by very high voltage transmission cables (several tens of thousands of volts). These cables can be buried in the substrate (embedded), laid on the bottom or sitting in open water (for floating devices). The magnetic field (MF) is strongest at the surface of the cable and increases with the intensity of the current carried. It decreases rapidly with distance from the cable. It is therefore stronger in the vicinity of a cable in open water or laid at the bottom, but weaker when the cable is buried or encased. In the latter case, the cable does not emit an electric field as it remains trapped inside the cable by an external metal screen.

The long-term effects of EMF are poorly understood for most groups of marine organisms (cetaceans, elasmobranches, crustaceans, etc.). Although submarine power transmission cables have been installed for decades (connections to islands), few studies are available on the effects of magnetic fields except, notably, the effect of an offshore wind turbine cable from the Nysted wind farm on several fish species[68]. However, many groups of animals are sensitive to minute variations in magnetic (cetaceans) or electric (elasmobranches) fields. It should be noted that electric fields can be induced in the animals' bodies when they pass through the magnetic field produced by the cable. It is also necessary to differentiate between EMFs[69] associated with alternating and direct currents, which have very different intensities and ranges.

Marine Current Turbines

POTENTIAL IMPACTS DURING CONSTRUCTION

> Permanent: Degradation of seafloor benthos

Again, the footprint of the structure itself must be considered. This also concerns the anchoring of electrical cables: in the presence of strong currents, the substrate is generally hard (rocky) and cable burial is therefore not feasible, nor indeed always necessary due to the lack of dredging and trawling in these areas. The impacts on benthos are tied to the destruction of the habitat at the site, and the possible displacement of the more mobile species. Benthic habitats have a wide range of resilience capacities.

> Temporary: Resuspension of materials

Depending on the particular project, seabed remodelling operations may involve the resuspension of materials. Since the areas suitable for marine current turbines experience fast currents, the quantity of mobile materials is generally limited, but the effects of their resuspension may be felt for some distance.

POTENTIAL IMPACTS DURING OPERATION

> Permanent: Disruptions of hydro-sedimentary regimes

The operation of the turbines modifies the hydrodynamics downstream of the structures (wake effect). As the turbine captures some of the energy, this change favours the sedimentation of particles transported by the water mass under the influence of currents. Hydro-sedimentary modifications can locally modify benthic habitats in the case of commercial scale hydrological deployment. However, evidence is limited, and this phenomenon is not well known in the context of hydro turbines.

For a commercial fleet, composed of a large number of turbines, a long-range effect on sediment transit could disrupt habitats several kilometres away (e. g. hydraulic dunes, which play an essential role as nurseries for certain fish species).

> Permanent or temporary: Chemical inputs[70]

Water turbines are likely to cause impacts related to anti-fouling treatments used to prevent the colonization of machines by marine organisms, or anti-corrosion devices.

Other chemical pollution risks may be limited.

© EDF / TOMA

Rance Tidal Power Plant © Y. Le Gal - EDF

Tidal barrage

POTENTIAL IMPACTS DURING CONSTRUCTION

> Permanent: Disturbance of the hydrodynamic regime

The construction of a tidal power plant involves major work; this phase is best illustrated by the example of Rance. At the time (it is likely that the procedure would be different today), the estuary was closed for the construction of the tidal power plant. To this end, two systems were installed upstream and downstream in order to create the dam. This closure of the estuary lasted three years, during which time the estuary's functioning was greatly modified. As the tide no longer directly affects the estuary, it has been desalinated by the flow of the Rance River. The stabilization of the water mass in the vicinity of the coast at 8 m has led to a conversion of habitats between 8 and 13.5 m into terrestrial habitats and a significant shrinkage of the foreshore. Organisms are very sensitive to changes in salt concentration in their environment, as they are adapted to specific conditions under which they survive.

> Permanent: Habitat destruction

The physical influence of temporary structures on the ground and the exposure of certain areas of the estuary lead to the destruction of existing habitats. Estuaries are areas of high ecological value, and these habitats can be nurseries or spawning grounds; their disappearance therefore puts the species that depend on them at risk.

By transforming the Rance ecosystem, the dam has caused its gradual siltation. Some species have disappeared (sandeel, plaice) but others have since returned (sea bass, cuttlefish).

In fact, the fauna has totally transformed, as the smaller and faster species now account for the majority of the fauna. Their speed allows them to pass through the propellers of the barrage, which is impossible for the slower species (although a seal calf and a small porpoise have managed to do so). There are also fish spe-

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

69 France Energie Marine (FEM), unpublished, Guide GHYDRO, chapter dedicated to EMF.

70 For example, the fleet of turbines planned off Paimpol-Bréhat should not include any gearbox, cooling system, mechanical transmission or power electronics, or lubricating or cooling fluid. The off-shore converter would be hermetic and therefore unlikely to affect the surrounding environment (unless there is a defect or leak). It would contain about 4 m^3 of a non-toxic and biodegradable refrigerant.

cies such as sea bream (grey and royal), mullet (thicklip grey and golden grey), ray (thornback and cuckoo), pollack, wrasse and even, for some years, small sea bream.

POTENTIAL IMPACTS DURING OPERATION

> Permanent: Hydro-sedimentary disturbances

Electricity production by a tidal power plant requires a difference in water level on either side of the dam. To achieve this difference, water is impounded, which modifies the periods of natural immersion and exposure associated with the tide. As a result, when water is retained in the basin, suspended particles tend to settle more quickly in the absence of currents, resulting in siltation upstream of the dam. At the same time, however, it has been shown that the vast majority of sediments are of marine origin, yet the volumes of seawater entering at each tide have decreased due to the operation of the structure, so the volume of suspended solids that may be deposited has decreased. While siltation behind the dam and in the calm areas of the Rance estuary is undeniable, it is quite comparable to what is happening in similar nearby estuaries. A significant deposit of silt on another type of environment, however, can destroy it and leave an area where species that used to feed are now absent.

A study by Le Mao[71] ((based on fish catches in the eastern part of the Rance River between 1982 and 1984), demonstrated the impact of sudden changes in levels on certain invertebrate and fish populations. Since then, the operation of the tidal power plant has been modified to limit tide level variations to values present in the natural environment.

At Rance, the modified ecosystem underwent a period of stabilization for several years after construction, before reaching an ecological balance (although different from that which existed before construction)[72].

> Permanent or temporary: Chemical inputs

Some submerged metal components require anti-fouling treatment, with impacts already discussed above. However, cathodic protection (active or passive) has allowed a reduction in the number of painted surfaces.

Wave energy converter

POTENTIAL IMPACTS DURING CONSTRUCTION

> Permanent: Modification of the seabed

This usually involves floating devices, bottom-mounted devices or oscillating water column systems. Floating systems require anchorage points on the bottom; however, these occupy a small area, and the depth can be considerable (reduced effect on benthos). In the case of oscillating water column systems, they can be installed on pre-existing structures, which minimizes the natural surface area artificialized by construction. However, due to the diversity of wave and wave energy exploitation processes, the footprint on the seabed can vary considerably between projects.

POTENTIAL IMPACTS DURING OPERATION

> Permanent: Hydro-sedimentary disturbances

Wave power systems, by extracting some of the energy from the wave and changing its propagation characteristics, can also modify sediment transport. Indeed, swells and currents interact, so that any disturbance of the swell is likely to affect sediment transport by currents (e. g. longshore drift). Waves and swells also affect the resuspension and deposition processes of sediments. Broadly-speaking, wave energy systems reduce the agitation of the surface and water column, thus promoting sediment deposition.

> Permanent or temporary: Chemical inputs

Wave power systems also raise the issue of chemical pollution related to anti-fouling treatments and anti-corrosion devices.

There are also, in the case of certain types (Pelamis for example), risks of pollution from lubricants used in hydraulic motors and accumulators.

Ocean thermal energy conversion (OTEC)

POTENTIAL IMPACTS DURING CONSTRUCTION

> Permanent: Modification of the seabed

The degradation of the seabed depends mainly on the location of the plant. A shore-based power plant involves the deployment of a large diameter pipe from the shoreline to the seabed to reach cold water at a depth of about 1,000 metres, with potentially very severe impacts when considering an installation inside (or along the edge of) lagoons, and the presence of coral reefs.

The footprint of these systems, as well as the associated anchoring device, should be considered. Floating power plants will be anchored to the seabed by chains, for example.

> Temporary: Resuspension of materials

All mechanical operations that move the seabed induce a resuspension of materials into the water column. The impacts vary according to the type of project, but will involve the clogging of fish respiratory systems, the reduction of photosynthesis in phytoplankton (and thus their development), and impacts on sedentary filter feeding invertebrates on the seafloor.

POTENTIAL IMPACTS DURING OPERATION

> Permanent or temporary: Chemical inputs

Systems that use the thermal gradient of the sea also require substances such as ammonia. This point cannot be ignored: a significant leak of this fluid into the environment would certainly be very serious for organisms, given the quantities involved.

To counter the recurrent marine bio-fouling problem and improve system performance, a biocide dose (0.02 ppm daily molar concentration) is used, which is five times lower than the US regulatory threshold. Now, the biocide dose must be reduced to 0.01 ppm, 10 times below the US regulatory threshold.

Coral reef in Martinique © Thomas Abiven

> Permanent: Vacuuming of organisms

The exploitation of the thermal gradient between the surface and the bottom of the oceans requires the pumping of a large volume of cold water and surface water. The suction of water into intake pipes can affect various organisms. Some organisms do not have the ability to escape (plankton, larvae and juveniles) while others can swim and struggle against this suction. The organisms affected are those present at the relevant water extraction depths: pumping is generally carried out at a depth of about 100 m (above the thermocline) and at around 800 - 1,000 m (usually in open water). In addition, a filtration mesh prevents larger organisms from being dragged into the system. The individuals sucked in will suffer physical impacts against the walls of the pipes, pressures, and also temperature changes. Plankton are susceptible, with mortality among some individuals. Among the macrofauna, their size relative to the filter mesh and their swimming speed will determine whether they will be carried into the collecting ducts. Little is known about the mortality induced by this process, as data is virtually non-existent

> Permanent: Temperature changes

The temperature difference between surface extracted water and water discharged back into the environment is about 4°C. Organisms can be sensitive to thermal variations, which can influence population growth and the presence of species. Therefore, it is important to choose the appropriate water discharge point. This should consider the water temperature of the receiving environment, but also predict the behaviour of the discharge plume (e.g. sinking due to higher density, dilution in the water body due to hydrodynamic conditions). The composition of species throughout the water column strongly depends on water temperature. Thus, it is important to minimize the temperature difference that may exist between the discharge water and the receiving environment e.g. discharging the cooled water to the depth corresponding to its temperature.

> Permanent: Upwelling artificiel

Deep waters are rich in the nutrients needed for plankton development. When cold water is pumped (only in an open circuit), nutrient-rich water is released into a higher level of the water column. When the light conditions and nutrient supply are met, this action can promote the growth of plankton, and consequently their consumers. The natural phenomenon of upwelling is well known to fishers, as these nutrient-rich areas are favourable to the presence of fish that come to feed.

71 Le Mao P., 1985, Peuplements piscicole et teuthologique du basin maritime de la Rance, impact de l'aménagement marémoteur, ENSAR, 125p.

72 Trigui Rima-Jihane, Desroy Nicolas, Le Mao Patrick, Thiebaut Eric, 2011, Preliminary results on long-term changes of estuarine benthic communities 45 years after the implementation of a tidal power station in the Rance basin. Colloque scientifique du golfe normand-breton "Biodiversity, ecosystems and uses of the marine environment: what knowledge for integrated management of the Normano-breton gulf?" 2-3 November 2011, Saint-Malo. https://archimer.ifremer.fr/doc/00156/26692/

However, when water contains excessive nutrients, phytoplankton blooms may occur (which may not necessarily be harmful, but may change the ecosystem). It is therefore important to consider nutrient input from discharge waters, as this can lead to oxygen depletion in the water. This phenomenon may also lead to the proliferation of toxic microalgae (such as *Dinophysis, Pseudonitchia, Alexandrium*, etc.).

Recommendations for the protection of biodiversity[73]

For the preservation of marine and coastal biodiversity, we recommend:

- the development and implementation of existing methods to mitigate seabed erosion, due to water movement around turbine foundations. These include the placement of rock and gravel placement around the base, anti-erosion mats, etc. However, this issue is generally addressed in the design criteria, as seabed erosion is a technical design criterion for foundations. These expensive and sometimes ineffective measures are not necessary for all foundations (e. g. if jacket foundations are used).
- further development and implementation of existing methods to mitigate sediment resuspension during installation (during ground levelling or cable trenching) and limit changes in the hydro-sediment regime (by choosing foundations that are elevated above the seabed or those with a small footprint).
- limiting the risks of pollution from chemicals and lubricants. Technological solutions already exist, with lthe double sealing of submerged systems and the installation of recovery tanks. ■

Cuttlefish © Boris Daniel / Marine Protected Areas Agency

Threat: Barrier effect and collision risks[74]

© Le Roux- EDF

Offshore wind turbines

Due to its simple physical presence, a wind farm constitutes a barrier to the passage of various species, with a risk of actual collision. The "barrier" effect applies not only to migration, but also to daily movements between resting, feeding and nesting areas.

Underwater obstacles are fixed and of a limited surface area, but the aerial part of wind turbines is a concern for birds and chiropterans in particular.

Bats are especially vulnerable to night-time collisions because wind turbine lighting (imposed by maritime and aviation regulations) can attract the insects on which they feed, up to several dozen kilometres offshore.

Research on the risk of collisions between birds and wind turbines is still very limited. A recent study[75] indicated that the majority of collisions occur over just a few days a year, when bird navigation is hampered by poor weather conditions.

Similarly, several bird species seem to avoid wind farms during their migration. Nevertheless, most migrations are carried out at night and birds can then be attracted by the compulsory lighting of wind farms. Studies have shown that the number of eiders and geese crossing areas where wind farms are located has decreased by a factor of 4 or 5 since construction. However, given the overall length of the migration, the energy losses that can be attributed to the barrier effect of a wind farm and its bypass would appear insignificant. This detour does not seem to increase the risk of mortality during migration, although this conclusion should be qualified in the case where many wind farms are located in a migration corridor (for example, in the North Sea). In this case, the cumulative effect of such detours could significantly impact on the survival rate of some species. On another note, if a fleet is located on a man-

73 IUCN. 2010, Greening Blue Energy. Ibid.
74 IUCN, 2010, Greening Blue Energy. Ibid.
75 FARQUE P., 2013. Interactions between seabirds and offshore wind farms: knowledge, context and solutions on the French coast – Action 3.C – Report from FAME Project. LPO-SEPN.

datory crossing point, such as a strait, the risk of collision during migration could be increased tenfold.

Importantly, different species have different flight heights, and therefore differing risk of collision with the blades. The only estimates of measurable energy costs are those of species that cross a region on a daily basis, for example between feeding sites and resting or nesting sites. In these cases, wind farms may cause the fragmentation of coherent ecological units for these birds.

It has, however, been shown that some seabird species (e. g. diving birds and sea ducks) avoid wind farms (there is no data on other systems), not only during their construction but also during the operating phase. The significance of effects on local bird assemblages depends largely on the availability of alternative bird habitats.

For marine mammals, the impacts of noise disturbance caused by wind farms on communication and long-distance navigation are virtually unknown. In any case, it is clear that the "acoustic barrier" effect is greater during construction, hence the need to plan for this phase to be avoided during the migration season. A proliferation of wind farms separated by short distances could create a migration barrier for marine mammals, particularly in strategic passage areas such as the English Channel.

In addition, the electromagnetic emissions from cables could cause disturbances to marine mammals that use the Earth's magnetic field for orientation and migration.

There is also the risk of collisions with ships, which may increase if shipping traffic intensifies.

With regard to marine mammals and fish, there are no reports of collisions and injuries associated with the structure itself. They are believed to have the ability to detect and avoid these installations (echolocation). However, in the case of floating wind turbines, the chains connecting the floating section to the anchors may cause injuries. The effects of electromagnetic fields from cables could also be an obstacle to the movement of certain species that use the Earth's magnetic field for orientation (cetaceans, turtles) or are sensitive to natural electric fields (elasmobranches, for example).

Sea turtles, which are threatened globally, could be disturbed by the low-frequency sounds emitted by turbines. They show extreme fidelity to their routes, which may make them more sensitive to this type of disruption.

Therefore, the evasive behaviour caused by wind farms varies greatly depending on the species. Studies remain necessary to qualify the barrier effects (visual, acoustic, electromagnetic) associated with wind farms and their impact on different marine animal populations.

Marine Current Turbines

Marine current turbines form an obstacle in the water column with which marine mammals, fish and diving birds may possibly collide. This risk depends on the structure and diameter of the turbine, but also on the species in question, its size, and its ability to move and identify the obstacle, as well as environmental conditions such as current speed and visibility.

Scopoli's shearwater (Calonectris diomedea) taking flight © Steven Piel / Marine Protected Areas Agency

© Piton-Rodriguez

The number of submerged structures should also be considered because it increases the probability of contact from individual animals. The risk of collisions is certainly present, and the avoidance of areas frequented by marine mammals for the establishment of marine current turbines should be favoured where possible.

A 16 m diameter turbine (such as Open Hydro, TGL, etc.) operating at 15 rpm (round per minute), has a blade tip speed of 12.5 m/s. To avoid the blades[76], animals require a swimming speed in the same range as the current and be able to detect the obstacle early enough and anticipate blade rotation. It is therefore difficult to assess the risk of collisions at a particular site and for the species that inhabit it, without prior in situ experimentation.

Tidal barrage

The temporary structures required to drain an area where the dam is being built are impassable obstacles to the passage of individuals from one section to another. An estuary free of any construction allows for the passage of certain fish from the sea to fresh water to breed. The placement of obstacles on rivers is a barrier to the movement of various species, which can seriously affect their survival rate or reproductive success.

A study[77] conducted in the Rance estuary found that the specific composition and diversity of fish and cephalopod populations were comparable to those of equivalent Western English Channel populations. The study populations were characterized by movements of varying amplitude and intensity, and permanent exchange occurred at all stages of development between the impoundment and the open sea; the passage through turbines is made without significant direct mortality as shown by sampling in the sluice gates and numerous observations. The barrage is therefore open to life, whether planktonic organisms or larger animals (fish, cephalopods and even decapods).

During the operation of a tidal power plant, submerged turbines are driven by the flow of water from one compartment to the other. This rotation can cause injuries to fish. In addition, the structure itself is a barrier to the movement of organisms, particularly those whose life cycle is shared between rivers and the marine environment.

76 Wilson et al., 2007 : Collision risks between marine renewable energy devices and mammals, fish and diving birds
77 Le Mao P., 1985, Ibid.

Wave Energy Converters

The risk of collision with wave structures that could lead to the death of fish or marine mammals seems low. However, the presence of anchor chains can cause injuries to these animals, particularly if they are located in preferred movement zones (migration routes, etc.).

Also worth mentioning is the risk of marine mammal collisions with ships, which could increase if traffic increases.

Recommendations for the protection of biodiversity[78]

For the preservation of marine and coastal biodiversity, we recommend:

› taking into consideration the migration of turtles, marine mammals, birds, bats and some fish, if known,

› avoiding important resting, breeding and feeding sites, and the travel routes between these sites. However, in many cases, these areas are not well enough known.
- By locating fleets where water depths exceed 20 metres, or by avoiding habitats where biomass is high, it is possible to avoid benthic feeding sites for seabirds.
- For example, according to a commonly applied Ramsar Convention criterion, an area can be considered important for a species if more than one percent of its population resides in it or frequents it. It is possible to obtain detailed specific sensitivity indices for the impacts of wind farms on seabirds[79]. (Multiplying these indices by the densities of bird species for specific areas provides an estimate of the areas with the highest sensitivity to wind turbines (and therefore those least suitable for future projects).

› that, if there is a risk of overlap with migration pathways, corridors several kilometres wide should be maintained between wind farms.

› that it may be possible to rethink the alignment of the turbines in such a way that they are more visible to birds, in accordance, of course, with the regulations concerning maritime and aeronautical navigation. Lighting could also be adjusted to a level that preserves the safety of navigation, but reduces the potential attraction for birds and chiropterans, again in compliance with maritime and aeronautical navigation regulations (which could be adapted to avoid over-illumination due to the overlapping of regulatory obligations). ■

Cargo in the Strait of Dover © Marie-Dominique Monbrun / Marine Protected Areas Agency

The "reef effect": Opportunity and Threat

Submersion of artificial reefs off Etretat © Jean-Claude Grandchamp, IN VIVO

■ The structures will provide new areas to be colonized. Ecological succession will take place and thus facilitate the development of biomass.

Structures that span the water column from the surface to the seabed can accommodate different organisms depending on depth and light penetration. At the surface in particular, due to the oscillation of the tides, these structures will shelter intertidal and subtidal communities and will host a multitude of organisms such as barnacles, amphipods, bryozoans and molluscs.

The bases of the structures, depending on their shape and arrangement, may serve as areas for breeding, feeding or refuge from predators[80]. In this way, different parts of a food web are established and, as shown by various overseas studies[81] on installed wind turbines, in some cases there is an increase in biomass comparable to that observed around artificial reefs.

However, some scientists consider this to be more of a concentration of surrounding biomass than an actual increase[82].

Estimates of the radius of influence on wildlife around an artificial reef range from 5 to 600 metres[83]. Wilhelmsson (2006) schematically shows both the positive and negative influences on wildlife species abundance as a function of the radius of impact, during the operation of offshore wind turbines. For example, the first 5 metres[84] generally show a positive 'artificial reef' effect (depending on the original environment), with an increase in the biomass of blue mussels, decapods (e. g. crabs and lobsters) and benthic fish. Phytoplankton depletion is generally observed due to high densities of filter organisms (mussels) on and around the turbine, which could affect the growth of filter feeders on the seabed, up to a radius of 20 metres[84].

The deposition or filtering of organic matter from fish and invertebrates associated with turbines can influence benthic communities up to 40 metres away[85]. This may lead to local changes in the composition of macroinvertebrate assemblages, as well as modifications in physico-chemical and other environmental characteristics in the vicinity of the structures.

78 IUCN, 2010, Greening Blue Energy, Ibid.
79 MEDDE-DGEC, Juillet 2010, Guide de l'étude d'impact sur l'environnement des parcs éoliens, page 90.
80 MEDDE-DGEC, 2012, Etude méthodologique des impacts environnementaux et socio-économiques des énergies marines renouvelables.
81 Wilhelmsson, et al., 2006; Wilhelmsson & Malm, 2008; Maar, et al., 2009; Kellison & Sedberry, 1998; Bray, et al., 1981; Davis, et al., 1982; Kurz, 1995; Jordan, et al., 2005 ; Grove, et al., 1991; Fayram & De Risi, 2007 ; Stewart, et al., 2007; Larsen & Guillemette, 2007
82 http://www.ifremer.fr/dtmsi/colloques/seatech04/mp/article/7.eolien_offshore_impacts/7.1.IFREMER.pdf
Drévès L., Berthou P., Latrouite D., Leblond E./ Ifremer RST-DEL/SR/04.06, Juillet 2004, Projet de parc éolien offshore de la Côte des Isles : Etude Océanologie & Activités Halieutiques. Rapports de résultats de recherches scientifiques et techniques.
83 IUCN. 2010, Greening Blue Energy. Ibid.
84 Wilhelmsson, et al., 2006; Wilhelmsson & Malm, 2008; Maar, et al., 2009.
85 Kellison & Sedberry, 1998; Bray, et al., 1981; Maar, et al., 2009.

These impacts are only expected to be of major importance in protected habitats that support vulnerable species or where the scale of development is more substantial.

The net biodiversity gain therefore depends on:

- the diversity of the environment prior to construction: not all soft substrate environments are poor in biodiversity - underwater sand dunes and mudflats, for example, host a rich diversity of species and provide invaluable functional roles;
- the new ecosystem that has been created: the "reef" effect can indeed favour the introduction or increase of non-native, or possibly invasive species ("stepping stone" effect between foundations within a fleet). The project can also, by changing the dispersal patterns and distributions of species inhabiting the area, favour opportunistic species such as mussels, brittle stars, *Halidrys siliquosa*, Japanese wireweed, slipper snails etc. This will generally benefit species with a short larval phase (hours or days) that can spread from one structure to the next.

In summary, the marine structures not only generate an increase in biomass but also lead to changes in species composition; it is therefore difficult to conclude whether this change is positive or negative. What is clear is that the loss of one habitat (and the services it provides) cannot be offset by a different one, and that additional knowledge is needed about the effect of MRE parks on biodiversity, in terms of both biomass and diversity.

In this context, the gain would result from the "refuge" or "reserve" effect (more than the "reef" effect) due to the impacts of fishing (take of target species or by-catch, and damage to benthic habitats). The gain is therefore indirectly due to the presence of structures and regulatory access restrictions. However, there may still be an indirect negative effect, through the shifting of fishing activity to areas that are under-exploited, better preserved or more sensitive to the impacts of fishing gear. ■

Residual impacts[86]

© Sylvain Michel

■ If the developer of an MRE project works within a mitigation framework and identifies, avoids and minimizes the impacts of a given development, there will still be impacts. These may be of varying importance, depending on the fragility of the area and species. Residual impacts may include (but are not limited to):

- habitat loss on the actual sites of generators, foundations, erosion protection, cables and power stations and in the surrounding vicinity.
- changes in species assemblages due to the physical presence of the facilities and the impacts they have on the interactions between predators and prey.
- noise and electromagnetic fields that can still cause behavioural changes in some species despite the mitigation measures taken to reduce these impacts.

Although the restriction of fishing activities in an area may have beneficial effects on the marine environment within the MRE farm, some biological and social impacts may still occur if the fishing effort shifts to other areas.

MRE project developers are increasingly focusing on taking measures necessary to mitigate or compensate for these residual effects. Biodiversity offsets are a way of ensuring that project development avoids a net loss of biodiversity, or even a net gain. Compensation measures, if absolutely unavoidable, must be technically and financially feasible. However, the possibility of implementing offset measures must not be used as a pretext for allowing environmental degradation that could be otherwise avoided or reduced.

Compensation, which in accordance with French regulations must be in kind and not in financial form, must be quantifiable. The likely biodiversity losses must be predicted and compared with the expected benefits in terms of species composition, habitat structure, ecosystem functions and the use of biodiversity by other users.

Research is underway on possible compensatory measures for French offshore wind projects (theses supported by EDF-EN and IUEM).

Furthermore, the Business and Biodiversity Offset Programme (BBOP)[87] is currently considering many of these aspects in relation to real case studies and is working with developers to design and implement biodiversity offset projects for their operational sites (but this is currently only applicable to terrestrial sites). The objective is to achieve zero net loss of biodiversity (no net loss) by projects, or even a net gain (net positive impact).

Even though compensatory measures in the marine environment are still relatively new in Europe, the United States has been implementing them for the past ten years or so, but only in coastal areas (mangroves, coral reefs, sea grass beds). For example, the State of Florida has developed a method for calculating the size of offsets specific to terrestrial and marine wetlands. Known as the *Uniform Mitigation Assessment Method (UMAM)*, it allows the evaluation of the ecological value of an ecosystem on the basis of numerous functional indicators.

However, compensation in the marine environment in Florida raises some questions about the degree of equivalence for at least two reasons (Levrel et al., 2012[88]):

› (1) The indicators used to assess compensation are short-lived species, and the monitoring carried out on compensatory measures is too short (5 years), whereas it takes some time for a disturbed ecosystem to regain its balance.
› (2) Two major techniques are used (creating artificial reefs and transplanting corals) regardless of the type of impact measured.

Therefore, one cannot overstate the importance of indicator choices when carrying out compensation activities, and the number of ecological engineering techniques available for the marine environment is at present limited. As the latter point is a major constraint on the implementation of compensation, further R&D would be desirable. In this context, we note recent French initiatives such as those certified by the Pôle Mer Méditerranée[89]. These projects focus in particular on eco-design (building materials are designed to be eco-friendly or even to provide added ecological value through the creation of habitats), as well as the transplantation of sea grass beds and the improvement of artificial reefs. ■

> **"Research is under-way on possible compensatory measures for French offshore wind projects.**

86 IUCN. 2010, Greening Blue Energy. Ibid.
87 Link: https://www.forest-trends.org/wp-content/uploads/imported/Biodiversity%20Offset%20Design%20Handbook.pdf
88 Levrel H., Pioch S., Spieler R., 2012. Compensatory mitigation in marine ecosystems : Which indicators for assessing the « no net loss » goal of ecosystem services and ecological functions? Marine Policy, 36, 1202-1210.
89 Liste des projets labellisés par le Pole Mer Méditerranée : http://www.polemermediterranee.com/

Synthesis

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Marine energy sources could be rapidly developed in the coming decades, especially if sufficient support is provided by governments and industry for the technologies that are still at the experimental stage. It is essential to identify and assess negative as well as positive effects on the marine environment (both of which must be assessed to determine the net environmental impact of the project, and thus allow the design of possible compensatory measures). This is an essential condition if MRE systems are to be accepted locally.

This report by the French Committee of IUCN broadly evaluates the impact of the various existing techniques. The major potential impacts of the development of marine renewable energies on the marine environment that were assessed in this study include: noise, habitat loss or modification, the "barrier" effect for migration, the risk of collision, disturbances related to electromagnetic fields, and shipping-related hazards for certain species.

However, various mitigation measures can be implemented during construction, operation, maintenance, or decommissioning to reduce risks to local biodiversity, such as adapting construction dates, avoiding sensitive sites, or developing a design that takes into account the ecosystem in which the project is located.

However, not all technologies have the same impacts.

It is essential to consider the most productive and least impacting energy systems, while taking account of the development times of each system.

Ongoing research, working models, and development of test sites for techniques with less impact on the environment are all essential. Indeed, the further development of mature technologies such as wind power, which are valuable in terms of economic development, structuring activities, and knowledge of environmental impacts, benefit all types of MRE.

However, further research is needed to minimise the impact of these technologies in a climate of continuous improvement (lack of opportunity for hindsight should not be an obstacle, but rather an incentive to share data and experiences).

It should be recalled that in this study, only biodiversity has been taken into account: the French Committee of IUCN is well aware of the other issues that legitimately influence political decisions (such as the maturity of the sector, the potential costs of production in the short and long term, social acceptance etc.), and especially the need to promote short-term technical solutions, in order to create and boost the industrial sector at the national level.

In view of this first global analysis of the impacts of these sectors on the environment, it would appear that floating wind and offshore wave energy (wave power through coastal development, port dikes and coastal areas have similar impacts to coastal current turbines) are the most appropriate options for a biodiversity-conscious MRE development strategy.

As these technologies are not yet at a mature stage of technological development, it would take some years to develop them in French waters.

It is also important to be better able to compare MRE systems with existing marine activities and to remember that MREs are in combination with pre-existing disturbances. Depending on the technique used and the species concerned (marine mammals, for example, for whom fishing is the primary source of anthropogenic mortality), fishing, for example, could have potentially greater impacts than MRE. This may also be the case for oil platforms and for some impacts (noise) of maritime transport.

It is therefore important to remember that MRE projects do not and will not form the sole source of impacts to marine and coastal environments. It is therefore essential to assess the cumulative impacts of MREs and existing activities at a relevant scale. Strategic environmental analyses conducted on the various French coastlines, as part of the Marine Environment Action Plans, should be used to contain these impacts. ■

At this stage of the assessment, and from the biodiversity perspective, it is worth highlighting the following conclusions:

- the development of floating wind turbines appears promising compared to the development of fixed wind turbines, because this technology reduces the degradation of the seabed and makes it possible to utilise more distant marine areas, thus minimising use conflicts - the question of the risk of collision between marine mammals and anchor lines nevertheless remains as an issue to be addressed;

- the development of large-scale, offshore exploitation of ocean currents and wave energy, or systems that are integrated into existing coastal structures, would appear to result in only limited potential damage to the coastal environment;

- during construction, and over extended periods, tidal power barrages cause major disturbances to estuarine ecosystems, which are of high biodiversity value. In comparison, even if developed on a large scale, marine current turbines (although closer to the coast), and floating wind or wave power, would probably have a lower impact on biodiversity. However, these technologies are not currently among the most advanced, and it will take several years before they can be deployed in French waters.

Of course, these preliminary results must be carefully examined and confirmed by environmental assessments at the appropriate scale (strategic assessment). In addition, beyond the overall considerations relating to the different systems, the level of impact remains highly dependent on each project, and must be assessed as part of the impact study. In addition, knowledge is still limited and some technologies are not mature, which can distort the assessment of their effects. Research and experimentation must therefore be carried out as a matter of priority in order to better understand the impacts of emerging and mature technologies that have not yet been applied on a large scale or in environments typical of French waters.

Thematic Summaries

Thongweed (Himanthalia elongata) on the Sein causeway © Yannis Turpin / Marine Protected Areas Agency

BIODIVERSITY PROTOCOLS: ASSESSMENT AND MONITORING

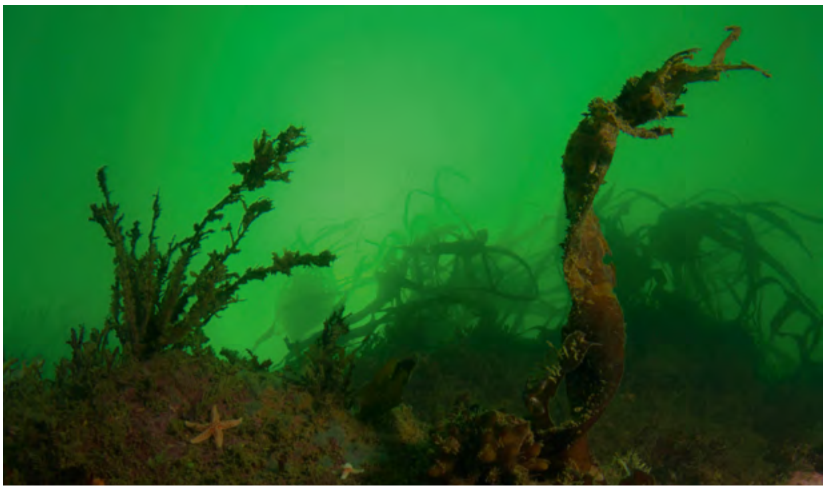
PROVIDE AN INITIAL CONDITION REPORT AND RELEVANT AND COORDINATED FOLLOW-UP

Common dolphin © Pelagis/Gautier

Explanatory notes

Directive 2011/92/EU stipulates that "projects likely to have significant environmental impacts, in particular because of their nature, size or location, shall be subject to a permit application procedure and an assessment of their impact". This EU legislation is transposed in France through the provisions of the Environmental Code on impact assessments.

European countries have transposed this directive into national law. In the case of France, it is indicated in the annex to Article R122-2 of the Environmental Code created by Decree No. 2011-2019 of 29 December 2011 that any project falling into the category of development, works and works "Energy" and Subcategory 27 "Offshore energy production facilities" is subject to impact assessment. Thus, development projects for MRE projects must adhere to the "avoid/reduce/compensate" process and must present the measures proposed in the Environmental Impact Assessment (EIA).



Degraded kelp field © Frédéric Lechat

THE TWO LEVELS OF ENVIRONMENTAL ASSESSMENT

The main instruments used to assess the environmental impacts of projects and programs are:

› Strategic Environmental Assessment (SEA) – the assessment of environmental impacts related to projects and programmes (including multiple projects), undertaken primarily by government authorities to ensure that the plan or programme meets environmental objectives;

› Environmental Impact Assessment (EIA) – used for individual projects by (a) a developer to enable, based on environmental impacts, decisions to be made regarding project development, mitigation plans and ongoing monitoring, and (b) authorities, to verify that a given project complies with environmental legislation.

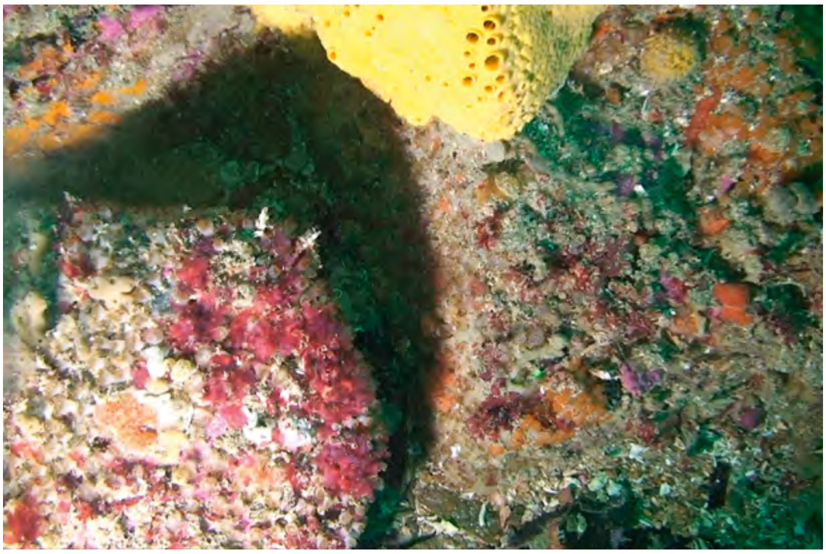
THE REFORM OF IMPACT STUDIES IN FRANCE

In accordance with the Grenelle laws, the reform of impact assessments, a key tool of environmental law, took shape with the enactment of Decree No. 2011-2019 of 29 December 2011 on impact assessment reform for construction or development projects, which came into force on 1 June 2012.

This legislation reforms the content and scope of impact studies on construction or development projects. Henceforth, the projects referred to in the annex to article R. 122-2 of the Environmental Code are now subject to impact assessment only. The list of projects submitted becomes positive, and simpler (removal of the financial threshold of a work programme). We note that Category 27 states that all offshore energy installations are subject to an impact study, and that it is mandatory in all circumstances (no longer a threshold concept).

The text also redefines the content of an impact study (R122-5). In particular, there is an increase in the number of topics to be addressed (including cumulative effects) and an obligation for the developer to present measures according to the "avoid/reduce/compensate" approach (article R122-4-II-7°) as well as new measures including:

› 5° the obligation to present an outline of the main alternatives considered by the petitioner or the contracting authority and the reasons why, with regard to environmental or human health effects, the submitted project was selected ('avoid/reduce');



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› 8° descriptions of the methods used to both establish the baseline condition referred to in "2." and to assess the effects of the project on the environment. Where more than one method is available, an explanation of the reasons for the choice is required;

› justification if the petitioner is unable to compensate;

› a description of the main methods of monitoring the measures and their effects, an estimate of the costs relating to them, as well as a discussion of the expected effects of these measures.

Effects monitoring by the state is also being strengthened with the issuing of orders, deadlines for assessments and the strengthening of the administrative police.

General principles

CONSIDER THE ECOLOGICAL SERVICES PROVIDED BY MARINE AND COASTAL ECOSYSTEMS[90]

To preserve marine and coastal biodiversity, we recommend assessing the suitability of different MRE development scenarios at different scales, taking into account the vital ecological services provided by marine and coastal ecosystems. It is worth noting that these services are provided by any ecosystem in a healthy state of conservation and not only by MPAs.

90 UICN France (2014). Panorama des services écologiques fournis par les milieux naturels en France - volume 2.2 : les écosystèmes marins et côtiers. Paris, France.

TAKE CUMULATIVE IMPACTS INTO ACCOUNT AT THE APPROPRIATE SCALE

The issue of cumulative impacts associated with a new activity must be addressed in these analyses.

As mentioned above, environmental (and socio-economic) impacts should be assessed in the broader context within the project area of influence (not only for the project itself) to provide an overall picture of cumulative impacts.

DEVELOP STRATEGIC ASSESSMENTS (SEAS) BASED ON MONITORING OF INDIVIDUAL PROJECTS (EIA)

Suitable assessments of cumulative effects at the scale of the individual impact study could be incorporated into strategic documents produced on a broader scale.

ESTABLISH A BODY TO OVERSEE ENVIRONMENTAL ASSESSMENT

For offshore wind power tenders, the French government plans to set up a consultation and monitoring committee for each project (see paragraph 6.4.1 of the specifications). This body will be in place for the duration of the project (development, construction, operation, decommissioning). It is intended as a forum for dialogue and can make recommendations to ensure that local issues are given greater consideration. However, it is not specifically aimed at environmental issues.

Overall, it was noted that there is no national working group with experts from all sides to discuss these topics. We should move towards a more holistic approach to research, with an ecosystem approach, a national vision, etc. A strong "MRE" axis, for example, will be developed within COMER.

CSRPNs can also play a key role in assessing the effectiveness of measures taken to remove, limit or compensate for the impacts of projects on the marine environment, if they are given this authority.

It will also be necessary to consider the role of the future French Biodiversity Agency: we recommend that it be given sufficient resources to ensure the control and monitoring of projects (human and financial resources), but also the appropriate regulatory tools.

Operational principles

For the preservation of marine and coastal biodiversity, we recommend:

› CREATING MAPS OF THE SEABED, WITH EMPHASIS ON THE NEED FOR ECOLOGICAL CONNECTIVITY

Planning over space and time is vital. In keeping with this concept, site studies should be carried out before the tendering process begins, as is done in the United Kingdom (DEFRA). In this way, there is little duplication, and it avoids the conflict of uses (projects can be staggered over time using initial scoping studies).

In France, this approach would allow operators to be aware, upfront, of the risks related to their project site. Here, they find themselves with sites with environmental "constraints" (and related costs) that they only discover when carrying out their research.

We have noted that planning is mandatory at European level (cf. Directive 2001/42/EC). In general, what has not been done in the planning phase must be done in the project phase, then in the operational phase, thus multiplying the costs.

The planning phase has several objectives: to ensure the compatibility of Energy/Ecology plans and programmes, to anticipate cumulative impacts, etc.

It requires a solid understanding of ecosystems, particularly high-value areas, for a thorough impact assessment.

We recommend leaving "blue" areas between MRE sites to retain a refuge, habitat, corridor or feeding ground for biodiversity.

Organisms respond differently depending on the size of the EMR fleet under construction (duration of impacts varies over time, from a few months to several years). The risk of mobile organisms abandoning the area is likely to rise as the duration of the work increases. It is therefore essential that the construction of a large fleet be carried out in a phased approach, which consists of dividing the construction into several phases, building part of the fleet completely and connecting it to the grid, and then building the other sections later. Consequently, the impacts will be localized in time and space during the construction stage.

› IMPROVING KNOWLEDGE, CAPITALIZING ON INFORMATION AND IMPROVING ACCESS TO THAT INFORMATION

We have little knowledge of the impacts of these structures over time: during the construction phase, during operation, but also during decommissioning. Knowledge of the effects of repeated disturbance also needs to be improved.

Appropriate baseline data on the state of the marine environment, the distribution of sensitive species and habitats, and the migration routes of birds, fish and mammals are generally very scarce in relation to the requests for impact assessments. There is a need to increase research on species distribution and abundance, including annual cycles and population structure and status, but also to develop analytical tools to assess ecosystems and possible cascading effects.

It would also be of interest to carry out strategic research to develop species-specific sensitivity indices for offshore wind energy installations (they currently only exist for birds) at different life stages and in different regions.

More research is also needed on the effects of noise on different species, as well as on the mechanisms and indicators underlying bird avoidance behaviour, in order to develop appropriate mitigation strategies if necessary. This is also the case with regard to the impacts of electromagnetic fields that act as barriers to fish migration.

We emphasize the need for studies to be conducted in a completely independent scientific manner, and with oversight.

Finally, with respect to cumulative effects, there is limited methodology, and knowledge of these effects remains poor.

© Frédéric Lechat

One response may be to create a database of marine impact studies.

This research could be financed in the first instance by the government, making it possible to retain public data, or be carried out collectively by operators (within the framework of France Energies Marines, for example).

This is done in Anglo-Saxon countries.

In France, after selection in the tender process, all costs are borne by the chosen developer, which creates a number of uncertainties.

This collaborative approach to research appears to be an opportune way of limiting costs and ensuring more effective planning.

France Energies Marines could participate in the coordination of these studies.

› IMPROVING THE MONITORING OF ENVIRONMENTAL IMPACTS, INCLUDING CUMULATIVE IMPACTS, AT BOTH THE "EIA" AND "SEA" LEVELS

Knowledge of the marine environment remains deficient. Much information will therefore come from feedback from early projects, hence the importance of setting up an environmental monitoring programme to verify the assumptions used.

Some EIA standards require up to two successive full years of data before they can approve the construction of wind farms. However, these time delays should be viewed as a pragmatic approach as they are generally too short to fully understand the ecological effects for each site in question, including the seasonal and year-to-year variability at the ecosystem and species levels.

The baseline data available for a given marine area strongly influences the quality of the EIA, which must be taken into account during the site selection and authorization processes.

EIAs for offshore wind farms are carried out at various scales, with different scopes and with differing levels of detail. This is a consequence of a lack of comparable national standards and of differing interpretations of EIA requirements by the authorities that must provide their consent.

To avoid arbitrary or unsound approaches, we recommend the development of sound, scientifically rigorous standards and the definition of thresholds for impact assessments at the national level that can be adapted at the regional level.

It should be noted that such an approach is underway via the consultation launched by the DGEC to establish a guide for studying the impact of offshore wind farms.

We recommend the establishment of international guidelines and the development of information exchange networks (such as EMODNET - European Marine Observation Network) to guide the execution of EIAs.

The relevant criteria on which predictions of impacts are based should be clarified. Effects on populations (particularly sub-populations) and on species are essential in impact assessments and aggregation processes, if conducted at the appropriate scale (for example, for marine mammals, there will be no benefit in conducting an assessment over a small area).

However, there are generally no regional or national agreements on acceptable levels (i.e. impact intensity) or scales (i.e. reference population chosen and biogeographical distribution affected) of disturbance for the species in question. These weaknesses need to be addressed at the national and transnational levels. The establishment of standards is necessary: the MSFD could provide the relevant framework in continental Europe.

› IMPROVING THE LINKING OF PROJECT OVERSIGHT AND MONITORING PROGRAMMES BY STRENGTHENING SYNERGIES AND COORDINATING PROTOCOLS

We also stress the need to harmonize the protocols developed as part of these follow-ups, at a national level, or even to standardize them. All stakeholders, first and foremost operators, are in favour of a framework for carrying out EIAs. This would provide certainty for the process and avoid subjective interpretation by different administrative bodies.

It is vital that project developers not be left to tackle these issues on their own.

However, this would require an agreement between developers and, above all, institutional leadership.

Finally, we would emphasise that not all uses of the marine environment currently require an impact study ! However, by operating through other activities, monitoring could be better coordinated (for example, taking advantage of transport vessels or weather towers to carry out environmental monitoring in the area).

Conclusions

Reducing negative impacts and fostering potential positive effects requires *comprehensive* and *holistic* studies of the environmental impacts of marine renewable energy projects.

To this end, we therefore recommend the following:

- Create seabed maps that highlight the need for ecological connectivity
- Enhance knowledge, capitalize on information and improve access to it
- Improve the monitoring of environmental impacts, including cumulative impacts, at both the EIA and SEA levels
- Improve the link between project tracking and monitoring programmes by strengthening synergies and coordinating protocols

Ongoing monitoring will be crucial in analysing the extent to which early mitigation strategies have been successful in avoiding or reducing impacts on the marine environment.

Future decisions can incorporate the latest advances and thus mitigate new threats.

By conducting rigorous environmental impact studies and systematic environmental management, the industry will be able to continuously improve its practices and procedures.

For more information
- IUCN. 2010, Greening Blue Energy

© Sylvain Dromzée / Marine Protected Areas Agency

FOCUS:

Marine mammals - Monitoring methods, limits and areas to be developed

Harbour seal © Pelagis/Vincent

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One important part of the environmental monitoring process when installing a wind farm is the monitoring of marine mammals. These animals are often difficult to track due to being unobtrusive, spending little time on the surface and/or travelling long distances.

However, this is a major issue in MRE projects: the acoustic sensitivity of marine mammals makes them particularly vulnerable to noise. Collisions with ships and changes in habitats and resources are also potential impacts for these animals.

Overseas experience generally suggests three main ways of monitoring marine mammals as part of MRE: visual monitoring (aerial or by boat), passive acoustics and telemetry. These are classic population monitoring methods that have proven their efficacy.

However, the choice of method(s) requires a case-by-case study to determine their relevance and whether conditions suit their implementation. Indeed, aerial visual surveys make it possible to cover a large area but their cost makes it impossible to sample at a fine temporal scale. Boat observations can be used to target a specific area more precisely, but are highly dependent on weather conditions. Passive acoustics provides continuous monitoring of the study area, but the cost of instruments and analyses makes large-scale spatial sampling impossible methods specifically targets seals: telemetry makes it possible to respond to this problem by observing individual movement strategies and habitat use.
However, extrapolation to the colony on the basis of just a few animals is difficult. In short, no single monitoring method is ideal, with each having its advantages and limitations. A combination of several methods will reduce bias.

Even using these methods, it remains difficult to assess with certainty the level of impact of an EMR installation on a given site. Indeed, that requires a detailed knowledge of the distribution, migration patterns, behaviours and sensitivities of marine mammals, which we do not currently have.

Therefore, the advancement of knowledge about marine mammals on the French coast should be encouraged in order to better understand the potential impacts of MRE parks and their possible consequences, with a view to proposing coherent and relevant mitigation measures. This could include involvement in existing or future research programs. This could also involve sharing monitoring rather than site-by-site monitoring, which would increase the coherence of the study area and the analyses carried out, while optimizing costs.

FOCUS:

The GHYDRO project

© Alstom

The objective of the GHYDRO project is to develop a methodological guide that will provide stakeholders in marine current power projects with decision support tools for the environmental integration of equipment and fleet operations.

This document proposes an initial set of recommendations and methods to:

› describe the initial condition,
› identify and analyse potential ecological changes,
› develop an environmental monitoring program.

The scope of the GHYDRO project includes the three phases of a hydroelectric project (installation, operation and decommissioning) as well as all of its marine elements (turbines, converters, cables, ships, etc.).

To bring together as many skills as possible, France Energies Marines has formed a consortium of specialists in tidal current technology and in the marine environment. They come from research institutes and industry. France Energies Marines has also consulted numerous experts in the marine environment field, technology developers and coastal zone users.

The methodological guide is intended to be widely distributed, to:

› environmental authorities,
› developers of marine current power projects,
› environmental consulting firms,
› users in areas being considered for future marine current power projects.

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In the coming months and years, GHYDRO will evolve through an iterative process as marine current power projects progress, and initial feedback on interactions with the marine environment is received.

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FOCUS:

The protocol developed by the Concarneau MNHN for monitoring the impacts of developments

'Great scallop' in a seagrass bed © Frédéric Lechat

This protocol was adopted as part of the MSFD. This annual inventory makes it possible to monitor the changes in fauna and flora during projects developed in the marine environment.

The "ECBRS" protocol of the Concarneau MNHN, implemented by the *Estuaire Loire Vilaine* on the Guérande bank, provides for annual monitoring (transects) of subtidal rock communities at 9 sites between the Loire and Vilaine estuaries since 2009. It focuses in particular on:

› the depth ranges of the different algal zones;
› the composition and density of the species defining the depths (kelp and other macroalgae);
› species composition (characteristic species and opportunistic species);
› floristic species richness;
› the study of *Laminaria hyperborea* blades and their epibiosis.

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FOCUS:

The SIMEO buoy, a marine ecosystem monitoring station

AN INNOVATIVE MULTIFUNCTIONAL BUOY FOR MONITORING MARINE BIODIVERSITY

The SIMEO project - Instrumental Station for Ecological Monitoring in the Ocean - aims to develop a range of floating marine instrumented stations dedicated to the observation of marine vertebrates and their environment. It is a collaborative project led by Biotope, in partnership Nke Marine Electronics, IRD, Ifremer, the Mer Méditerrannée and Mer Bretagne Atlantique clusters, Transferts LR and Oséo.

The principle is to combine on the same autonomous buoy several advanced measuring instruments (radar, sonar, video system, etc.) which can conduct obtain almost continuous measurements in order to collect biological, meteorological, physical and hydrological data and transmit this data to the land for further use.

SIMEO APPLICATIONS

At a time when Marine Renewable Energies (MREs) are in full development, the consideration of ecosystems is an important issue. In the realm of marine biodiversity monitoring, SIMEO is a success story, allowing unique data sets to be analysed and synthesised to serve as a decision-making tool:

- for site investigations;
- in the context of impact studies for development projects such as offshore wind farms;
- for the monitoring and surveillance of Marine Protected Areas (MPAs).

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FOCUS:

Description of the SEM-REV project, led by the Ecole Centrale Nantes

© ECN/SEM-REV

SEM-REV is an experimental site of the Ecole Centrale Nantes with the necessary equipment at sea and on land to develop, in operational conditions, systems for the collection of marine energies, mainly from waves and offshore wind. The Research Laboratory in Hydrodynamics, Energetics and Atmospheric Environment (LHEEA) of the Ecole Centrale Nantes and CNRS thus actively participates in the development of marine renewable energies. As a partner of industrial enterprises and research laboratories, the Laboratory plays an important role in the development of new energy production facilities.

To this end, the School has a concession for a 1km² offshore site off the Guérande bank, which has been delineated, referenced and has been equipped with instruments since 2009 (to obtain data on waves, currents and weather in the area). The school has also acquired an oceanographic vessel to facilitate onsite work, and has provided a local scientific team with monitoring and control facilities at Le Croisic.

The wave energy collection prototypes will be positioned in the centre of the offshore area, and connected to land by cable to transfer the generated energy. The power connection from the SEM-REV site has been studied and optimized in coordination with the various stakeholders.

Since January 2014, it has also had the necessary permits to test floating wind turbines. The first production system will be in place by mid-2015.

The SEM-REV sea trial site also provided input for the European SOWFIA (Streamlining of Ocean Wave Farms Impact Assessment) project, by providing feedback under real-world conditions.

The SOWFIA project aims to facilitate the development of coordinated, standardised and monitored environmental and socio-economic impact assessment (IA) tools at the European level for the development of offshore wave energy.

As part of this project, a summary of the situation country by country was prepared, analysing:

- the manner in which environmental impact assessments are conducted,
- the process of obtaining approvals,
- the planning of the use of the maritime public domain,
- the consultation process.

Operational recommendations have been proposed for implementation in the short term. Strategic recommendations will facilitate actions and strategies in the longer-term.

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CUMULATIVE IMPACTS, CONFLICTS AND SYNERGIES

Horns Rev wind farm off Esbjerg © Fabrice Nodé-Langlois

Explanatory statement

France has great potential for the development of some types of MRE, but they vary in terms of environmental costs and socio-economic benefits. We must then address the issue of conflicts: MRE systems require natural maritime space, and this has consequences in terms of competition for existing or planned uses.

Maritime and coastal areas are used for many purposes such as transport, the exploitation of marine resources (mineral, biological or energy), leisure activities and tourism. The development of renewable marine energy is therefore occurring in areas already subject to multiple pressures.

A marine spatial planning will not only alow to solve these issues but also the following ones. In principle, the ocean is a public space open to all users, even if in certain areas (MPAs) it is possible to try to restrict certain uses. These conflicts impact on biodiversity, because when a decision is made to close one place to an activity, the pressure is usually shifted elsewhere.

Moreover, we cannot systematically install environmentally-impacting structures in natural environments where there are no users.

Currently, marine activities overlap, but there is little focus on cumulative impacts or optimizing usage to use the human and financial resources more efficiently. This therefore creates power relations that drive underlying conflicts, whether between uses, between old and new occupants, between industries etc.

This has consequences for project approvals, due to the fears of elected officials and residents of coastal municipalities, or professional users worried about facing limitations or bans in or around MRE fleets.

It is therefore essential to examine the impacts of MRE projects not only in isolation, but also to consider the other uses of the marine environment in question.

Cumulative impacts

We recommend the standardization of criteria and methods for assessing cumulative effects, at appropriate spatio-temporal scales.

Cumulative impacts can be assessed at two levels:

› local impacts of a given project combined with other existing human pressures ▸ In France, the reform of legislation on impact studies now provides for these cumulative impacts to be addressed (cf. Decree No. 2011-2019 of 29 December 2011).

› larger scale impacts that occur as a result of the existence of several MRE systems in an area or region.

These impacts must be assessed at the strategic scale (i.e. at the level of the national development policy or programme). This scale would ideally match the ecoregional scale (biogeographic region).

Synergies between activities

The viability of a combined wind and wave farm is currently being tested in Denmark.

A hybrid device coupling a floating wind turbine and a hydro turbine is also being tested in Japan[91]. Facilities could share the same foundations, power transfer lines and maintenance operations. These different energy sources also have complementary periods of maximum performance.

However, a concentration of different types of MRE also means concentrating and aggregating the environmental impacts (e.g. in terms of barriers to migration and the loss or fragmentation of habitats etc.). Broadly speaking, the cumulative impacts may be more pronounced than the sum of the impacts of each project.

Specific examples of interactions with other activities

AQUACULTURE AND MRE FARMS

While it is becoming difficult to find areas for aquaculture development on our coasts (urbanization, pollution etc.), MRE farms could offer opportunities to exploit areas further offshore thanks to their infrastructure.

These areas would experience less land-based pollution: experiments on blue mussels in particular have yielded excellent results, showing fewer cases of parasitism than among mussels harvested from the coast.

© Marius Born, Winterthour

91 See: http://www.mer-veille.com/mix-energetique/un-systeme-eolien-hybride-innovant-au-large-du-japon-22084426

FISHING AND MRE FARMS

There is no technical or regulatory reason why certain fishing activities (except trawling, which raises obvious technical questions) should not be conducted in marine energy production areas, which generally use space in a non-intensive manner.

There is a general trend of increasing marine biomass around immersed MRE structures. This "reef effect" is also favourable to commercial species, with a possible spillover effect to adjacent areas. These areas could therefore have a positive effect on fish stocks, provided that fish spend enough time there and do not avoid them because of noise or other forms of nuisance. Another prerequisite for positive effects on fish stocks is that fish reproduction or feeding efficiency is not significantly affected in the MRE area.

The joint development of resource management projects and an MRE project may therefore prove to be a useful solution, both to ensure the sustainability of the resource and to strengthen coastal fishing.

However, this increase in biomass is partly related, in the case of foreign experience, to the absence of fishing in the vicinity of the farms. A further explanation relates to the greater availability of food, originating from species fixed or attracted to the hard artificial substrates of the MRE structures. Bottom trawling, which seriously threatens the benthic environment, poses obvious safety concerns due to the underwater cables that connect the fleets to the land. As a result, trawling is often prohibited or reduced within fleets, and these areas, ranging to several square kilometres in size, become marine areas within which no-take zones may exist. Thus, the long-term impacts may appear positive with the creation of these restrictive zones in terms of harvesting natural resources.

These activities are therefore becoming more suitable to long-lived species. However, opportunistic species are the first to benefit from the availability of new hard substrate when they colonize foundations.

However, ecosystems differ from site to site, and thus require case-by-case studies.

General principles

It is important to stress that this new activity should be as biodiversity-friendly as possible, and that when MRE systems are deployed, the cumulative impact should be at most equal to the impact of pre-existing activities, and if possible lower. This should logically, in some cases, lead to a reassessment of other activities in order to distribute the burden equitably over all maritime activities, taking into account all associated environmental, social and economic impacts and benefits.

We recommend, given that the development of MRE is a public policy objective and the state regulator can define the conditions for carrying out all activities in an area, that to ensure that cumulative impacts are kept at an acceptable level, any constraints are imposed on all existing maritime activities in the area, rather than on MRE generating facilities alone.

Figure 10 illustrates this approach: if the proposed MRE project would result in excess environmental impacts, two approaches are possible, including:

- concentrating mitigation efforts on the last activity to be introduced (the MRE fleet), at the risk of significantly increasing production costs,
- sspreading the efforts across all activities that impact the environment (e.g. limiting certain fishing techniques, or the movement of commercial vessels in the area, or the number of visitors by pleasure craft etc.).

For the same environmental result, this type of strategy can maximize socio-economic benefits.

Figure 11 below illustrates the possible effects in terms of employment and wealth generated in the area, before and after the establishment of a wind farm (which allows the development of a new offshore aquaculture activity).

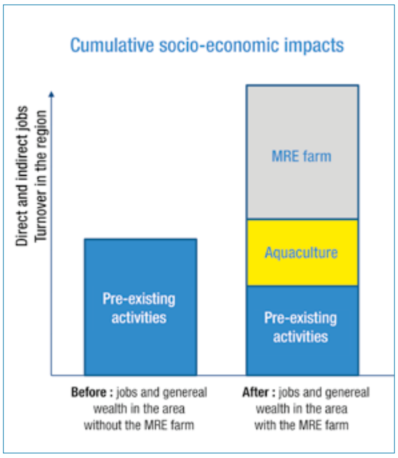


Figure 11

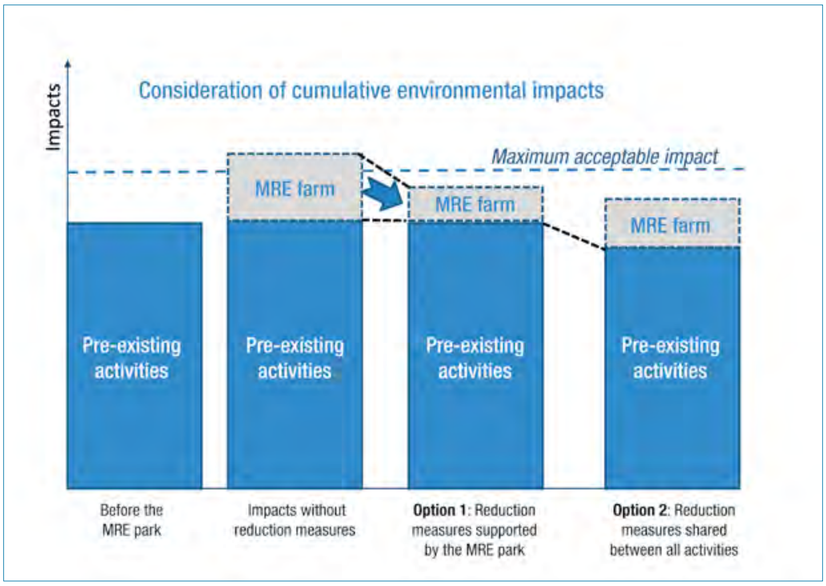


Figure 10

Such an approach would clearly require environmental assessments for activities that are not subject to regulation.

These approaches will probably be explored in the DCSMM's monitoring and measurement programs.

Operational principles

For the preservation of marine and coastal biodiversity, we recommend:

› TO LIMIT CONFLICTS:

1. that existing users of the marine environment be informed of the progress of the project and that it be carried out in consultation.

The pre-existing stakeholders are able, through their experience in the area, to provide technical expertise to the baseline description of areas and in the assessment of the ecological impacts and economic consequences for their activity.

2. the study of the option to exclude trawling within French MRE project areas.

Generally, trawling appears to concentrate the problems, since it potentially leads to additional costs, technical difficulties (cable protection) and risks for benthic biodiversity.

It is clearly not a question of prohibiting all fishing practices within the fleets. Some fishing practices have environmental impacts that do not compound those of the MRE fleets, or better still, have diminished impacts due to project synergies, so it is entirely legitimate to consider maintaining them. We therefore believe that a case-by-case study is necessary.

In addition to the safety zones surrounding MRE fleets, it may be useful extend the "no-take zones" to increase the benefits for marine and their habitats. This would benefit marine mammals in particular, for whom incidental catch is the most serious pressure in France. MRE parks often act as feeding areas, attracting many individuals. This concentration, combined with fishing in close proximity, could increase the probability of incidental capture.

› TO PROMOTE SYNERGIES:

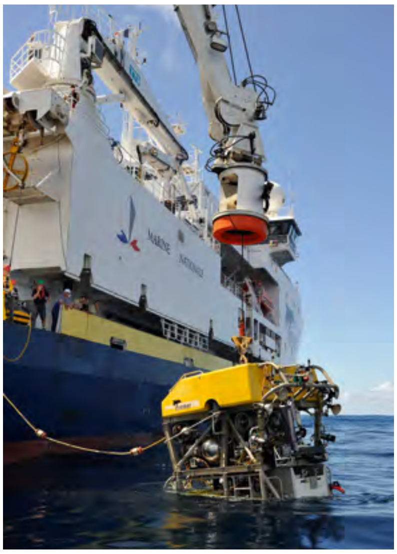
3. the setting up of a joint procedure for applying for authorisation for several marine uses (wind power, artificial reefs, algoculture, fishing, etc.) in the same area.

At present, several procedures are necessary under different legislation, and the issue of co-uses (e.g. seaweed cultivation + wind power) is not satisfactorily addressed by sectoral regulations. This change would allow for an assessment of cumulative impacts, which is currently the sole responsibility of the most recent arrival.

4. the improvement of dialogue with the research, meteorological and maritime transport communities.

Indeed, the technical resources (generally expensive) can, in this case, be jointly used for different purposes.

This objective is, notably, pursued by the synergistic "Marine Energy" group within the French Maritime Cluster ('Cluster maritime français').



Victor 6000 © Ifremer, Olivier Dugornay

Indeed, the development of MRE is an opportunity to acquire new scientific knowledge about the marine environment.

5. to take action in terms of taxation.

In particular:

› the introduction of a tax or the abolition of the tax advantages (e.g. adjustment of tax bonuses or penalties), in cases where the exploitation is conducted in an unfavourable way for the preservation of marine and coastal biodiversity. For greater coherence, other activities might also be covered. This tax can then be used for environmental purposes (knowledge, evaluation, remediation, etc.),

› a review of the allocation of the tax on offshore wind turbine installation
Currently, the tax is intended to allocate 50% to coastal municipalities, 35% to fishers and only 15% to projects "that contribute to the sustainable development of maritime activities or to the achievement or maintenance of an ecologically sound marine environment, as provided for in Article L. 219-9[92] of the Environment Code".

We recommend that this tax could be amended so that it could more greatly (if not totally) benefit the enhancement of knowledge and the protection of the marine environment.

In effect, paradoxically, a proposed new activity would be required not only to be conducted in a sustainable manner, but also to finance the transition to sustainability of other, potentially competing maritime activities which are not subject to environmental assessment.

As mentioned, those projects promoting biodiversity would in turn benefit fishing and other environmentally dependent activities (tourism, etc.).

Plongeur au-dessus d'un champ de laminaires dans le Parc naturel marin d'Iroise
© Yannis Turpin / Agence des aires marines protégées

Similarly, this mechanism[93] could be used to finance the cost of biodiversity screening assessments and monitoring, which are essential for the proper management of marine biodiversity, which is directly impacted.

This would require a revision of the allocation of the tax on wind turbine installations, so that it can directly contribute to biodiversity-related projects, which would be selected by a steering committee that would include professional fishers.

Conclusions

MRE installations represent new maritime activities requiring permanent occupation of maritime space. This will require the various stakeholders, the State in the first instance, to consider the compatibility of uses and cumulative impacts, and to organise coordinated management of the sea.

In order to optimize the use of space while limiting cumulative impacts, certain impacting activities could thus be limited, or even prohibited, to compensate for the impacts of new MRE installations.

However, if the development of projects is well planned and coordinated, the marine environment could in some cases benefit from these developments, as might certain activities that depend on it (fishing, for example).

Through spatial planning of the marine environment combined with action plans involving all stakeholders, cumulative and synergistic impacts could be better anticipated and managed, with impacts and opportunities for all sea users taken into consideration.

For more information, see

- IUCN, 2010, Greening Blue Energy
- CNDP, 2010, Bilan du débat public - Projet de parc éolien en mer des Deux Côtes
- Contribution de Green Cross France et Territoires (GCFT), juillet 2013, Commission particulière du débat public pour le projet de parc éolien en mer au large de la baie de Saint-Brieuc, Cahier d'acteur
- Danish Offshore Wind, novembre 2006, Key Environmental Issue, published by Dong Energy, Vattenfall, The Danish Energy Authority, and the Danish Forest and Nature Agency
- ADEME (Pays de la Loire), Rapport : Quelques éléments de retour d'expérience sur l'éolien fixe en mer (from Dan Wilhelmsson, Department of Zoology, Stockholm University)

FOCUS:

Floating offshore wind farms in the Mediterranean Sea: opportunities for fishing and aquaculture?

In 2013, the Pôle Mer Méditerranée carried out a study on the feasibility of developing fishing or aquaculture activities within floating offshore wind farms.

This prospective study aimed to identify Research & Development projects, as well as potential national or European collaborations likely to lead them.

The study was based on:

1. A collaborative approach involving fishermen, aquaculturists and energy specialists;

2. A thorough assessment of the environments of floating offshore wind farms;

3. A discussion on fisheries and aquaculture in the context of the deployment of floating wind farms;

4. A socio-economic assessment.

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92 Decree of 27 January 2012 on the use of resources from the tax introduced by Article 1519 B of the General Tax Code. Article L. 219-9 corresponds to the implementation of the MSFD via the PAMM to meet the planning and preservation needs of the environment.

93 Note that the tax is based on the capacity (megawatts) of each production unit. Its tariff is set at 13,623 Euros per megawatt, as provided for in Article 1519 B of the General Tax Code, but its amount changes each year according to the "value index of the total gross domestic product".

MARINE PROTECTED AREAS AND MARINE RENEWABLE ENERGIES

© Marion Peguin

Explanatory statement

The United Nations Convention on the Law of the Sea requires States Parties to protect and preserve the marine environment. The Convention on Biological Diversity sets the objective of establishing a coherent and linked network of marine protected areas by 2020 on a global scale. At the regional level, France is a party to six regional sea conventions that concern the seas that lie within its territory. In addition, at the EU level, France is involved in the management of Natura 2000 sites. It also commits itself to achieving, by 2020, the good ecological status of its waters within the framework of the new European Marine Strategy Framework Directive (MSFD).

In 2007, the national strategy for marine protected areas was based primarily on the extension of the Natura 2000 marine network and the establishment of 10 marine parks. The "Grenelle Environment Forum" and the "Grenelle Sea Forum" then set out the ambitious objective, for marine management and protection, of classifying 20% of areas under French jurisdiction as MPAs by 2020. To date, 7 marine natural parks have been created or announced.

As of 2013, the MPA network occupied around 4% of the waters under French jurisdiction in mainland and French overseas territories. With the creation of the Coral Sea Natural Park in New Caledonia, this will increase to 16%.

However, MPAs incorporate different forms of protection with various objectives, from strong protection (wilderness areas, core national parks) to sustainable integrated management of marine natural resources such as PNMs (marine nature parks). The various protection instruments can have a regulatory status (such as nature reserves) or land status, such as *Conservatoire du Littoral* (Coastal protection agency) sites. In some cases, a site can combine both approaches.

Marine protected areas (MPAs) play important roles in biodiversity protection. Beyond MPAs, all measures to protect the marine environment contribute directly or indirectly to preserving healthy and productive environments and the activities that depend on them, such as reduction of marine pollution, noise, artificialization, etc. However, this study must examine the compatibility of MRE developments and MPAs with various states of protection, thus raising the question of whether the presence of artificial structures such as those associated with the production of MRE, and the existence of associated impacts on the marine environment, are compatible with the protection objectives of a marine protected area.

The Environment Code defines an open list of marine protected areas (Law of 14 April 2006)[94] :

- maritime parts of national parks (L.331-1), national and regional nature reserves (L.332-1),
- biotope protection orders (L.411-1),
- marine nature parks (L.334-3),
- Natura 2000 sites with a maritime portion (L.414-1),
- marine sections of areas under the control of the *Conservatoire du littoral*.

The decree of June 3, 2011[95] added 9 new categories to this list:

- RAMSAR (International Convention on Wetlands) sites,
- UNESCO World Heritage Sites,
- Biosphere reserves,
- National Hunting and Wildlife Reserves with a marine section,
- sites protected under the Regional Seas Conventions.

General principles

The table below groups the different tools for protecting marine environments according to their degree of protection in the IUCN classification, with category I.a being the strongest protection. The IUCN categories in which they have been classified show that different management objectives can be associated with the same protection status.

IUCN CATEGORIES	MANAGEMENT GOALS	EXEMPLES OF MPA CATEGORY
Ia Strict Nature Reserve	Scientific research	National nature reserve, Integral biological reserve (national park)
II National Park	Ecosystem protection and recreation	National park (core area)
IV Habitat/Species management area	Conservation with management intervention	Nature reserve *Conservatoire du Littoral* site Biotope protection order Natura 2000 site at sea
V Protected Landscape or Seascape	Landscape conservation and recreation	National park (buffer zone)
VI Protected area with sustainable use of natural resources	Sustainable use of natural ecosystems	Marine nature park

Figure 12: IUCN categories and management objectives

The development of marine renewable energies must be accompanied by consideration of the potential impacts on marine ecosystems. Depending on their category and their species, habitats and uses, marine protected areas may or may not accommodate MRE projects, which may in turn be subject to different constraints and frameworks on a case-by-case basis.

94 Act No. 2006-436 of 14 April 2006 relating to national parks, marine natural parks and regional natural reserves.

95 Decree of 3 June 2011 identifying the categories of marine protected areas within the scope of competence of the Marine Protected Areas Agency (AMP)..

The table below shows the analysis made by the Agency of Marine Protected Areas (AMP) of the possibilities of implementation according to the type of MPA. We have added a column to explain the regulations that refer to it.

TYPE OF MPA	POSSIBILITY OF ESTABLISHING RENEWABLE MARINE ENERGY SYSTEMS	COMMENTS
National nature reserve	Incompatible	They benefit from strong protection, as a ministerial decree prohibits any activity harmful to the environment
Regional nature reserve or Corsican nature reserve	Vigilance	
Marine National Park	Not compatible in the core areas of parks	Not all areas of the park are subject to the same degree of protection. In the heart of a marine park, works and installations are prohibited, while in the buffer zone, they require the authorization of the national park managing authority
Marine Natural Park	Vigilance	The PNMs combine protection with the sustainable management of activities and natural marine resources. The establishment of an activity likely to significantly alter the marine environment is subject to authorization from the Marine Protected Areas Agency or by delegation from the PNM Management Board
Natura 2000 site at sea	Vigilance	An impact study must accompany applications for approval for installations, works and structures that may affect these sites
Biotope protection order	Incompatible	Important protection: the prefectoral decree prohibits, regulates and makes certain activities subject to authorization
Conservatoire du Littoral sites	Incompatible	An environmental schedule of conditions accompanies the Public Maritime Domain (DPM) Temporary Occupation Authorization

Figure 13: Categories of MPA and the potential for the introduction of marine renewable energy systems

Some high-protection categories may appear incompatible with the development of MRE. These include national nature reserves, national park cores or areas subject to biotope protection orders.

However, it should be noted that the percentage of marine protected areas that are apparently incompatible with the development of MRE in fact represents less than 2% of waters under the jurisdiction of mainland as well as French overseas territories. This is very low overall, even though they are a significant percentage in coastal areas.

Some "MPA" areas (IUCN categories IV to VI) are already being used or are under consideration for the development of particular technologies:

› This applies to the Fécamp area selected for the first wind power tender, and the Paimpol-Bréhat tidal current turbine test site, both of which are located in Natura 2000 areas. Raz Blanchard, the main site proposed in a call for expressions of interest to set up pilot current farms, is located close to the future Normand Breton Marine Natural Park. The second site (the Fromveur Passage) is located in the heart of the Iroise NIP;

› The Tréport wind farm project, proposed in the second call for tenders, would have 20% of its surface area in the Marine Natural Park of the Picardy Estuaries and the Opal Sea.

Operational principles

For the preservation of marine and coastal biodiversity, we recommend:

› 1. DEFINING NATIONAL AND REGIONAL ZONING TO BETTER PRESERVE MARINE AND COASTAL HABITATS.

On land or at sea, the importance of the project's impacts is directly linked to the choice of location. This goal therefore demands consideration of:

› the areas that should not be exploited,

› new marine biodiversity reserves to be created to preserve endangered species or habitats,

› the technologies to be promoted in order to preserve the ecological services provided by marine and coastal environments,

› the cumulative impacts of several MRE fleets within the same region.

A number of studies abroad and in France (ADEME, SMNLR) have identified these impacts. However, we reiterate that there is no complete study tailored to French ecosystems.

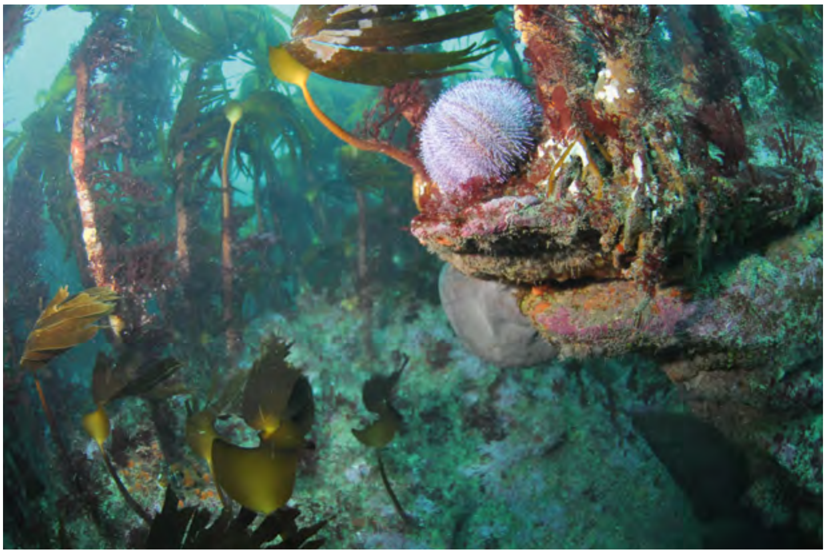
In addition, fragile habitats are sometimes selected by project proponents, at the risk either of unacceptable legal impacts or uncertainties if the project is approved, or of significant financial losses for the developer.

However, prior knowledge of the habitats present on the site and their level of sensitivity would allow areas of particularly rich habitats with no or low resilience to be excluded at the time of site screening.

Knowledge of the impacts of MRE on marine and coastal biodiversity needs to be improved, but we know that there are breeding and nursery areas, such as seagrass and eelgrass beds, kelp forests, coral reefs etc., which provide ecological services that cannot be easily restored given current knowledge.

To better support operators, we recommend the creation of marine habitat, coastal habitat and ecological issues maps at the national and coastline scales.
We recommend, where this is not already provided for in the regulations of specific MPAs, that particularly sensitive areas be identified and that restrictions be placed on the development of MRE parks.

This concept can be incorporated into the Marine Environment Action Plans (PAMMs), which are the environmental component of future coastal strategic plans.



A typical underwater landscape of the Iroise Sea, with Laminaria hyperborea
© Yannis Turpin / Marine Protected Areas Agency

This would allow the definition of different levels of sensitivity:

› For any protected or particularly sensitive species or habitat, it would seem necessary to consider relocating the operation to another area, the only way to completely avoid destruction of the sedentary or less mobile species and habitats present,

› in certain high-value areas, it would be necessary to conduct more in-depth environmental studies than in other areas, to plan longer-term monitoring, and to recommend the assessment of cumulative impacts. The latter may be mitigated by limiting certain existing activities in the area.

Generally, we recommend that priority be given to developing projects in marine areas already impacted by human activities

› 2. CHECKING THE COMPATIBILITY OF THE MRE PROJECT WITH THE CURRENT MANAGEMENT OBJECTIVES OF THE MPA

Generally, we recommend avoiding MPAs, even if regulations allow their development.

However, it is clearly necessary to consider local conditions. Collaborative management in MPAs (see the following box) is an attractive solution to enhance the value of an MPA.

This is not always possible, however, for highly localized energy resources (e. g. tidal currents).

Currently, only Natura 2000 sites and Marine Nature Parks appear to be the focus of MRE projects. Since the management objectives generally include the sustainable management of activities and resources, the development of MRE does not seem incompatible as long as it does not degrade sensitive habitats.

When the only available energy resources are located in a sensitive site for which regulations do not prohibit exploitation, and if the social benefits are significant, then the permitted exploitation should be coupled with recommendations such as:

- the establishment of stricter, well defined specifications,
- exhaustive monitoring of environmental impacts, combined with evolving measures to reduce and compensate for the impacts observed,
- consideration of reducing other activities with the same impacts (fishing, dredging, etc.), in order to control cumulative impacts. The priority activities will be those with lower socio-environmental benefits than MRE.

The management boards of the marine natural parks will systematically decide on the development of MREs in their area, since the regulations require their assent. To this end, it is essential to make a clear decision on the exploitation of marine renewable energies based on the park's management guidelines. In addition, all marine user groups must be adequately represented on the Management Board.

However, other types of MPAs could be affected indirectly or remotely, even if no structures are installed within their area.

We therefore recommend that for each project:

- a decision is made by CSRPN, following an analysis of the direct and indirect impacts of the project,
- managers of adjacent marine protected areas (within a defined radius depending on the size of the project) are also involved in decision-making.

› 3. USING THE OPPORTUNITY TO ESTABLISH AN INDUSTRIAL SECTOR IN A CONTEXT OF COLLABORATIVE MANAGEMENT

Some MPAs, in particular PNMs, are areas of research (knowledge of interactions, ecosystem services and the reserve effect, maximisation of synergies in terms of multiple activities, and socio-economic integration in exploited areas) that are favourable to both developers and MPAs.

Indeed, these natural environments are better documented and their condition better monitored than elsewhere. Managers can also provide their expertise on the impacts of human activities on their site. The interactions between MRE systems and marine ecosystems will therefore be easier to study and improve. These

This monitoring will make it possible to build on information, particularly on the resilience of ecosystems around such structures and on the positive and negative impacts on biodiversity, reserve effect, etc.

MPAs can thus contribute to expediting the emergence of MRE technologies that are most eco-friendly.

Finally, it should be noted that initial site condition studies conducted as part of EIAs can contribute to the improvement of knowledge of the marine environment. Thus, the Marine Protected Areas Agency is jointly responsible with Ifremer for the marine component of the Nature and Landscape Information System (SINP), to which these studies can contribute information. If MRE proponents provide the data acquired through their projects to MPA managers, they will contribute to the effective preservation of the marine natural heritage.

Conclusions

It will therefore be necessary to consider, on a case-by-case basis, the desirability of developing MRE projects in sensitive areas such as MPAs, taking into account all the risks and benefits to biodiversity. We must not forget that MPAs have challenges related to the functioning of marine ecosystems, whether as habitat for many protected or fished species, as migratory stops for marine mammals and birds, or as a major contributor to biodiversity. In addition to these 'ecosystem' challenges, there are multiple uses within a limited space. The concept of marine protected area has a tangible application here.

For more information, see

- IUCN, 2010, Greening Blue Energy
- Mission d'étude parc naturel marin 3 estuaires, August 2010, contribution to the public debate on wind power projects on two coasts
- AAMP website: http://www.aires-marines.fr/Concilier/Energies-marines-renouvelables-et-AMP
- French Committee of IUCN 2010, Protected areas in France: a variety of tools for biodiversity conservation

FOCUS :

The development of marine current power in the Iroise Marine Natural Park

The island of Ushant from the air © Julien Courtel / Marine Protected Areas Agency

The Iroise Marine Natural Park is subject to two marine renewable energy projects, both of which are hydro-turbines.

Firstly, the installation of a current turbine working model by SABELLA ("Sabella D10" project) in the Fromveur Passage (the core of the park) is planned for the summer of 2014, after receiving approval from the park's management in 2011.

Secondly, a call for expressions of interest for the establishment of a pilot farm was launched at the end of 2013 by the Government via ADEME in the same area.

Iroise Marine Natural Park management provided feedback on the two projects. To this end, they deemed that the environmental impacts of renewable marine energies depend on the sensitivity of the natural heritage. These impacts are also proportional to the size of the project and the number of production units located on the site. Farms may have different effects on the natural environment. For example, impacts from a farm comprising one or more machines capable of making an unconnected island (such as Ushant) self-sufficient will differ from a farm comprising several dozen units, which may impact marine currents and whose main electricity production will need to be routed to the mainland.

It is also necessary to consider the cable length, its path (in the middle of benthic communities) and the landing area of these cables on the mainland (which may vary depending on the output power). All of these parameters will influence the coastal and littoral environmental impacts.

Based on available information, the park management approved the deployment of a pilot tidal current farm in the Fromveur Passage, intending it to be a benchmark site of excellence at the national and European levels. The Board made several recommendations:

- The seabed footprint should be limited by favouring elevated installation systems rather than a system lying flat on the seabed;
- In situ monitoring of equipment will better understand the potential impacts of a possible industrial-scale deployment. This monitoring will need to consider the possible environmental impacts (habitats, species, etc.) and impacts on other uses, particularly commercial fishing;
- The electrical connection cables must be buried and their routing must favour sedimentary substrates, while avoiding the rocky bottoms of the Molène archipelago. The landfall of the cables on the mainland must be in keeping with the integration of the infrastructure into the landscape;
- The site will be restored at the end of the experiment.

The management board felt that the presence of the marine park would allow for more comprehensive environmental monitoring, and would allow for effective feedback.

Parc naturel marin
Iroise

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ELECTRICITY CONNECTION: SOME IDEAS FOR CONSIDERATION

Explanatory statement

Currently, the energy produced by MRE fleets is exported as electricity (although other forms may eventually be considered for distant fleets, such as hydrogen or ammonia). It must be routed ashore via submarine cables that are connected to the electricity grid. A cable provides this routing for each production site (comprising several machines) to the coast. This applies to offshore installations rather than coastal installations such as tidal power plants. Cables are buried or anchored to the seabed between production sites and the coast for technical reasons (risk of displacement under the influence of currents or swells) or to avoid damage from maritime activities (dredging, trawling, anchoring) that may or may not be allowed in the area.

The same issue may arise on the coast, with the possibility of conflicts: how to reconcile the passage of cables connecting to the onshore power grid with the challenges associated with sensitive coastal areas?

IMPLEMENTATION PRINCIPLE

Several factors should be taken into consideration:

1 / After a call for tenders by the French government, the chosen consortium is responsible for building and operating the future offshore wind farm.

The electricity produced by the turbines is routed to an offshore substation built by the producer. This is the starting point for the connection to be built by the Electricity Transmission Network (RTE).

2 / RTE is responsible for the public electricity transmission network. As such, it is responsible for connecting the wind farm from the offshore substation to its very high voltage electricity grid on land.

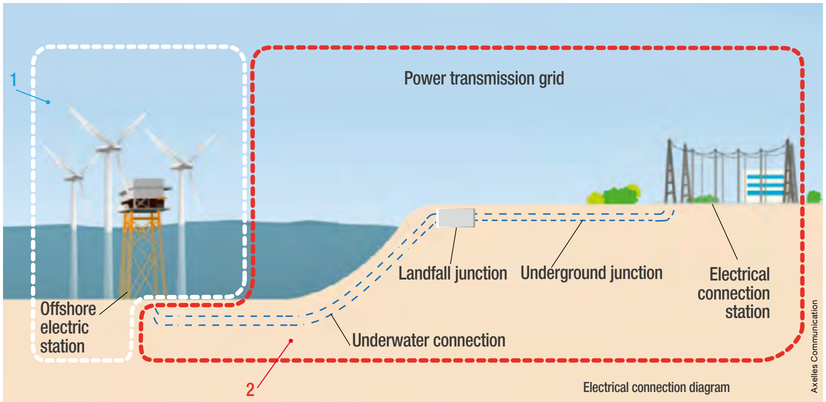


Figure 14: Diagram of the operating principles (Source: RTE)

To avoid any disruption or damage, the cable is trenched or covered at the seabed.
Trenching consists of digging a furrow in the sea floor in which the cable is laid. This technique is preferred. However, some types of very hard or inconsistent substrates are unsuitable: the cable is then laid on the seabed and covered with rock-fill, for example. Surveys of the substrate determine the feasibility of trenching.

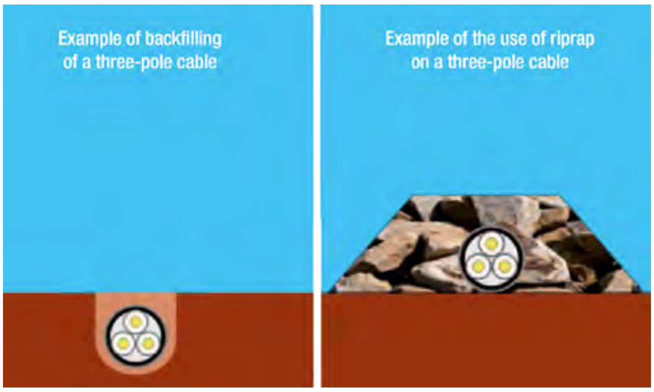


Figure 15 (Source: RTE)

Once on land, the submarine cables are connected to the underground cables within two "junction chambers" installed underground, each approx. 20 m long by 6 m wide and 3 m deep. This is known as "landfall".

The optimal landfall location is defined in consultation with local stakeholders.

Connections can be submarine and/or underground. The connection must be such that the upstream network is able to evacuate the power fed into it. As a result, substations (between the underground link and the public electricity transmission grid), a structure of a few hectares, are most often pre-existing. The substation is chosen according to the strength of the upstream network. Sometimes they must be specially built (as in Saint-Nazaire for the wind project), but this is not normally the case. Modifications of this substation may also be considered to promote its integration into the landscape.

THE RULES IN FORCE

Facilities related to the connection of MRE parks to the shore-based electricity grid must comply with the Coastal Law.

Article 25 of the Brottes Act[96] clarifies the specific provisions related to MREs under the Coastal Act.

Article 146-6 of the Town Planning Code, which sets the conditions and limits of occupation and development in outstanding areas, now provides that "*conduits within the public electricity transmission or distribution network designed to promote the use of renewable energies may be authorized in outstanding areas."*

Article 146-4 of the Town Planning Code lays down the conditions for urbanisation on the coast, and in particular within the 100 m strip. It prohibits any construction or installation other than in urban areas within 100 m of the upper shoreline, but now specifies that "*cthis does not apply to works connecting marine renewable energy installations to the public electricity transmission or distribution networks"*.

It also states that:
"These structures must be installed underground and with minimal environmental impact.
Approval for the construction of facilities, mentioned in Point 1 of Article L. 323-11 of the Energy Code, is refused if the pipelines are likely to harm the environment or remarkable sites and landscapes.
Their implementation is subject to a public inquiry in accordance with Book I, Title II, Chapter III of the Environmental Code."

96 Law n°2013-312 of 15 April 2013 aimed at preparing the transition to a low-carbon energy sector and containing various provisions on water pricing and wind turbines.

General principles

IMPACTS ON THE MARINE ENVIRONMENT

> Release of heat

When electricity is routed through the cables, there is a loss of energy which is manifested by heat release in the immediate vicinity of the cable. Organisms are adapted to specific conditions, so local temperature increases can cause some marine species sensitive to very small temperature variations to move in order to be in their optimal temperature range. Species composition among sensitive species may therefore be modified around cables.

However, the Connecticut Siting Council (CSC, 2001 - see bibliography) examined the effect of heat radiating from cables welded to the seabed as part of the "Cross Sound Cable Interconnector" project, a system of high voltage direct current, trenched cables between New England and Long Island, New York. The CSC estimated that the increase in seafloor temperature immediately above the cable was 0.19°C while the corresponding increase in water temperature was 0.000006°C. Potential heating is therefore considered impossible to detect in relation to natural fluctuations in the surrounding sediments.

> Electromagnetic fields

The effects of generated electromagnetic fields are difficult to determine. Existing connection cables (to islands) are not normally monitored, although in the United Kingdom, an in-tank study was carried out on sharks and rays:

"For the Thanet Offshore Wind Farm site, English Nature stated that (given the current level of information available to date) there would be no significant impact on elasmobranch populations inhabiting the wind farm area and along export cables".

However, the results did not allow any conclusions to be drawn on the effects on fish.

Temperature and electromagnetic field parameters are especially important to study and monitor when located in a rocky environment where cables are not buried.

> Chemical pollution

The risks of contamination of the water with chemical substances (and the health risks from pollution of bathing and shellfish areas) due to long-term wear and tear of submarine cables are unlikely (cables being trenched, covered or fixed). In addition, it is worth noting that modern cables do not contain heavy metals.

Nevertheless, the BERR study (see bibliography) indicates that "cable burial will reduce potential environmental effects [...]" and that, "ISO 14001 certified cable manufacturers are required to demonstrate effective ways to minimize environmental risks".

At the end of the operation or cable life, developers must restore the site so, in theory, no cables should be abandoned. On the other hand, it will be worth considering the advisability of removing inert cables in view of the environmental impact associated with this removal.

> Impacts of trenching (burial)

Cable trenching is often recommended because it reduces or even cancels the impacts related to electromagnetic fields (reduction) and heat (cancellation) respectively. This technique is also used at the request of other users (fishers, sailors, divers), because the cables between the transformer and the shoreline are at risk of entanglement. Trenching is thus a safety measure in response to this risk. It may also be a technical choice, particularly in view of the risk of cable degradation when exposed to currents, waves and swells. Finally, cable trenching within the fleets is commonly called for to maintain activities such as trawling and dragging: in this case there is an accumulation of impacts related to marine activities and trenching operations.

Conversely, in the absence of any fishing activities in the area, trenching is not necessarily required and the environmental impacts are minimized. Thus, the choices made in the design and management of parks will determine the impacts.

The Paimpol experience shows that the impact of siltation on benthic ecosystems in the immediate vicinity can be significant (since there is a dead zone for a few weeks, resuspension of materials, risks of noise, wildlife disturbance). It is, however, spatially limited around the trenching footprint, and temporary (wildlife recolonized the substrate, and within one year, density or diversity were comparable to that of control areas).

> Impacts on hard substrates

The level of impact on benthic ecosystems on hard substrates depends on the substrates in question and the degree of colonization by wildlife (in highly hydrodynamic areas, species are specialized, but not abundant). Further studies are underway on the Paimpol cable.

> Impacts on the coastal environment

The electricity transmission network on the French coast (very high voltage) is currently not very dense, and poorly adapted to the absorption of large quantities of energy. Except for a few specific areas (nuclear or coastal thermal power plants), there is limited capacity. In addition, the network does not extend offshore (existing subsea interconnections cannot accommodate the production from offshore parks). To overcome these issues, each area of favourable conditions is the subject of a study by RTE on connectivity, the purpose of which is to assess the impact on the network. These impacts are highly dependent on the size of the MRE installation and the shore-based network. Given the current network design, its development to accommodate large quantities of energy produced at sea could be achieved by developing additional high-voltage land lines, which raises land use planning, environmental and acceptability issues.

These effects could be reduced by creating at-sea extensions of the transmission network that could accept the MRE fleet's output.

Such deployment is envisaged as part of long-term strategic planning, which is implemented by RTE in particular in the ten-year network development plan[97], and in TYNDP[98], a European plan drawn up by the ENTSOE network operators' association. The impacts of network extensions are studied as part of an economic and social study.

Operational Principles

For the preservation of marine and coastal biodiversity, we recommend:

› 1. DEFINING A GENERAL STRATEGY FOR OFFSHORE NETWORK EXPANSION AND CONNECTION

The connection of an offshore production site to the onshore network requires the cables to pass through a point on the coast. The Electricity Transmission Network (RTE) organization is responsible for connecting offshore wind farms, as outlined of the call for tenders issued in July 2011.

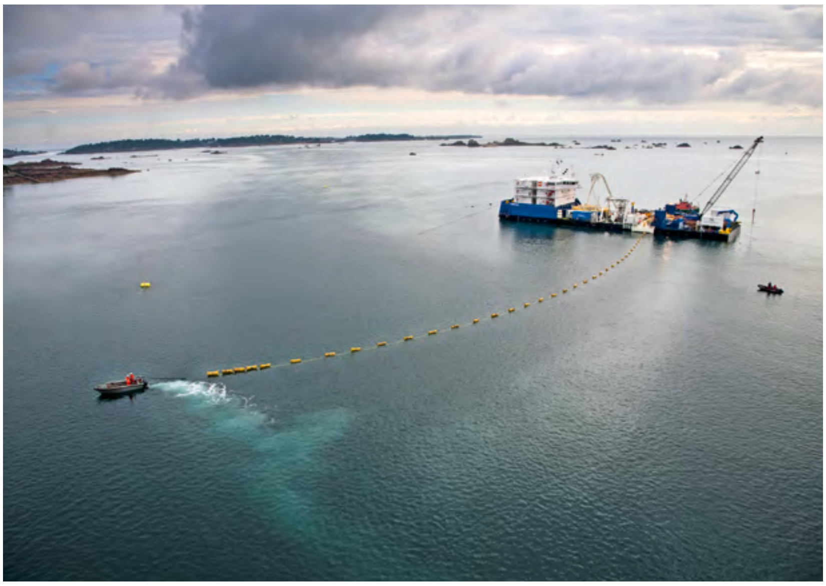
To avoid a proliferation of cables and connections, a strategic vision of the offshore extension of the electricity grid must be developed, taking into account interconnection needs and future areas of offshore production capacity.

This approach should allow for progressive development, optimization of investments, and overall reduction of the environmental impacts associated with cable laying.

This vision must address not only land network connections, but also the growing need to integrate the development of land and maritime power grids.

› 2. OPTIMIZING THE CHOICE OF CONNECTION SITES TO REDUCE ENVIRONMENTAL IMPACTS

It is worth noting that the choice of route is the result of consultation with all stakeholders, leading to compromises with regard to environmental and technical constraints.
For junctions, as for other structures in the public electricity transmission network[99], the choice of location must be that of "least environmental impact", depending on the sensitivity of the habitats on the



site, the nature of the soil, the elevation range, shipwrecks of cultural significance, etc. The circular of 9 September 2002 on the development of public electricity transmission networks details the consultation and planning methods aimed at ensuring the integration of the network into its environment. The Environmental Code, in Article R122-5, then requires that these choices be clearly explained in the impact study.

We recommend, in general, to avoid natural coastal areas when siting this connection, but it is clearly essential to develop a strategic, global vision for the whole region.

Of course, it is also necessary to ensure that areas are protected along the entire length of the route from the MRE farm (not only at the landing point). Also, the longer the cable length, the greater the environmental impact, and the greater the volume of raw materials required (copper etc.). It will be important, project by project, to conduct a study and choose the routes that result in the lowest overall environmental impact.

Various approaches appear possible and should be explored, including:
› the use of already highly artificialized areas such as ports rather than natural areas that we are trying to preserve

97 https://www.rte-france.com/sites/default/files/synthese_sddr_2014.pdf
98 https://docs.entsoe.eu/dataset/ten-year-network-development-plan-2014
99 http://circulaire.legifrance.gouv.fr/pdf/2009/03/cir_26580.pdf

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(note that this can be made difficult by an already congested subsurface, or by heavy traffic).

› where no artificial space available, or when other factors warrant it, the use of appropriate technologies such as directional drilling allow the land-sea boundary to be crossed underground over several hundred metres to the exit point.

› 3. IMPROVING OUR KNOWLEDGE OF THE EFFECTS OF ELECTROMAGNETIC FIELDS

Electricity production from MREs requires the transmission of energy to the onshore grid. The connection cables emit an electromagnetic field, the effects of which are poorly understood. No significant impacts have been identified in the available literature, although the limited number of studies make it impossible to derive firm conclusions on this subject. A tank-based study was conducted in the United Kingdom but, although some fish changed their behaviour, the researchers were unable to reach any general conclusions about the effect on fish.

We recommend that research programmes be developed on this subject, which are essential for impact assessment and the design of effective mitigation measures.

Research should benefit from the use of existing island-continent connection cables and monitoring data, where available.

It is worth noting that wind farms, but especially tidal current turbines and wave energy converters, may be located in rocky substrates, and therefore the cable will be anchored rather than buried. Again, additional research must be conducted to improve knowledge so that appropriate measures can be implemented if needed.

› 4. DEVELOPING A COMPLETE PICTURE OF THE POSITIVE AND NEGATIVE IMPACTS ASSOCIATED WITH CABLES

Similarly, to ensure that all environmental issues are addressed in their entirety, and in accordance with current EIA regulations, the impact assessment must include an assessment of the impacts of all aspects of the project.

Although complete ring-fencing is not the desired result within a wind farm zone, the presence of connection cables between wind turbines can lead, depending on the way the farms are managed, to a total or partial ban on certain maritime activities, particularly for safety reasons. For example, the use of some trawling devices in fisheries activities may lead to cable entanglement. These potential costs should be measured in relation to the existing activity.

In return, an area no longer trawled, for example, would be expected to see improvements in ecosystem health. This would increase the biomass available for fisheries around the prohibited area, as a result of the "reserve effect".

The designation of these areas must be done in consultation with all marine user groups (fishers, in particular).

Conclusion

Reducing negative impacts and promoting potentially positive impacts requires research into the environmental impacts of marine renewable energy production projects in a comprehensive and strategic approach.

In conclusion, we recommend:

- ongoing monitoring to analyse the extent to which early mitigation strategies succeed in avoiding or reducing impacts on the marine environment,
- further research be conducted in this field,
- that impact studies be conducted by integrating new knowledge as soon as it becomes available.

For more information, see

- IUCN, 2010, Greening Blue Energy
- Kalaydjian R., 2011. Submarine cables. Ifremer Issy-les-Moulineaux.
- English Nature, 2006, Thanet Offshore Wind Farm site
- BERR_Câbles, 2008, Review of cabling techniques and environmental effects applicable to the offshore wind farm industry – p°108 : "The potential increase in temperature is therefore impossible to detect in relation to natural fluctuations in the surrounding sediments"
- Connecticut Siting Council (CSC), 2001, projet "Cross Sound Cable Interconnector"
- MEDDE-DGEC, 2012, Étude méthodologique des impacts environnementaux et socio-économiques des énergies marines renouvelables

FOCUS:

Experimental restoration of eelgrass beds

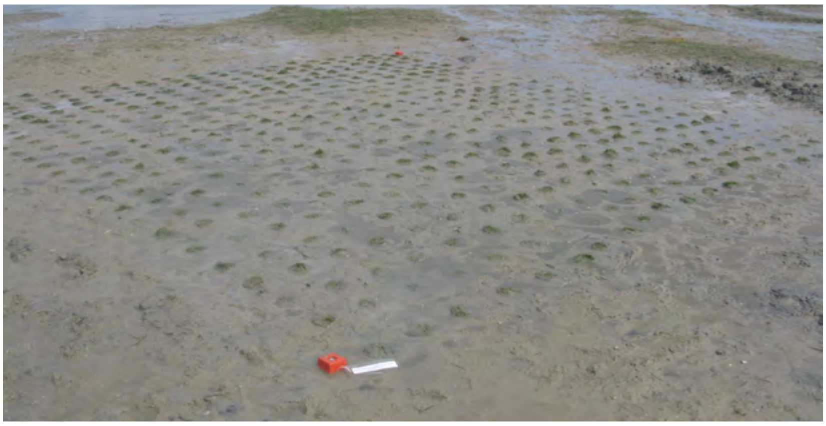
The wind turbine demonstration farm developed by EDF on the Horaine plateau off the island of Bréhat will be connected to the distribution network by a 16 km submarine cable to a shore-based delivery station located in Ploubazlanec (Côtes d'Armor).

This cable, laid in June 2012, crosses dwarf and common eelgrass beds at the landfall in Launay Cove. As these are environments of great ecological interest, EDF has tasked "In Vivo Environnement" with trialing an experimental measure to restore these beds after burial of the cable. This will test transplanting techniques and improve knowledge of the recolonization mechanisms of these plants. The experiment involves trials of cuttings (without sediment) and the collection and replanting of clods (with sediment) and comparing the results with natural recolonization.

By monitoring the area around the cable and the dynamics of eelgrass bed recovery in areas of transplanted stock, the impact of cable burying on eelgrass beds was accurately quantified, and the "rootball" transplant method for both species was validated. The survival of the transplanted stock and their growth varied according to bathymetric depth but were generally satisfactory. The best results were observed for the lower foreshore *Zostera noltii* meadow and the deepest *Z. marina* meadow, where growth was comparable to that of the natural control meadows.

For both species, the first signs of natural recolonization were observed 10 months after the end of the work in areas where the cable excavation had been reconsolidated.

These results were presented at the SHF's "Energies marines renouvelables" (Renewable Marine Energies) conference in Brest in October 2013.



June 2012

August 2012

August 2013

Transplanted dwarf eelgrass © Julien Dubreuil / IN VIVO

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DISMANTLING: SOME IDEAS FOR CONSIDERATION

Out Newton Wind Farm (United Kingdom) in 2006 © Havvindparken Sheringham Shoal / Harald Pettersen / Statoil

Explanatory statement

Since the life cycle of an average offshore MRE fleet is estimated at 25 years, there is little data available on the issue of decommissioning. However, experience in the oil and gas sector can be adapted for wind farms. In the same way as oil platforms, wind turbines could be dismantled and recycled, disposed of in approved landfills, or reconditioned and reused. The turbines could also be partially removed or tipped over on site.

Concerning cable removal, since 1998 the Ospar Convention has prohibited the total or partial abandonment of disused offshore facilities, unless otherwise agreed. The ICPC has identified good practice for the management of disused cables.

In France, the laying of cables in the public maritime domain is subject to:

› obtaining a licence to use the DPM (art. L2124-3 of the General Code on the Property of Public Persons, CGPPP, and decree no. 2004-308), as well as the payment of a State fee;

› an impact study and a public inquiry (the above decree and art. 553-2 of the Environmental Code in the case of offshore wind turbine cable).

The obligation to remove cables at the end of the concession or operation stems from Articles L2122-1, L2132-2 and L2132-3 of the CGPPP (protection of the use and integrity of the DPM), of the aforementioned Decree 2004-308, art. 2, which requires the concession applicant to specify "where applicable, the nature of the operations necessary to reverse the modifications to the natural environment and the site, as well as for the restoration or rehabilitation of the site at the end of the licence or its use". Article 8 of the same decree requires the operator "to ensure the effective reversibility of modifications made to the natural environment". Regarding offshore wind turbine cables, article 553-3 of the Environmental Code makes the operator responsible for their dismantling and for site restoration as soon as the operation ends, and requires the provision of the appropriate financial guarantees.

General principles

IMPACTS ON THE MARINE ENVIRONMENT

> Fixed and floating wind turbines

Degradation of the seabed

Currently, no existing farms have reached their operating life of approx. 25 years, so no dismantling operations have been conducted. However, it can be expected that the decommissioning of wind turbines will have negative impacts on the seabeds on which they are fixed as well as on the new habitats created as a result of the construction phase.

Resuspension of materials

The dismantling of installations will inevitably lead to a resuspension of materials, which, as during the construction phase, will affect plankton, lfilter feeders and fish in particular, but pelagic fish are presumably able to avoid an area with too high a turbidity level. If the substrate has been polluted during the construction or operation phase, this resuspension makes the pollutants present available to organisms.

Noise

The dismantling phase will involve the presence of ships, which are sources of noise emissions and disturbances for organisms. Depending on the techniques used during this phase, the type of foundations initially chosen, and the choices made regarding site remediation, there will probably be other sources of noise pollution. For example, if you choose to remove everything, the gravity foundations will be a problem: one solution would be to use explosives, but the impacts could be very significant.

> Marine Current Turbines

Note: Only current turbines using tidal currents are discussed here, and not offshore thermohaline currents.

These technologies are still relatively new and there is still no feedback on the dismantling of current turbines. Noise emissions, local degradation of the seabed and resuspension of materials can be expected.

> Ocean thermal energy

It is difficult to assess the impacts of decommissioning, as the technology is not sufficiently advanced to be able to elaborate on this point. However, as with any dismantling operation at sea, damage to the seabed can be expected when uninstalling the anchors and connecting cables. Depending on whether it is a coastal or offshore installation, the removal of pipes used to pump water can locally destroy the benthos. The disappearance of the artificial upwelling created by the MTE OTEC? may also have an impact.

> Wave energy converters

Here again, depending on the type of structure considered, the methods used during dismantling will differ. It is not currently possible to determine what the impacts will be during this phase.

> Tidal barrages

It is difficult to describe the impacts of this phase. During the dismantling of a tidal power plant, various disturbances such as noise, the resuspension of materials and seabed degradation are likely.

Operational principles

For the preservation of marine and coastal biodiversity, we recommend a discussion on decommissioning at the national level.

OPTION 1: COMPLETE REMOVAL

If a wind farm is completely removed, the same should apply to all related disruptive effects. However, some sediment resuspension problems can occur, especially if the cables had been buried, resulting in the disturbance of any sensitive habitat. In addition, there is a risk of disturbing habitats that have been created and evolved over the years, in many cases constituting islands of comparatively undisturbed hard substrates in regions otherwise do-

© Dubois

minated by soft substrates. Moreover, if a wind farm has effectively protected an entire area from the destructive effects of other impacting activities, this protection is likely to disappear along with its structures.

New technologies may provide better alternatives, but experience to date with the dismantling of oil platforms has favoured explosives and cutting-up. Explosives kill most animals living in the area closest to each turbine, and fish with swim bladders are the most affected. Given the large number of turbines and the surface area they cover, the impacts could be significant if this technique were used.

Even if, originally, it was assumed that all turbines would be removed, the dismantling of the parts of the wind turbines below the seabed surface could, in many cases, be called into question.

OPTION 2 : LEAVE THE STRUCTURES IN PLACE, NOTABLY BY TIPPING THEM OVER

Another option is to leave the structures submerged in place. The turbines on the bottom would emit no noise and would no longer have moving parts. If left in place, the structures would become permanent because the degradation rate of high-carbon steel is extremely slow. Any habitat that has been created, and any habitat alteration caused by the physical presence of the facilities, would then be maintained.

OPTION 3: ONGOING MODERNIZATION

In contrast to oil and gas, wind resources are renewable, and are not exhausted at the end of the concession: it is therefore conceivable that the wind farm can remain in operation, with continuous maintenance and improvements if necessary. In this case, both the positive and negative impacts of the operation of the facilities on the marine environment will continue.

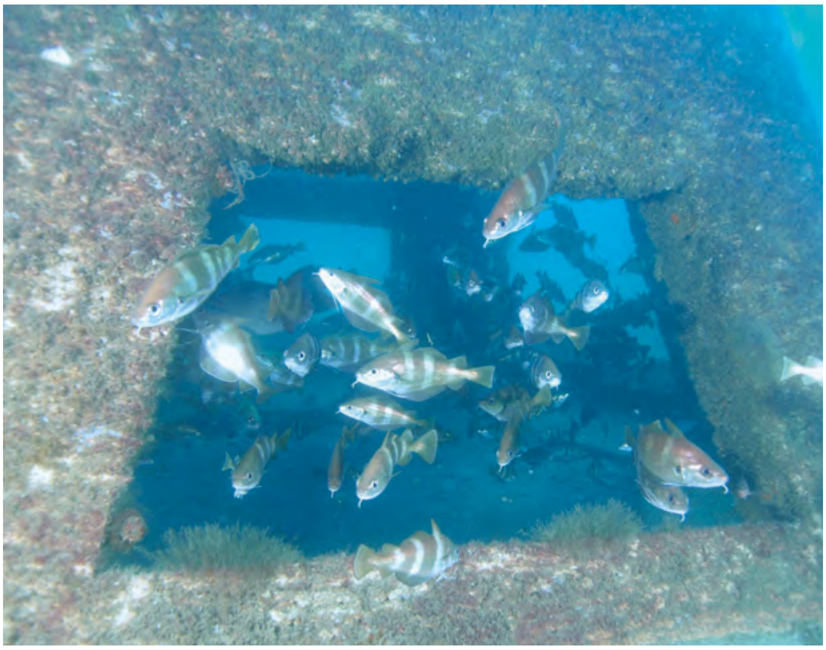
In conclusion, decisions on the fate of installations will inevitably have to be taken on a case-by-case basis.

Ultimately, we currently have little information.

The issue of optimal decommissioning plans must be addressed in due course.

However, we recommend:

- that during the impact study, all options are assessed in advances;
- that the dismantling plan be developed progressively, in an adaptive manner, but that it be clarified several years before dismantling. This will allow all stakeholders to be prepared, and the authorities to still have the capacity to exert pressure at the time of the decision.



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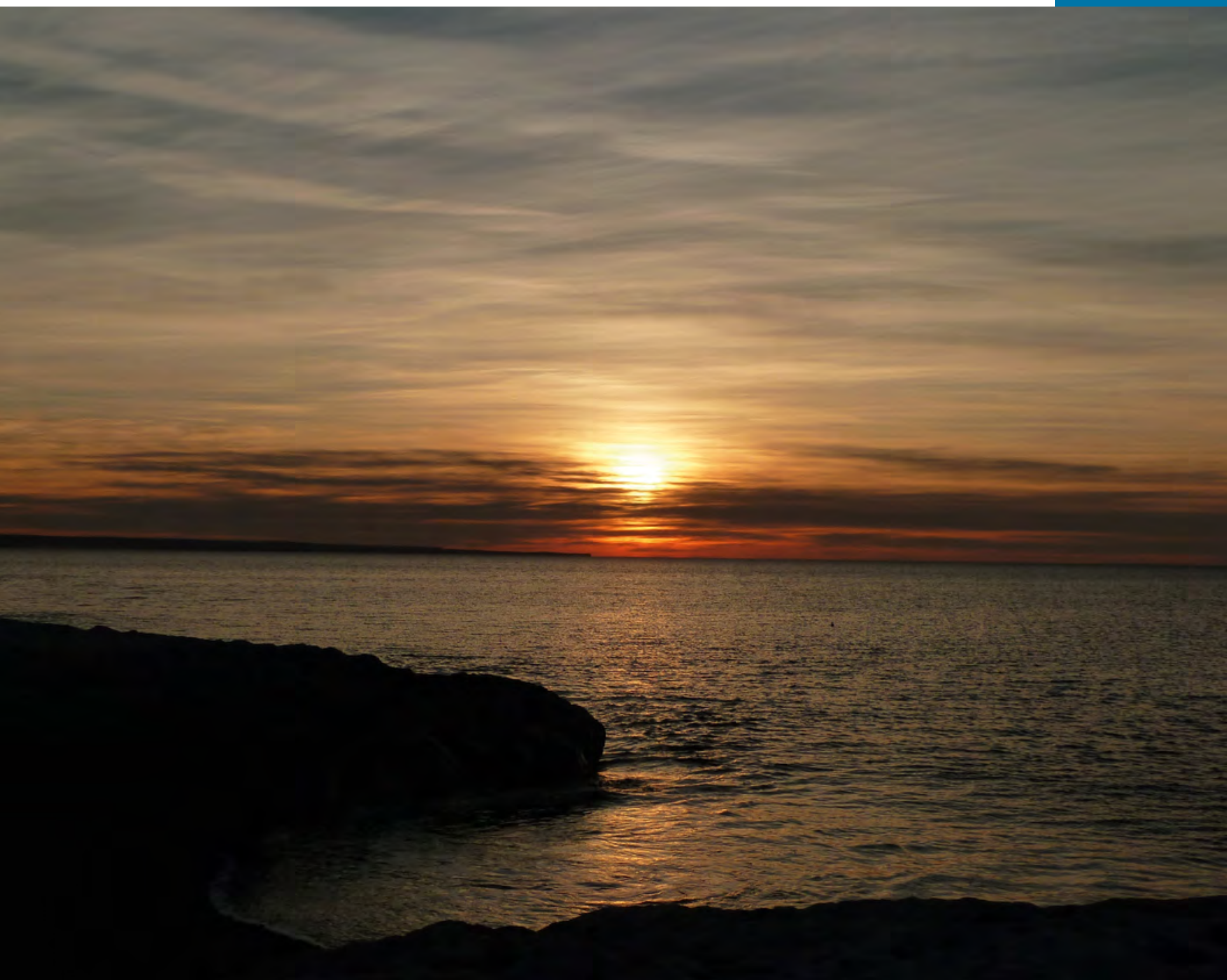
Conclusion

It would be advisable to create a national working group dedicated to decommissioning, with the following focal points:

- Establishment of initial environmental states before decommissioning,
- Ongoing review of decommissioning plans in accordance with new techniques that may become available within 20 or 30 years,
- Analysis of the new ecological balance achieved within the wind farm, in particular at the base of the submerged structures.

For more information, see

- IUCN, 2010, Greening Blue Energy
- Kalaydjian R., 2011, Submarine cables, Ifremer Issy-les-Moulineaux



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