JULY 2022

Towards Sustainable Development of Marine Renewable Energies in the Mediterranean

Project co-financed by the European Regional Development Fund

This report was edited by Plan Bleu - Regional Activity Centre of UNEP/MAP:

Tour la Marseillaise, 16è étage
2 bis, Boulevard Euroméditerranée – Quai d'Arenc
13002 Marseille, France
www.planbleu.org

Co-authors: Martina Bocci, Céline Dubreuil & Francesca Coccon

Contributors: Eloïse Faure (Plan Bleu), Séverine Michalak, Arnaud Terrisse (Plan Bleu)

Preferred citation: Plan Bleu (2022) Towards Sustainable Development of Marine Renewable Energies in the Mediterranean, Interreg MED Blue Growth Community project.

Table of contents

LIST OF ACRONYMS

ADEME - Agence de l'environnement et de la maîtrise de l'énergie / Agency for the Environment and Energy Management
BE – Blue Energy
BEL – Blue Energy Labs
BSH – German Federal Maritime and Hydrographic Agency
BSO – Business Support Organisation
CESEC – Central and South Eastern Europe Energy Connectivity
CfD – Contracts for Difference
CSR – Corporate Social Responsibility
DSF – Document Stratégique de Façade / Strategic Coastal document
EC – European Commission
EDF – Electricity of France
EIA – Environmental Impact Assessment
EMEC – European Marine Energy Center
EMF - Electric and magnetic fields
Enel GP – Enel Green Power
EU – European Union
FiT – Feed-in tariff
GEM - Generatore Elettrico Marino/ Marine Electrical Generator
GIS – Geographical Information System
GVA – Gross Value Added
HVDC - High-Voltage Direct Current
ICZM – Integrated Coastal Zone Management
IDON - North Sea Interdepartemental Consultation Directorate
IEA – International Energy Agency
IFP-EN – IFP Energies nouvelles
IPCC – Intergovernmental Panel on Climate Change
ISWEC – Inertial Sea Wave Energy Converter
KP – Knowledge providers
LCOE – Levelized Cost of Energy
LLC – Limited Liability Company
MDB - Multilateral Development Banks
MED – Mediterranean

MEDENER – Mediterranean Association of National Agencies for Energy Management
MPA – Marine Protected Area
MRE – Marine Renewable Energy
MSME – Micro Small and Medium Enterprise
MSP – Marine (or Maritime) Spatial Planning
MU – Multi-use
MUP – Multi-use Platform
MUSICA - Multiple use of Space for Island Clean Autonomy
NECPs – National Energy and Climate Plans
NFFO – National Federation of Fishermen's Organisations
NIMBY – Not-In-My-Backyard
NL – Netherlands
NMCs – Northern Mediterranean Countries
NMS – Noise Mitigation Screens
O&M – Operation and Maintenance
OBREC – Overtopping BReakwater Energy Conversion
OE – Offshore Energy
OME – Observatoire Méditerranéen de l'Energie / Mediterranean Energy Observatory
ORE – Offshore Renewable Energy
ORECCA - Offshore Renewable Energy Conversion platforms – Coordination Action
OTEC – Ocean Thermal Energy Conversion
OWC – Oscillating Wave Converter
OWE – Offshore Wind Energy
OWF – Offshore Wind Farm
OWT – Offshore Wind Turbines
PAM – Passive Acoustic Monitoring
PBR – Photobioreactor
PGL – Provence Grand Large
PRO – Pressure-retarded osmosis
PTO – Power Take Off
PV - Photovoltaic
R&D – Research and development
R&D&I - Research, Development and Innovation
RAE - Regulatory Authority for Energy
RES – Renewable Energy Sources
REWEC - Resonant Wave Energy Converter
RPV – Resources-Processes-Value

SDG – Sustainable Development Goal
SEMCs – Southern and Eastern Mediterranean Countries
SGE – Salinity Gradient Energy
SMEs – Small Medium Enterprise
SNML – Stratégie Nationale pour la Mer et le littoral / National Strategy for the Sea and the Coastline
SoED – State of Environment and Development in the Mediterranean
SWAC – Sea Water Air (Cooling) Conditioning
SWOT – Strength, Weaknesses, Opportunities and Threats
TEC – Tidal Energy Converter
TEN-E - Trans-European Networks for Energy
TRL - Technology Readiness Level
UK – United Kingdom
UN - United Nations
UNEP/MAP – United Nations Environment Programme / Mediterranean Action Plan
UNITED - Co-location pilots boosting cost-effective, and ecofriendly and sustainable production in marine environments
US – United States
VAT – Value Added Tax
WE – Wave Energy
WEC – Wave Energy Converters
WT – Wind Turbines
WWF – World Wildlife Fund

1. Overview

The Mediterranean Sea covers an area of approximately 2.5 million km^2 with a 46,000 km long coastline shared between 22 countries and a population of over 460 million. Of this population, one third resides in coastal areas, which have been increasingly urbanized over the last few decades [9].

The Mediterranean is characterized by several marine-based activities on which surrounding countries largely base their economies. Well-established activities include (i) fisheries and aquaculture, that generate a Gross Value Added (GVA) of over €4 billion and some 353,000 jobs; (ii) maritime transport, with a GVA of €27 billion and 550,000 people employed in the sector; and (iii) coastal tourism, generating a GVA of €135 billion and 3.2 million jobs [10].

However, these traditional economic activities, which have been guaranteeing the livelihood of coastal communities for centuries, are all at risk, in particular tourism, marine transport and fisheries, as the Mediterranean is and will be increasingly affected by climate change in the course of the 21st century, with severe impacts on the environment and human welfare [11]. As a result, the adoption and development of sustainable and efficient forms of energy production are strongly needed in order to mitigate climate change while, addressing growing local energy demand and securing the sustainable energy independence of coastal areas. As such, given the emphasis which the EU places on renewable energy in an effort to transition to a low carbon economy - the EU target for 2030 is that 32% of electricity will be generated from renewables (Directive 2018/2001) - it is assumed that the Blue Energy will become an important maritime industry in the Mediterranean Sea in the near future [10].

Harnessing Marine Renewable Energy (MRE) potential in the Mediterranean is crucial to contributing to the global and European efforts towards decarbonization, in the framework of the UN Sustainable Development Goals (i.e. SDG7 Affordable and Clean Energy and SDG13 Climate Action) as well as the European Green Deal. Developing renewable energy is also essential for achieving Objective 4 - Addressing *climate change as a priority issue for the Mediterranean* - and Objective 5 - *Transition towards a green and blue economy* - of the Mediterranean Strategy for Sustainable Development. MRE represents an opportunity for economic growth in the region, can enhance the security of its energy supply and boost competitiveness through technological innovation. The continuous development of MRE technologies will also increase the efficiency of energy production.

> "Marine" and "Ocean Energy" encompass the energy generated by offshore wind, waves, tidal power, thermal energy conversion, salinity gradient [1],[2]. This sector is also generally referred to as Marine Renewable Energy (MRE). The term "Blue Energy" (BE) has been used to extend these definitions to further include energy obtained from marine biomass [2],[3].

As described by the State of the Environment report (SoED)[12], the Mediterranean continues to rely on energy imports and fossil fuels, despite improvements in renewable energy production. The dependence of the region on imports equals 40% of the energy mix. The introduction of renewable energy and energy-efficiency measures could see this drop to less than 25% [102]. Total energy production has been increasing since 1990, reaching 549 Mtoe[1] in 2015, well below the region's energy demand. Electricity demand almost doubled between 1990 and 2015. Renewable non-hydroelectricity production increased from 1% of total production in 1990 to 11% in 2015. The 2015 electricity generation mix also included 29% gas, 25% nuclear (of which 87% in France), 16% coal, 13% hydro, and 7% oil. There is an enormous but untapped potential for a further increase in renewable energy sources (wind and solar), especially in Southern Mediterranean countries, which could help meet rising energy/electricity demand at a lower cost, to ensure a cleaner energy sector and reduce energy dependency (the region currently imports around 58% of its fossil fuel demand, with 90% in NMCs and 20% in SEMCs).

Several reasons (environmental, technological and social) can explain the delayed implementation of marine renewable energies in the Mediterranean region and the lack of business development compared with other maritime areas such as the Atlantic or the North Sea:

- Mediterranean specific natural conditions with lower wind, tide and current as well as greater depths;
- Until now, developing and implementing marine energy technologies has not been a priority in the Mediterranean, as it was considered less cost-effective when compared to other renewables (e.g. solar or land-based wind energy);
- MRE sectors in the Mediterranean countries are at an early stage of development, and Research & Development (R&D) activities are expected;
- Administrative bureaucracy (e.g. long and uncertain authorization procedures);
- Financial barriers (e.g. lack of long-term financing, high and uncertain project development costs) and an extensive use of energy subsidies especially in SEMCs that leads to market distortions [109];
- Infrastructural barriers: SEMCs lack adequate electricity infrastructure;
- Regulatory barriers: SEMCs lack a stable and harmonized energy regulatory framework, a prerequisite for the deployment of wind energy;
- Societal barriers such as social reluctance since it is believed that the development of Blue Energy can negatively impact local landscapes and economies, as well as biodiversity.

However, there are many places in the Mediterranean Basin with considerable potential, in particular for offshore wind farming and, in a lesser degree, for wave and tidal/current farming development. Wind energy potential is especially high in the Southern and Eastern Mediterranean region. SEMCs are estimated to have a technical wind power potential of 21,967 TWh/year, 34 times more than the northern Mediterranean countries [109]. Moreover, the milder weather conditions enable the affordable testing of devices and stimulate the design of efficient technologies [2]. The Mediterranean therefore has the potential for both significant MRE production [6], [7], [8] and technological development. Several large-scale pilot projects are currently underway. To achieve this potential, incentive policies must be put in place, notably through launching calls for tenders to finance the construction of MRE parks. Mediterranean industry will be able to develop specific technologies addressing the local context with, for example,

[1] Million Tons of Oil Equivalent

floaters or anchors; and avoid useless replication and wasted resources, if the Mediterranean countries currently developing pilot projects share their experience with other countries.

A holistic approach to Marine Spatial Planning (MSP) is also needed in order to create the space necessary for BE development in the Mediterranean, while lowering competition for marine space and resources. Finally, actions must be undertaken in order to further boost social acceptance and eliminate prejudices related to the deterioration of the landscape from BE facilities. In addition, development in the Mediterranean region will need to take into consideration the level of maturity of other countries, which entered the MRE market 20 years earlier.

2. BE Technology developments: current state and perspectives

As introduced above, BE is considered in this report in a broad sense and includes: (i) offshore wind energy by means of floating or fixed-foundation turbines; (ii) wave energy (offshore and onshore), which can be embedded on manmade structures, such as ports and wave-breakers, or on floating buoys; (iii) tidal energy generated by differences in sea level or by marine currents, using floating, seabed moored, and kite-like turbines; (iv) ocean thermal energy, where the temperature difference between the air and ocean or between different ocean layers is used for cooling or heating buildings; (v) salinity gradient energy, i.e., energy extracted by using the difference in salt concentration between fresh and salt water; (vi) marine biomass, which includes seaweed farms or micro-algae absorbing seawater nutrients and CO_2.

As said, there is currently no commercial development of BE in the Mediterranean, despite their high potential impacts on socio-economic characteristics, and the readiness level is low for most Mediterranean countries. The two most advanced MRE, adapted and developed in the Mediterranean area are wind energy and wave energy (PELAGOS project, 2019a) [13].

Offshore wind is the closest-to-market BE technology (the first commercial floating wind farms are due to open in 2023), while the other most promising ocean energy technologies are (Pisacane et al., 2018) [2]:

- Converters extracting kinetic energy from tidal currents;
- Converters harnessing the difference in potential energy from the rise and fall of sea levels between high tide and low tide (tidal range);
- Wave energy converters, extracting kinetic energy from wind-driven waves;
- Ocean Thermal Energy Converters, harnessing temperature differences between deep and surface ocean waters;
- Salinity gradient converters, harnessing the chemical potential of differences in salt concentration in ocean waters.

The exploitation of each one of these resources has fostered the development of different technical solutions, in some cases adapting existing technology, otherwise leading to the design of new devices.

Beyond that, technological innovations devoted to enhancing efficiency in energy conversion and/or storage and distribution are equally important, and have a cross-cutting effect on all energy technologies.

Among all the MREs technologies, offshore wind energy, stream (in the Straits), waves (mainly for sites such as small islands) and Sea Water Air Cooling Conditioning (SWAC) show the most promise for the Mediterranean, although they are at different stages of maturity, depending on the technology.

Research and technology efforts have been mainly concentrated on wave and tidal energy converters, which represent the most appropriate and promising options for Mediterranean conditions. Several prototypes and pre-commercial devices have been designed and tested, some of which are now entering the commercial phase. The main advantage offered by such technologies is that, by being specifically tailored to the Mediterranean environment, they have had to specifically address the issue of efficiency due to the relatively low wave energy levels in the Mediterranean Basin. On the other hand, in order to export these technologies to the global market, it is necessary to prove their viability in more severe sea conditions and the actual feasibility of upscaling them. Parallel technological research and innovation activities are being conducted to enhance the efficiency of energy conversion and/or storage and distribution, and have a cross-cutting effect on all marine energy technologies.

Among offshore technologies, Levelized Costs Of Energy (LCOE)[2] values for bottom-fixed offshore wind are lower than for floating offshore technologies. However, the difference is expected to decrease by 2050. For wave and tidal technologies, LCOE values are significantly higher, but they are also on a decreasing trend (Union for the Mediterranean, 2021) [14].

The following paragraphs provide an overview of the aforementioned BE sources and their developments in the Mediterranean.

2.1 Offshore wind energy

Offshore wind power or offshore wind energy is the generation of electricity through wind farms in bodies of water, usually at sea.

2.1.1 Brief description of the technology

Offshore wind power is generated from the wind blowing over the sea. Fixed offshore wind turbines (OWT) are the most mature MRE source, taking advantage of the existing experience from onshore wind

[2] The levelized cost of energy (LCOE), also referred to as the levelized cost of electricity is a measurement used to assess and compare alternative methods of energy production. The LCOE of an energy-generating asset can be thought of as the average total cost of building and operating the asset, per unit of total electricity generated over an assumed lifetime. Alternatively, the LCOE can be thought of as the average minimum price at which the electricity generated by the asset is required to be sold for in order to offset the total costs of production over its lifetime. The LCOE is used to compare different energy-producing technologies regardless of unequal life spans, differing capital costs, size of the projects, and the differing risk associated with each project. (Source: https://corporatefinanceinstitute.com/resources/knowledge/finance/levelized-cost-of-energy-lcoe/)

turbine installations. Choosing the most suitable type of offshore fixed foundation depends on water depth, wave load and ground conditions, as well as turbine induced frequencies (interaction with wave load may give higher loads to the foundation). The most common foundations used for current offshore wind projects are Mono-pile and Gravity-based structures, followed by space frame structures, which are better for intermediate and deep-water depths.

Floating offshore wind is a breakthrough innovation market, as opposed to offshore wind with fixed foundations, whose development potential is limited mainly by the bathymetry of the oceans and seas- 40-50 meters deep being the threshold commonly accepted by the players of the market - as well as the social acceptability of the location of farms projects (PELAGOS project, 2017c) [28]. The development of floating OWF opens new opportunities in areas with deeper water (> 100 m) extending the available space for development and installation of plants. However, longer distance to shore implies energy losses during transport as well as higher costs for both distribution infrastructures and for construction and maintenance.

Innovative devices


Vertiwind (left © NENUPHAR), an innovative concept of floating vertical axis wind turbines, which are almost all designed on a traditional horizontal axis, are a technological breakthrough in the landscape of offshore wind farms.

With the **EolMed** project (right © IDEOL), an innovative foundation concept for floating wind turbines by IDEOL has been used. This foundation, a ring-shaped platform developed and patented by the company's engineers, is a breakthrough technological development in the floating wind turbine market. Made from steel or concrete and designed to support 2–8 MW turbines, Damping Pool® foundations are square structures with a typical side length of 35 to 55m.

2.1.2 Current state in the Mediterranean

The Mediterranean Sea is characterized by high wind potential, but its deep waters have so far limited the development of Offshore Wind Farms (OWFs). To date, there are no OWFs in the Mediterranean. A large number of offshore wind projects are at a concept/early planning stage, while many have been cancelled or remain in a dormant status [17].

Importantly, in the Mediterranean, practically no large installations of wind turbines with fixed foundations are possible due to the intrinsic features of Mediterranean Sea (continental shelf, depth). Floating offshore wind turbines appear to be a better solution for the specificities of the sea basin, as they are catered to much greater depths so that the installations can be distanced from the shore and preserve valuable landscapes (PELAGOS project, 2017a [18]).

For now, offshore wind is mostly deployed in the Northern Mediterranean - notably in France, Greece, Italy and Portugal. Twenty-three offshore wind projects are currently in the pipeline, most of which are in the planning and permitting development stages (Union for the Mediterranean, 2021) [14].

In April 2022, the first offshore wind farm in the Mediterranean was inaugurated off the coast of Italy. The Beleolico wind project is located in the Apulia region, just a few hundred yards off the Port of Taranto. The Italian offshore wind development company, Renexia, is the owner and developer. The project is a small installation by modern standards, featuring just ten bottom-fixed 3.0 megawatt near-shore wind turbines. The turbines have a total combined capacity of 30 megawatts (MW) and an estimated output of 58,000 megawatt-hours (MWh) per year, enough to power 21,000 homes. Three pilot projects for floating offshore farms have been approved in France and are scheduled to be built before 2023, in the Gulf of Lion, France:

- EolMed project operated by Qair, formerly known as Quadran Énergies Marines, (partners: Ideol, Bouygues TP, Senvion), with three 10 MW wind turbines mounted on steel floats and connected to the French Electricity Transmission Network (RTE) by an underwater cable. This project is located more than 18 km off the coast of Gruissan and Port la Nouvelle (Occitan region). The wind turbines will be at a 62 m bathymetry depth and anchored to the seabed. This fleet with a total capacity of around 30 MW will produce nearly 100 million kWh per year, i.e. the annual electricity consumption of 50,000 inhabitants. The construction of EolMed project started in May 2022 and production is expected to start by 2024;
- “Provence Grand Large'' (PGL) project located 17 km off Port Saint Louis du Rhône and led by EDF Renewables (partners: Siemens, SBM, IFP-EN, RTE) with three 8.4 MW wind turbines (Plan Bleu, 2020) [26]. Its entry to service, initially planned for 2020 was recently delayed following an appeal by an association in 2021 due to potential environmental impacts on sea birds. However, in April 2022, the Nantes Court of Appeal rejected the appeal and recognized the legality of the permit issued for to operate this pilot farm. The PGL project is the only offshore wind project in the world that will test a "taut-line platform" type float system, which has the specificity of offering stability comparable to that of installed offshore wind turbines and a reduced footprint on the seabed

compared to catenary technologies, as well as preserving the seabed and its biodiversity due to the absence of "ragging" by chains or cables. The Provence Grand Large (PGL) pilot project should be commissioned in 2023.

- “Les Eoliennes Flottantes du Golfe du Lion'' (LEFGL) project off Leucate led by Engie and EDP Renewables (Partners: Banque des Territoires, Principle Power, Eiffage, RTE and General Electric) with three 10 MW wind turbines sitting atop the semi-submersible WindFloat platform from Principle Power, Inc (see Table in Annex I). This project was the first in the Mediterranean region to obtain all required authorizations from judicial authorities (and without any possible recourse). In January 2022, the final investment decision by the project's shareholders allowed the construction phase to begin. The floating wind farm will generate about 110 GWh each year, a production equivalent to the consumption of more than 50,000 inhabitants. It should be operational by the end of 2023.

Two other Mediterranean floating wind farms are going to be developed in Sicily and Sardinia by GreenIT and Copenhagen Infrastructure Partners. The offshore wind farm developed in Sicily, off the coast of Marsala, will have a capacity of 250 MW and will consist of 21 turbines. It should be up and running in 2026. The second wind farm is to be developed in the sea area facing the south-western coast of Sardinia, consisting of 42 wind turbines with a power of around 12MW each for a total capacity of more than 500 MW. It is scheduled to enter commercial operation in 2028. Together, the two wind farms are estimated to be able to generate over 2,000 GWh of electricity annually, which is equal to the average annual power demand of about 750,000 homes.

2.1.3 Offshore wind potential in the Mediterranean

According to a recent study (Pantusa & Tomasicchio, 2019) [24], the theoretical maximum annual offshore wind production for the whole Mediterranean area is estimated to be around 742 TWh/year. The methodology behind this study was based on the use of an open GIS platform and considered bathymetric data, annual average wind speed data, environmental data, turbine technical characteristics and marine boundaries. Italy, Lybia, Tunisia and Greece have theoretically the greatest annual potential in terms of offshore wind power (cf. Figure 1).

Offshore wind energy has been highlighted as the most promising blue energy form by all 8 partner countries of the MAESTRALE project (Italy, Spain, Croatia, Greece, Slovenia, Cyprus, Portugal and Malta) even though in some regions the potential of this BE is characterized as low (e.g. in Slovenia the use of offshore wind energy is possible but on a very limited scale), since the wind speed is not as high as in other regions outside the MED region (MAESTRALE project, 2018) [40]. This impacts the feasibility of potential investments in these regions.

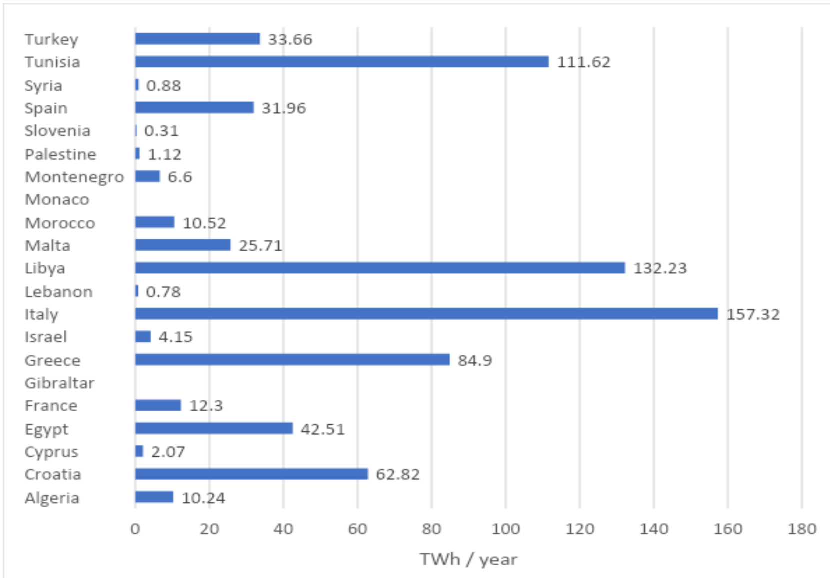


Figure 1. Theoretical maximum annual offshore wind power production for each Mediterranean country (Data source: Pantusa &Tomasicchio, 2019 [24].

In recent years, several studies focused on evaluating the available offshore wind power potential across the Mediterranean Sea have been conducted (see PELAGOS project, 2017b for references). According to these results, by considering wind speed at 80 m above sea level, the Gulf of Lion and the Aegean Sea are the most favorable areas for offshore wind energy projects, with a potential of 1,050 and 890 W/m^2 respectively. High offshore wind resources are also found in the offshore areas east and west of Crete, east of the Gibraltar Strait, in the western Ligurian Sea, in the Strait of Sicily and in the Otranto strait (see Figure 2).

By adding the bottom depth suitability to the criteria for identifying suitable areas for potential OWF development in the Mediterranean Sea, additional candidates are a large part of the Adriatic Sea and the Gulf of Gabes. Again, by adding more restrictions (e.g. distance to shore, existing grid connection, sea-floor sediments, etc.) the Aegean Sea, the Gulf of Lions, along the Mediterranean coasts of Spain, as well as along and off the North African coasts (especially off the Nile river estuary) are suitable places for OWF installations. However, other aspects (e.g. environmental, socio-economic, financial) that limit the development of this blue energy in the region should be taken into serious consideration in the analyses of potential locations for OWF (PELAGOS project, 2017b) [16].

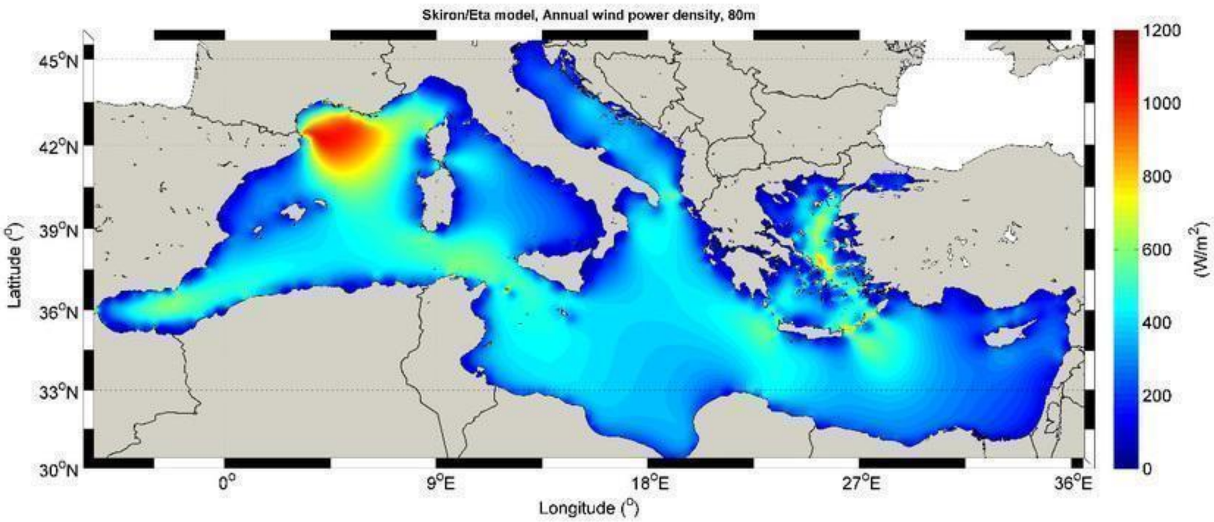


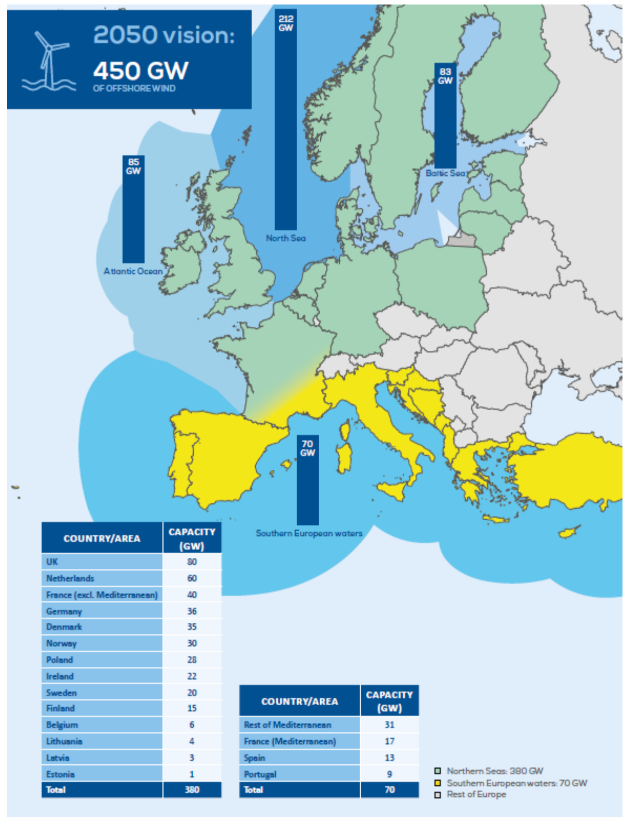
Figure 2. Mean annual offshore wind power density at 80 m (Source: CoCoNET project)

2.1.4 Energy capacity at EU level

Europe holds a leading position in OWE generation, with 110 offshore wind farms located in 12 European countries and 5,047 grid-connected wind turbines, for a total installed offshore wind capacity of 22 GW over approximately 5000 km^2 [23]. Just five countries – the UK (accounting for 45% of all installations), Germany (34%), Denmark (8%), Belgium (7%) and the Netherlands (5%) – account for 99% of this capacity. For a review of the existing OWF projects see the Global Offshore Wind Farm Database.

The EU offshore wind market accounts for 42% (12 GW) of the global market in terms of cumulative installed capacity, followed by the UK (9.7 GW) and China (6.8 GW). European companies are key operators on the global offshore wind market though they face increasing competition from Asian companies. The global levelized cost of energy (LCOE) for offshore wind decreased by 44% in 10 years, reaching EUR 45-79/MWh in 2019 (EU Offshore Renewable Energy Strategy - COM(2020) 741 final).

According to the European Commission, Europe will need between 230 and 450 GW of offshore wind by 2050, making it a crucial pillar in the energy mix together with onshore wind. 450 GW would meet 30% of Europe's electricity demand in 2050, which will increase by 50% from 2015 due to electrification. The capacity in the EU Mediterranean is expected to be 70 GW (Figure 3). In order to achieve this, the rate would need to rise from almost 0 to over 4 GW per year or 840 km^2 per year between now and 2027 (Wind Europe, 2019) [24].



COUNTRY/AREA	CAPACITY (GW)
UK	80
Netherlands	60
France (excl. Mediterranean)	40
Germany	36
Denmark	35
Norway	30
Poland	28
Ireland	22
Sweden	20
Finland	15
Belgium	6
Lithuania	4
Latvia	3
Estonia	1
Total	380

COUNTRY/AREA	CAPACITY (GW)
Rest of Mediterranean	31
France (Mediterranean)	17
Spain	13
Portugal	9
Total	70

Figure 3. EU OWE vision at 2050. Capacity in the EU Mediterranean is expected growth to 70 GW. Source: Wind Europe, 2019 [24].

2.2 Wave energy

Wave energy (WE) is the marine hydrokinetic energy that can be harvested from the motion of ocean waves. The mechanical process of wave energy absorption and conversion requires a moving interface, which can either be a partly or totally submerged moving body whose kinetic energy is harnessed by a Power Take Off (PTO), or a moving air/water interface subject to time-varying pressure as a function of wave incidence [2]. Wave energy highly depends on wind characteristics such as wind speed, its duration and the distance of water over which it blows (fetch length), the bathymetry of seafloor and currents. These variables determine the most important wave characteristics (i.e. significant wave height and energy period). The wave resource presents several advantages [16],[17],[18]:

- Waves present the highest energy density among available MRE sources;
- Energy losses are small even for long distances of wave propagation in the form of swell;
- The visual impacts of wave energy devices are often minimal, since some can be entirely submerged under water; and

- Seasonal variability of wave energy resource as well as electricity demand in temperate climates are highly correlated.

Additionally, compared with OWE, wave energy is more persistent and spatially concentrated. According to Giuliana Mattiazzo (2019), the wave resource is characterized by a high degree of predictive reliability with respect to solar and wind resources. This makes it easier to integrate renewable energy into the continental or insular power grid and it is a reliable generation node in smart grids.

2.2.1 Brief description of the technology

As many as 170 types of wave energy converters have been designed, but fewer than 20% are at the full-scale prototype stage 2GW [28]. Based on their orientation (with respect to wave direction and principle of operation), the predominant types of Wave Energy Converters (WECs) are the attenuator, the point absorber, the oscillating wave surge converter, the oscillating water column, the overtopping device and the submerged pressure-differential device (Figure 4).

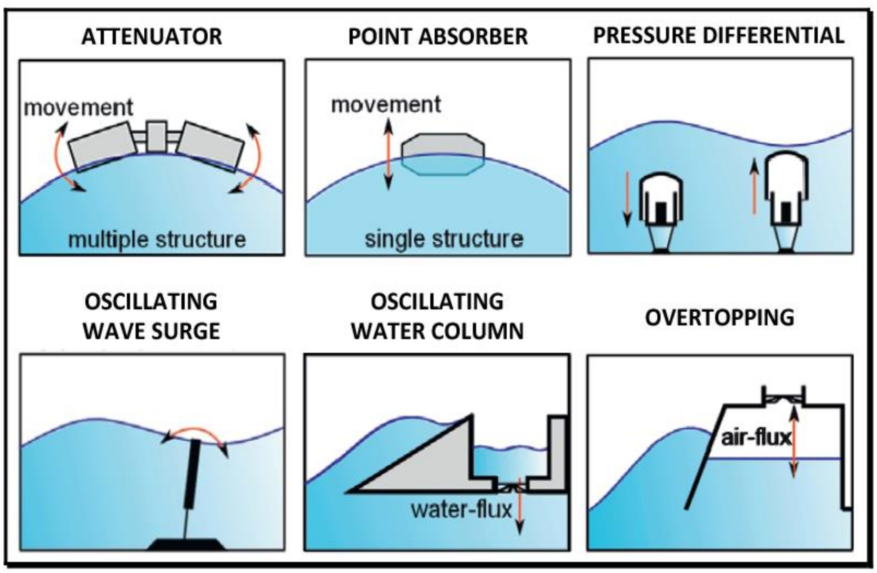


Figure 4. WEC main concepts. Source: Titah-Benbouzid & Benbouzid, 2014.

Wave attenuators are floating devices operating parallel to the predominant wave direction. Substantially, they ride the waves and capture energy from relative motion of the two arms as the wave passes them. They can be positioned either in shallow or deep waters and the wave output power varies from 200 kW to 2.5 MW. A well-known example is the P2 Pelamis device.

Point absorbers are capable of collecting energy from all wave directions. They are smaller devices, either floating or submerged, deployed in deep waters or near shore. They can be moored (e.g. AquaBuoy) or bottom fixed (e.g. Lysekil project) and the output power varies from 20 kW to 6 MW.

Oscillating wave surge converters capture energy from wave surges as they are positioned perpendicular to the wave direction (terminator type). They are mostly bottom fixed and slack moored (e.g. WaveRoller, Wavepiston), and mainly installed near shore (e.g. Aquamarine Power Oyster).

The Oscillating Water Column (OWC) consists of a column that is open to the sea below the water surface. Air is trapped in the inner space of the column and above the free-surface. The water oscillates up and down according to wave momentum, compressing and decompressing the air within the column and forcing it to flow through an air turbine to generate electricity. It is mostly a shore-based structure, such as LIMPET or Mutriku, but it can also be anchored in deep waters (e.g. Ocean Energy Buoy). The output power varies from 300 kW to 1 MW.

Overtopping devices are either floating or bottom fixed. The mechanical principle is to force water to pass over the structure, collect it in an above sea level reservoir, and then release it through hydro turbines. The potential energy of the water in the tank is converted to electricity with an output power ranging from 4 to 11 MW. A typical overtopping device is Wave Dragon.

Finally, submerged pressure differential devices are typically located near shore and attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential inside that pumps fluid through a system to generate electricity. Examples of submerged pressure differential converters include M3 Wave which has an output power from 50 to 150 kW.

Innovative devices

Besides the aforementioned WEC concepts, in the last decade the opportunity of combining offshore wind and wave energy technologies has arisen and research is being conducted on hybrid systems (see Pérez-Collazo et al., 2015 [30] for a review of the different concepts). The advantages of these hybrid systems include: a) a significant cost reduction; b) the opportunity of using the multipurpose platforms for hosting other marine uses such as aquaculture or maritime transport [2]; c) accelerated development of wave energy technologies by using the experience of OW; d) the guarantee of smoother power output and minimum energy production at a constant rate independently of meteorological conditions thanks to the integration of multiple sea energy converters.

The Pelamis snake (developed by Pelamis Wave Power Ltd) is an "attenuator" type float, consisting of a 140 meter long, 3.5 meter diameter articulated steel tube weighing 350 tons before ballasting, generating 750 kW. This system is now in the pre-commercial stage. Demonstration trials have been conducted in Portugal and in Scotland [1].

The Wave2Water device was installed in Greece (Figure 5). It can be used for desalination or for producing electricity or both and is modular (thus more units can be assembled in the basic configuration), capable of producing energy even at low sea conditions. It is a low-profile installation in order to avoid visual disturbance and operates at very low noise levels. The principle of operation relies on the oscillating motion due to the propagation of surface sea waves.

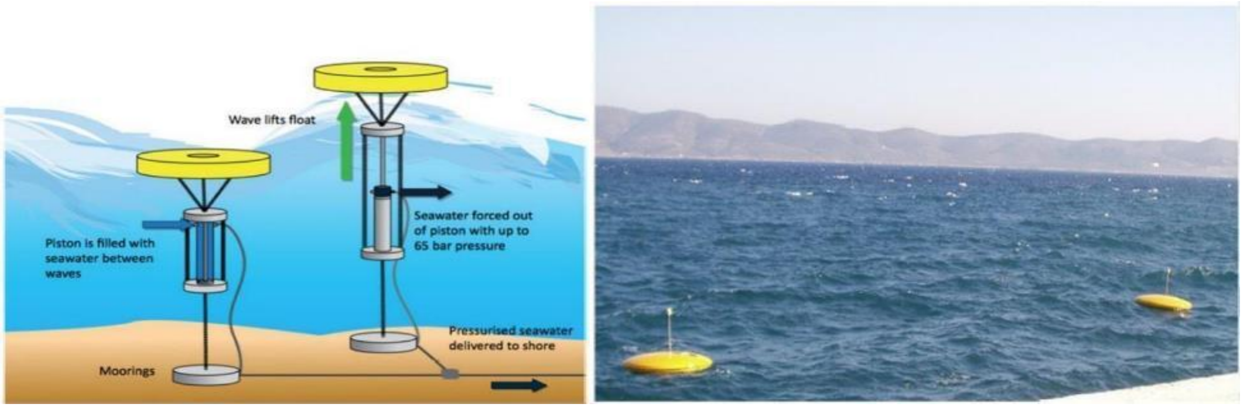


Figure 5. The Wave2Water wave energy converter (design principle, left) and in real sea conditions (right). Source: [SIGMAHELLAS]

2.2.2 Current state and development in the Mediterranean

Although sea waves and swell are present in the Mediterranean, the current generated does not enable the production of large quantities of energy because of the characteristics of the waves (short wave = small fetch). However, production systems can be deployed locally, particularly in insular territories, in order to provide them with additional energy, together with other renewable energies such as solar or wind [18].

Important progress has been achieved over the past decade, especially in Italy. Inertial Sea Wave Energy Converter (ISWEC) technology is one of the few Mediterranean concepts to have reached Technology Readiness Level (TRL) 7. It is based on the gyroscopic technology already used in marine applications for roll stabilization. The system is enclosed in a sealed hull and consists of a flywheel that rotates generating gyroscopic torque. The PTO then converts this torque into electrical power. In August 2016, the first full-scale prototype of the Inertial Sea Wave Energy Converter (ISWEC) was developed in Pantelleria and its environmental impacts were assessed. The device (8 m width and 15 m height for a nominal power of 100 kW) has been moored at 800 m from the shore, in a water depth of 35 meters [36].

Photo: ISWEC technology / https://www.eni.com/en-IT/operations/iswec-eni.html

The first ISWEC pilot plant (production of 105% of its rated power of 50 kW) has been active in Ravenna, Italy, since 2018. It is connected to a PC80 platform and integrated with a photovoltaic system. Finally, the first ISWEC industrial plant (100 kW nominal power) is currently being designed. It will be located at the Eni Prezioso platform in the Strait of Sicily. It is expected that the plant will be launched within 2022[3].

Another device for wave and tide energy harvesting is the H24-50KW machine. It is a small device that operates nearshore, completely submerged, and works seamlessly as a wave and tidal unit. The machine was bought by Enel GP and the energy produced at the test site of Marina di Pisa (Italy) was recently delivered into the Italian electricity grid [13].

A full-scale Overtopping WEC prototype (OBREC), completely embedded into a breakwater, was installed at the Port of Naples in 2015 for testing [17].

The first full-scale OWC (Oscillating Water Column) prototype in the Mediterranean (REWEC3) was successfully installed in the port of Civitavecchia (Rome, Italy) in 2015 [2].

In Jaffa Port, Israel, an off-grid pilot wave power station has been operating since 2014 for system improvement and modification and R&D. The station allows for the testing of new system components and floater designs & materials. In 2018 the system was expanded and connected to the national grid for a power expansion to 100 kW.

In April 2016, an innovative wave farm was installed near Gibraltar. The initial power plant had a 100 kW capacity and should be expanded to reach 5 MW in the next few years. The project utilizes wave converters from Eco Wave Power Ltd. The wave energy converters use floaters attached to a fixed structure [28].

The main advantage of these technologies is that, by being specifically designed for the Mediterranean, they specifically address the issue of efficiency linked to the relatively low wave energy levels in the basin. However, it is necessary to prove their viability in more severe sea conditions and the actual feasibility of upscaling to export these technologies to the global market.

2.2.3 Wave energy potential in the Mediterranean

In the Mediterranean Sea, the average wave energy flux is 3 kW/m. However, it strongly varies depending on the geographical location (Liberti et al., 2013). The most promising area for the installation of Wave energy converters extends between Sardinia and the Balearic Islands, with an energetic potential of around 9.5 kW/m (the highest of the Mediterranean). Other productive areas are the Levantine and the Ionian basins, the central-northern Aegean Sea and the area between Sicily and Tunisia [17], while the central and eastern Mediterranean Sea presents moderate wave energy potential with mean value around 6-7 kW/m [16] (see Figure 6). The wave energy potential for the Mediterranean Sea is therefore relatively low compared to the North Sea, which shows a wave power ranging between 10–60 kW/m, and

[3] https://www.eni.com/it-IT/attivita/onde-mare-energia.html

to the areas off the northern coasts of France and Portugal, which show an annual value of wave energy ranging from 30 to 50 kW/m [16]. However, storms in these Mediterranean areas are far less destructive than those occurring in the North Sea, thus reducing the threat to wave energy converter survivability. Therefore, it seems reasonable to think that wave energy exploitation is feasible in some areas of the Mediterranean Sea (Miquel et al., 2020).

There is currently a wide variety of WECs at different stages of development, with different shapes, sizes and working principles competing against each other. However, such a large diversity of devices prevents the wave energy sector from reaching convergence, hindering their progress to a marketing stage. Moreover, due to the increased risk and expenses of installing wave energy converters far from the coast, because of the more severe sea conditions that impact both the device and the necessary submerged structures and electrical connections, wave energy is not expected to become cost-competitive in Europe for the next 30 years [17],[2]. However, technology is developing quickly and together with past experience, has cut costs and time in half with respect to the big projects carried out at the beginning of the 2000s (Miquel et al., 2020).

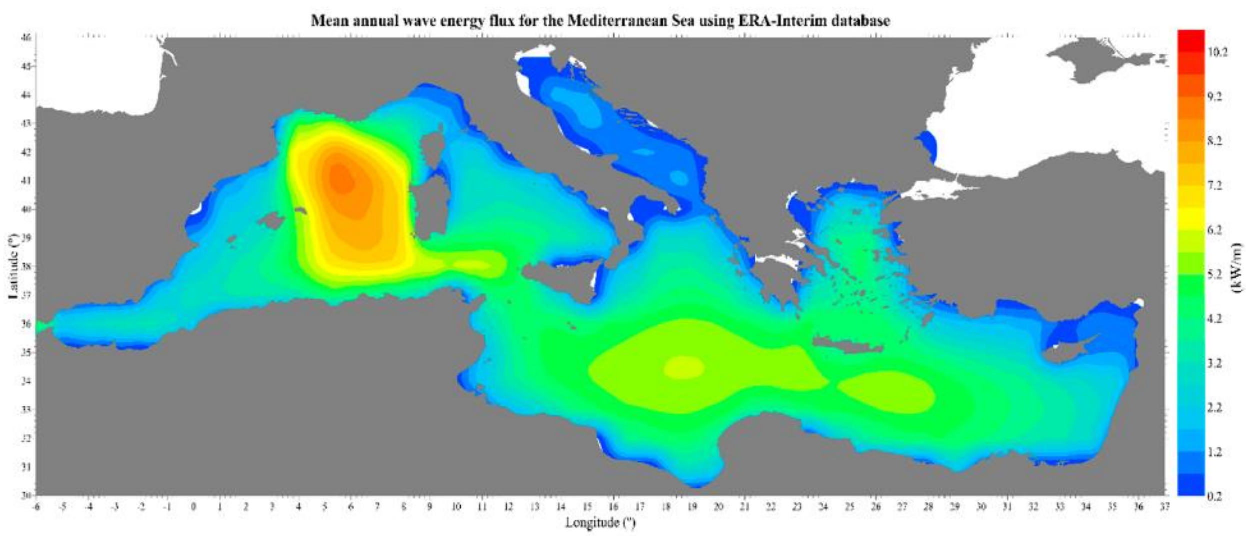


Figure 6. Mean annual wave energy flux in the Mediterranean Sea. Source: Soukissian et al., 2017.

2.2.4 Energy capacity at the global and European level

Ocean waves constitute a huge potential global energy source. According to several studies (see PELAGOS D3.1.2 for references), the theoretical (gross) global wave power resource, limited to deep water offshore, has been estimated at around 3700 GWh [17]. The Special Report on Renewable Energy Sources provided by the IPCC indicated a global estimate of 32,000 TWh/year [1], with the largest capacity between latitudes 30°-60° [15]. The EU Blue Economy Report 2021 stated that the theoretical potential of wave energy in Europe is about 2 800 TWh annually. At the start of 2020, the global installed capacity of wave energy was 12 MW, with 8MW (66%) installed in EU-27. In 2019, 600 kW of new wave energy capacity was deployed in the EU (Ocean energy Europe, 2020).

To date, numerous prototypes have been built leading to a multitude of design concepts that depend on water depths, locations and wave characteristics. Currently, across the globe there are more than 100 wave energy projects under various stages of development, involving over 30 countries, and more than 1000 patents have been filed [17].

As for offshore wind energy, Europe holds a leading position in Wave energy development. In 2000, the first grid-connected commercial scale wave energy device was Islay Limpet, Scotland (500 kW), which was decommissioned in 2013. In 2004, two prototypes of Wave Energy Converters (WEC) were deployed in the UK (Pelamis, 750 kW) and Portugal (Archimedes Wave Swing, 2 MW), while the first wave farm, comprising three Pelamis WECs for a total capacity of 2.25 MW, was Aguçadoura, in Portugal, which was installed in 2008 and operated only two months. In 2011 a commercial wave plant (Mutriku), consisting of 16 turbo generators for a total capacity of 296 kW, started operating in Spain, while in 2015 the SINN Power WEC module (20 kW) was installed for the first time in the port of Heraklion, Crete. Finally, Europe's first grid-connected wave energy array was launched in 2016 in Gibraltar, supplying 100 kW with an expansion plan to 1–5 MW [2],[16],[17].

2.3 Tidal energy

Tidal energy is the hydrokinetic energy that can be extracted either from the sea level fluctuations due to tidal range or from tidal-driven currents (PELAGOS project, 2017b). The mechanical process consists in extracting the energy from the flow of the currents, in order to activate a rotor or foil. A power take-off mechanism is then used to convert the generated mechanical motion into electricity.

The main advantages of this technology are that, unlike offshore wind and wave energy, tidal energy is a higher density energy form that it is characterized by high predictability, as it is dependent on tide variability which is largely deterministic.

However, tidal energy is only possible in sites where there is a good tidal range and where the speed of the currents is amplified by the funneling effect of the local coastline and seabed, for example, in narrow straits and inlets, around headlands, and in channels between islands (PELAGOS D3.1.4).

2.3.1 Brief description of the technology

Tidal energy includes both tidal range and tidal current technologies. Tidal range, usually referred to as tidal barrages, involves installing a barrage dam structure across a river that uses the ebb and flow of the tides to create the height difference essential for generating energy. This technology has been used since the middle of the 20th century and it is based on impounding water (tidal flow) within an estuary or bay which is released through turbines to be converted into electrical power.

Tidal current or tidal stream energy converters (TECs) involve installing turbines underwater in fast flowing tidal streams. There are several types of TECs (horizontal and vertical axis turbines, hydrofoil, ducted, rotating screw-like and tidal kites) (see Figure 7A) but, unlike wave energy, tidal energy technology has reached convergence by adopting the horizontal axis turbines in most of the relevant projects. Depending on the bottom depth and the position of the device, TECs may have gravity, piled or floating structures (see Figure 7B). First generation TECs operate with mean peak tide speeds above 2.5 m/s and at water depths of 25-50 m. More advanced TECs operate with a mean tide-speed of 2 m/s and water depths greater than 25 m. In any case, the aforementioned current speed thresholds are restrictive for most areas of the world's oceans, including the Mediterranean Sea [17].

A)

B)

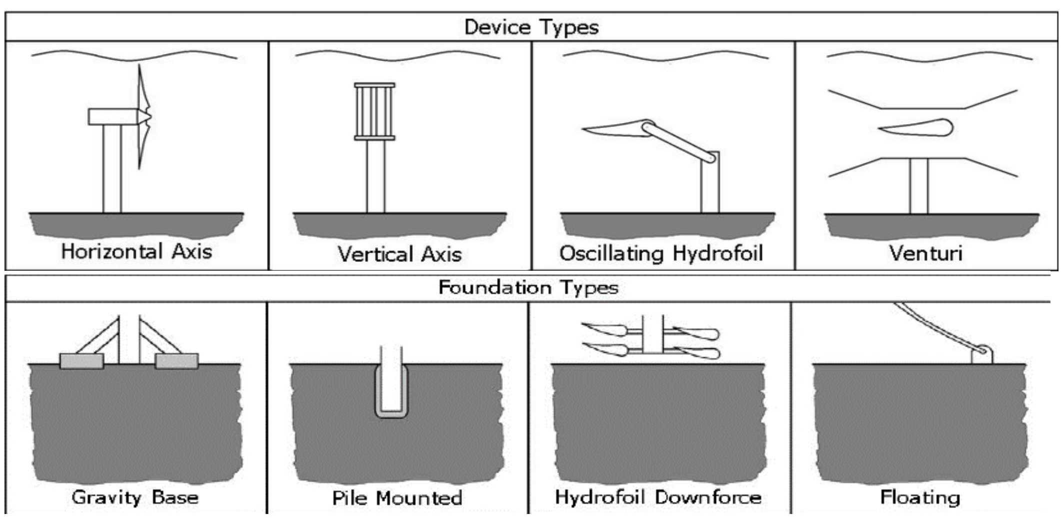


Figure 7. Different types of tidal current devices (A) and different types of foundations (B). Source: Walker, 2013.

For tidal technology, many converters are still in the R&D phase, but a small number of devices have undergone extensive sea testing using full scale demonstration devices.

The SABELLA turbines (Hydrohélix) are placed on the seabed, without surface grip, stabilized by gravity and anchored according to the type of seafloor. They have been tested in France.

The Kobold turbine is a rotor mounted on a vertical shaft, which produces mechanical energy using marine currents. A platform equipped with a Kobold turbine with a 6 m diameter, with three blades with a span of 5 m, designed by the Ponte di Archimede Company, was installed in the Strait of Messina in 2000 and is still in operation. The nominal power output is 30 kW, and the device is connected to the grid.

GEM, the Ocean's Kite, is an ocean current energy conversion system that consists of a submerged body with two horizontal axis hydro turbines. It is tethered to the seabed and free to self-orientate to the current. The device is placed at the desired depth thanks to its self-towing winch and is easily recovered to the surface for maintenance. Patented in 2005 after the experimental phase in towing tank, a first full-scale prototype of GEM has been deployed in the Venice lagoon [28].

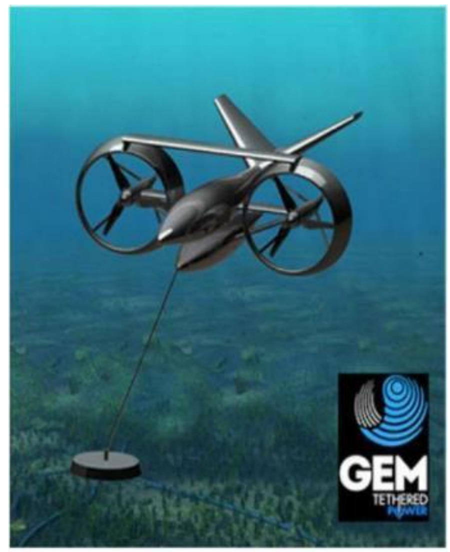


Figure 8. GEM Hydrokinetic horizontal marine turbine @ SEAPOWER

2.3.2 Current state and development in the Mediterranean

Tidal currents in the Mediterranean are generally low in terms of the level and power that they produce. Therefore, the sea basin exception for low tidal level is located through the Strait of Messina, which is a narrow and deep channel connecting two Mediterranean sub-basins: the Tyrrhenian and the Ionian Sea. The maximum current velocities at spring peak tides through the Strait vary between 1.8 m/s to over 3 m/s in 2009 (El-Geziry et al., 2009). The tides and the induced water circulation in this Strait are among the most intense oceanographic processes in the Mediterranean Sea (Cucco et al., 2016). Despite the very low amplitudes (water vertical displacement varies between 0.2 and 0.3 m), the water flow inside the Strait is intense, reaching up to 2.5 m/s in the spring (Cucco et al.,2016).

Tidal energy can therefore be harnessed mainly in the Strait of Messina, where energy production could reach 125 GW/h per year – an amount sufficient to meet the energy needs of cities such as Messina itself - thanks to currents reaching speeds of over 2 meters per second[4].

[4] Source: ENEA https://www.enea.it/en/news-enea/news/energy-from-the-sea-italy-ranks-first-in-the-mediterranean-area-for-technologies-and-public-investments

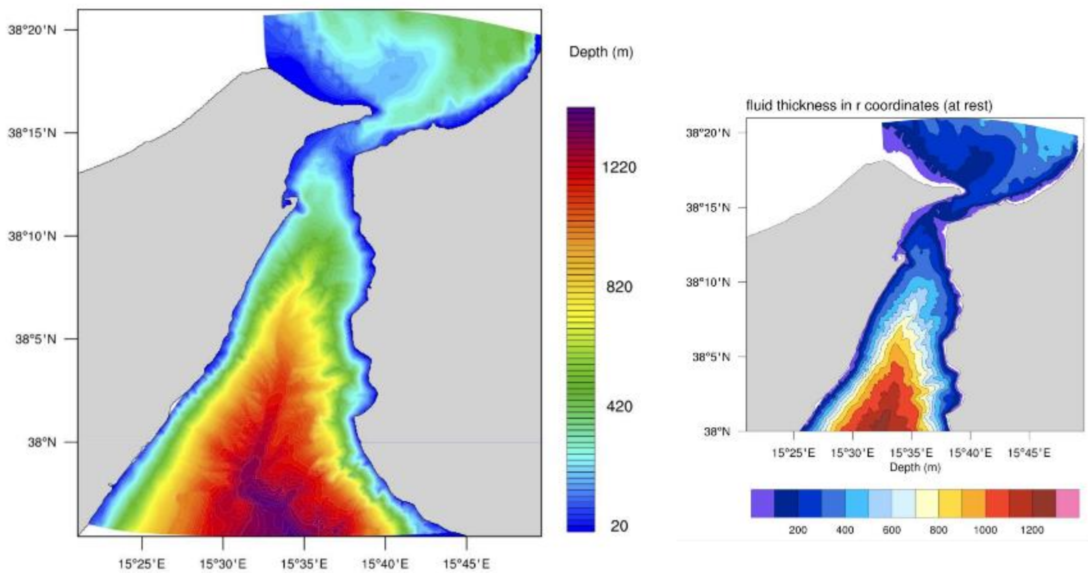


Figure 9: Strait of Messina Topography (Gianmaria Sannino, 2019)

Over the past decade, numerous technologies (e.g. floating TECs, small-scale TECs, multi-turbine platforms, etc.) have been designed and proposed. However, they are still in the concept/planning phase and it is projected that tidal energy may be deployed only in 2030, provided that major technology improvements are achieved (e.g. at least 50% cost reductions) [18] and may be cost-effective in 2050 [17].

2.3.3 Energy capacity at the global and European level

According to the EU Blue Economy Report (2021), Europe is a leader in the sector of wave and tidal energy, hosting 58% of global tidal energy technology developers. In 2019, 39.5 MW of a global total of 55.8 MW in ocean energy installed capacity came from in EU waters. The highest resource potential for this type of energy is along the Atlantic coast with further potential in the Mediterranean and Baltic seas. The theoretical potential of tidal energy was estimated at about 50 TWh per year (Source: European Commission, 2021).

In Europe, cumulative tidal infrastructure installed in Europe since 2010 have reached 27.9MW (See Figure 10). Tidal energy has hit the 60 GWh power production milestone.

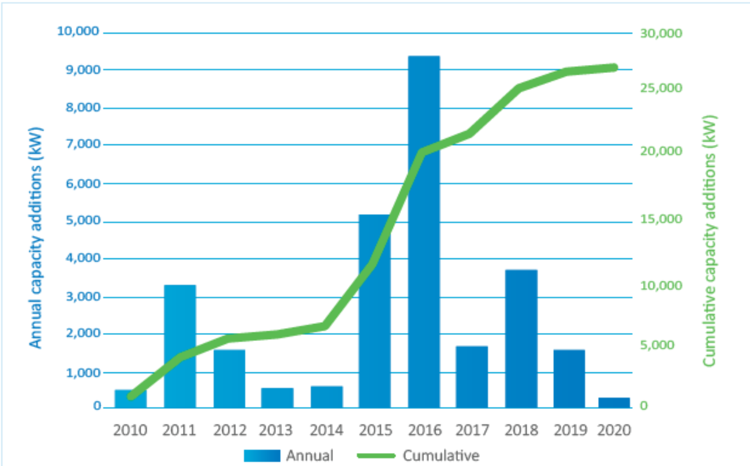


Figure 10. Annual and cumulative tidal stream capacity in Europe (Source: Ocean Energy. Key trends and statistics 2020)

Three devices were deployed in Europe in 2020 as pilot projects: Nova Innovation installed a horizontal axis, direct-drive turbine to expand its Shetland array, Minesto deployed its first kite in the Faroe Islands and Design Pro tested its floating vertical axis turbine in Orkney.

Among the ongoing projects is the La Rance Tidal power station in France (240MW). It is 390m long and 33 m wide with a maximum turbine flow of 6 600 m3/s. The power station has been built under the road and produces energy for around 225 000 inhabitants. Regarding sustainable issues, the power station planned to merge others with renewable energy but questions still persist regarding the lifetime of the infrastructure.

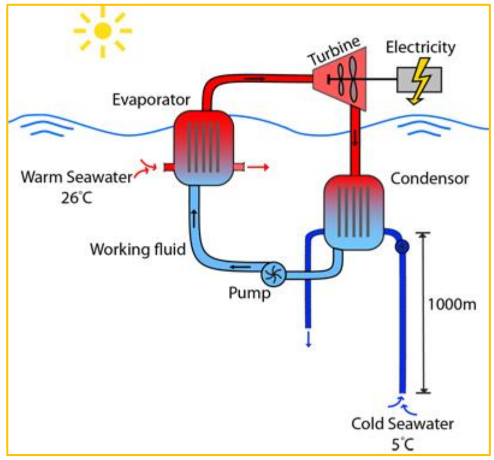
However, the Swansea Bay Tidal Lagoon project (320MW) in the UK, also known as the world's first tidal lagoon power plant, failed behind schedule. It was expected to be operational in 2021 but it is still in the planning stage due to litigation losses.

2.4 Thermal energy conversion

Ocean Thermal Energy Conversion (OTEC) is a marine renewable energy technology that uses the temperature difference between sea surface and deep water (temperature gradient or thermal energy) to generate electric power. Power plants can either be land-based or floating platforms.

The main advantages of this technology are the large resource potential, the continuous energy supply and the possibility of cooling without electricity consumption [34]. On the other hand, the efficiency of the cycle is strongly affected by the temperature differential between surface and deep layers (thermocline) which should be at least 20°C. Therefore this kind of technology is viable primarily in tropical areas. Another challenge is the need for developing large devices since the utilization of small temperature differences demand huge volumes of water [17].

Figure 11. Ocean Thermal Energy Conversion (OTEC) technology (Source: https://takvera.blogspot.com/2015/07/harnessing-ocean-temperature.html)



2.4.1 Brief description of the technology

Ocean Thermal Energy Conversion (OTEC) can be land or sea-based, fixed or on floating platforms. Considering the operational concept of existing convertors, there are three separate technology categories: open-cycle OTECs, closed-cycle OTECs and hybrid systems.

Open-cycle OTECs produce either electricity or desalinating water through multiple condensers. The main difference with the closed-cycle OTEC is that they use the warm surface water as a working fluid. The warm seawater evaporates in a vacuum chamber and produces steam. The vapor expands through a low-pressure turbine coupled to a generator and produces electricity. The vapor leaving the turbine is then condensed by cold deep seawater and, remaining separated from the seawater, provides a supply of desalinated water [33].

Hybrid-cycle OTECs combine the features of closed and open-cycle systems. The warm seawater enters a vacuum chamber to be converted into vapor. This vaporizes the working fluid of a closed-cycle system (ammonia) and the vaporized fluid drives a turbine to generate electricity. The steam then condenses and provides desalinated water [33].

Ocean thermal energy conversion (OTEC) [28] is most suited to equatorial and tropical waters of sufficient depth, where the temperature differential is at least 20 degrees Celsius all year round. Starting in 1930, several tests of OTEC technology have been performed but no large-scale projects have been implemented yet, mainly due to the harsh marine environment conditions. To date, the largest OTEC project ever built is the land-based plant located in Hawaii (power capacity of 1 MW), which operated from 1993 to 1998. Currently, around the world, several projects (up to 10 MW) are under development, and diverse concepts and prototypes are being explored. The most active countries in the OTEC sector are China, Curacao, Malaysia, Oman, Philippines, South Korea, the USA (Hawaii, Guam, Puerto Rico), and Zanzibar [34].

OTEC has a low theoretical efficiency, (7-8%), which could drop even further, to 2-3% in practice. However, OTEC farms can operate continuously and could reach capacity factors of up to 90%. Consequently, this technology can be applied in the Mediterranean only for SWAC - SeaWater Air Cooling Conditioning purposes. It can be used either on a large scale, with plants planned to be connected to district heating and cooling networks, or on a smaller scale for the heating and cooling of single buildings, in a sort of distributed energy system for local use, feasible to meet energy efficiency objectives.

2.4.2 Current state and development in the Mediterranean

A thermal difference of 20°C is needed to ensure proper efficiency of the device. In the Mediterranean Sea the temperature difference between sea surface and 1,000 m depths is less than 12°C (Soukissian et al., 2017). Therefore, the mean temperature vertical profiles do not meet the necessary requirements to use thermal energy to produce electricity. However, this resource is used for heating (winter) and cooling (summer) systems in order to reduce electricity consumption.

An alternative solution is **sea-water air conditioning** (SWAC) which is already developed in the Mediterranean, especially on the French Mediterranean coast. In October 2016, the Thassalia marine geothermal plant was inaugurated in the Port of Marseille. The plant harnesses the thermal energy provided by the Mediterranean, supplying sustainable energy for buildings with a 500,000 m^2 surface area in the new Eco-Cité Euroméditerranée, currently the largest urban renewal project in southern Europe. The plant reduces greenhouse gas emissions by 70%, power consumption by 40% and water consumption by 65%[5].

This is an innovative and environmentally friendly form of air conditioning that uses a renewable source of cold water located nearby. Cold deep-sea water is pumped to the surface, passes through a heat exchanger system and cools the water distribution network of the air conditioning (Figure 12). During this stage, the pumped water warms up by a few degrees and it is then discharged into the natural environment at a depth corresponding to its temperature. This technology avoids and replaces conventional electric air conditioning systems and is particularly suitable for island territories [18].

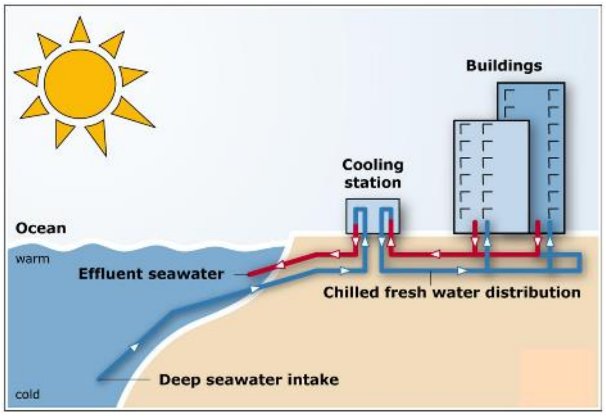


Figure 12. Seawater air conditioning system
(Source: http://www.ecopowerinternational.com/html/how_does_it_work.html)

[5] https://www.ksb.com/en-ee/magazine/success-stories/thassalia-marine-thermal-energy-project

In the Mediterranean Sea, temperature differences of 20° C will never be reached, not even between surface and sea bottom. This hinders the possibility for this OTEC to be used for electricity production. However, its alternative use described above (Sea-water air conditioning – SWAC), which is already being established in the MED area and tested in commercial projects, increases its perspectives in all the countries of the central Mediterranean region compared to other Blue energy technologies [40].

2.4.3 Energy capacity at the global and European level

According to Nihous (2007) [37] and Rajagopalan & Nihous (2013) [38], at a global scale the OTEC technology has a theoretically available energy potential of around 44000 TWh/year. However, this amount is quite limited on a practical level due to the potential impacts on the oceanic thermal structure. Therefore, the same authors claim that the more reasonable scenario for OTEC annual power production is around 7 TW.

With regards to Europe, most EU waters are not suitable for this type of BE.

2.5 Salinity gradient energy conversion

Salinity gradient energy (SGE), also known as osmotic energy, is the energy that can be generated from the difference in salt concentration between two fluids, typically sea water and river water. It is a large-scale renewable resource that can be harvested and converted to electricity. Locations where rivers flow into the sea are those most suitable for osmotic power deployment [16]. This is one of the main advantages of this technology as river mouths for SGE production are potentially abundant sites. This power generation technology can be used in countries with abundant freshwater resources flowing into the sea, such as the Netherlands and Norway. More importantly, as river flow into seas is a continuous process, SGE could potentially generate base-load power [18].

2.5.1 Brief description of the technology

Osmotic energy is obtained through the installation of special membranes between fresh and saltwater in order to control the diffusion process (see Figure 13).

Currently, two processes are used to harness salinity gradient energy: the reversed electro-dialysis process, based on fresh and salt water's difference in chemical potential and pressure-retarded osmosis, driven by the natural mixing tendency of fresh and salt water. Existing applications include “standalone power plants'' (located in estuaries) and hybrid solutions, which recover energy from production processes such as desalination or salt mining [17].

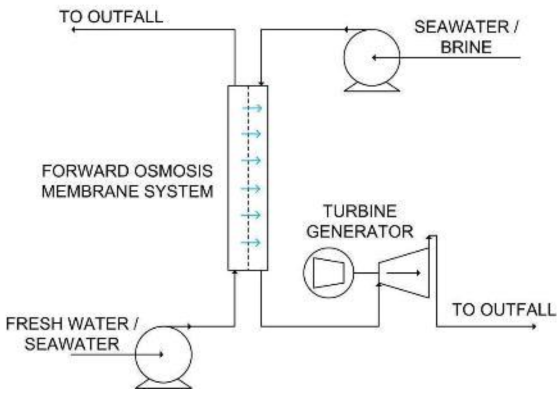


Figure 13. Pressure-retarded osmosis power generation. The process is driven by the natural mixing tendency of fresh and salt water. Source: Wikimedia

The first osmotic power plant (4 kW capacity) in the world was tested in 2009 in Tofte, Norway, but it was shut down in 2013 due to membrane fouling [17]. The station used sea-water from the fjord and fresh water from a nearby river circulating in two chambers separated by a semipermeable membrane. This type of technology is referred to as pressure-retarded osmosis, or PRO. At present, in Europe, there are pilot projects in Norway and the Netherlands, while research projects have begun in Germany and Italy. Recently, developments in membrane technologies aimed at reducing costs have led to an increasing interest in this sector, however osmotic power is still a concept under development and further research is needed for this technology to uptake [18].

An interesting future application relates to hybrid plants that use brine from desalination plants. A small RED pilot plant of this kind was operating in Trapani, on the west coast of Sicily. The RED unit was equipped with 50 square meters of ion exchange membranes and was tested with solutions of brackish water and saturated brine. The plant production was monitored for five months, reaching a power of about 2.7 W/m^2 for cell pairs [28].

2.5.2 Current state and development in the Mediterranean

Although some specific sites in the Mediterranean Sea are suitable, there is no technology currently developed to exploit this energy source (Alvarez-Silva et al., 2016). The expectation for the whole Med region is not high (only Croatia and Italy highlighted this BE as potentially exploitable) since only a few places show the features needed for the deployment of osmotic power (i.e. there is the need for fresh water input on the top layer water and high salinity water at the water layer below) [40].

According to Alvarez-Silva et al. (2016) [39], the promising candidates for salinity gradient energy utilization in the Mediterranean are the mouths of the Rhone River in France, the Po River in Italy and the Ebro River in Spain. These low salinity locations could be used as primary candidates for any future deployment of relevant osmotic power devices [16].

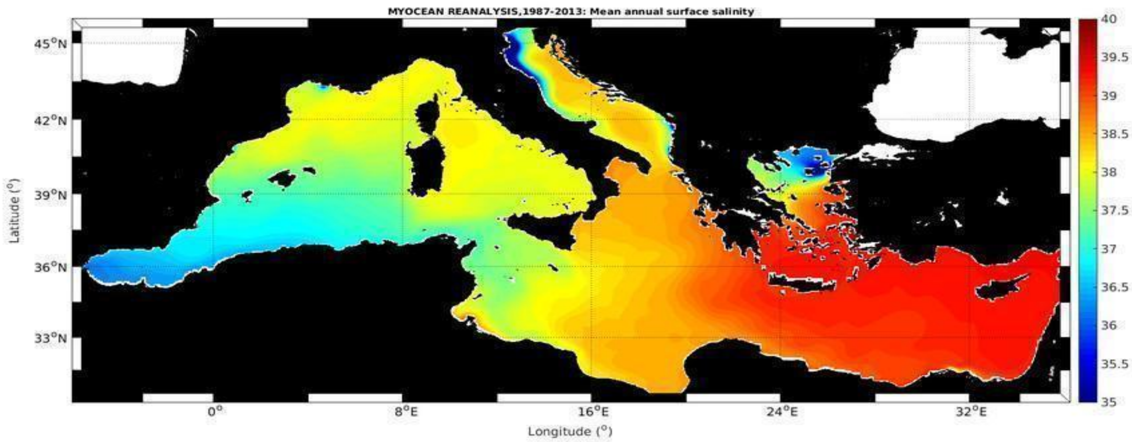


Figure 14. Mean annual surface salinity in the Mediterranean Sea. Source: PELAGOS project, 2017b.

2.5.3 Energy capacity at the global and European level

Globally, the total technical potential for salinity gradient power has been estimated at 657GW, which is equivalent to 5177 TWh of consumed electricity [28]. However, the lack of consideration of environmental and legal parameters may have led to an overestimation of this value. According to a more recent and detailed study, the globally extractable energy from river mouths is 625 TWh/year, equivalent to 3% of global electricity consumption [39].

Importantly, suitable river mouths for SGE production can be found all over the world. Among the suitable sites (i.e. river mouths with an energy density greater than 2.0 MW/m^3), approximately one third are located in the Mediterranean Sea and one third in the Caribbean Sea and Gulf of Mexico, making these the best two regions for harnessing Salinity Gradient Energy [18].

2.6 Marine biomass

The most well-known source of marine biomass is algae. The term “algae” refers to a wide diversity of organisms—from microscopic cyanobacteria, to giant kelp. Algae, and particularly the lipids they contain, can be converted into various types of biofuels, depending on the technique used, including biodiesel, biobutanol or bioethanol. Some algal species contain up to 40 percent lipids by weight, a figure that could be boosted through selective breeding and genetic modification. Methane can also be obtained, namely through gasification, pyrolysis or the anaerobic digestion process. Another source of marine biomass feedstock comes from the production of waste and residue from the fish farm industry. Recycling sludge or using fish waste together with manure from animal production could boost biogas production versus using manure or fish waste alone, providing a benefit to both sectors[6].

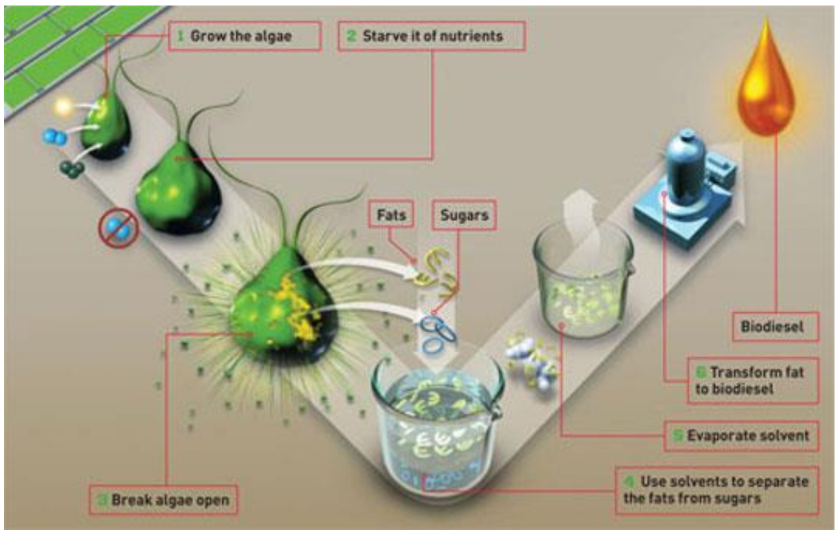


Figure 15. Conversion process of algae into biofuel (Source: Inhabitat).

The typical production process includes the following advantages: a wide variety of input sources such as combustion gas, seawater, brackish and waste water; suitability to many land and water types; availability of different production methods; likelihood of achieving good productivity levels when compared to most conventional (land-based) biomass feed stocks; and production of high-grade oils that can be converted into fossil fuel substitutes. Aside from algal oil production and upgrading costs, which are currently high, the most significant limiting factors affecting algal biofuels are those imposed by the need for locations with favorable climate conditions and suitable land, water and CO_2 resources.

At an industrial scale, there are two main methods for growing algae: in open-pond and closed-pond systems. A third system which is also often used is vertical growth.

Seaweed farms in coastal areas, whether or not combined with aquaculture, can withdraw nutrients from the water and produce biomass for energy recovery. Using photosynthesis, macroalgae quickly increase their mass and can be processed in bio-refineries to produce biodegradable, non-toxic, and sulphur-free biofuels, such as bioethanol of biogas and other added-value products. Techniques for cultivating macroalgae include sea-based (coastal and offshore) structures such as long-lines or rafts, as well as land-based tanks or ponds. Examples of cultivated species in European waters are *Alaria esculenta*, *Palmaria palmata*, *Saccharina latissimi*, and Ulva sp.

6 http://www.europeanbioenergyday.eu/bioenergy-facts/scrolling-bioenergy/marine-biomass/

Microalgae have also been experimented as a potential feedstock for biofuel generation. Accurate estimates of the potential sustainable production volumes of algae biofuels worldwide are difficult to obtain at present. The economic viability of algae biofuels is still tentative. This technology is still in its infancy and requires more research and pilot projects before it reaches commercialization.

However, algae biofuels have been intensely studied since the oil crisis of the 1970s. Since then, most fossil fuel companies have pursued algae biofuel research ventures, adapting production processes to make these sea plants a viable alternative energy. In recent years, however, many of these companies have abandoned their algae biofuel partnerships and projects due to the biological and economic limitations of this work [110]. They argue that it requires too much fertilizer, too much water, and too much energy to produce at scale. The industrial processes needed to convert microalgae into fuel could actually cause a net energy loss: Algae could take up to 53 percent more energy to produce than it would offer as a biofuel [110].

Currently, there are little or no commercial-scale examples producing algae-based biofuels. The major challenges which have been identified are high initial capital input costs for algae cultivation and processing systems (higher than agriculture), and the low value of co-products to offset higher production costs.

The production of biodiesel from marine biomass has yet to be implemented in the Mediterranean at an industrial scale. The technology was tested in the MED-ALGAE project started in 2012. The project involved twelve organizations (research organizations, academic institutions, energy agencies and private organizations) from six Mediterranean countries: Cyprus, Malta, Egypt, Lebanon, Greece and Italy. Its goal was to foster the development of microalgae as an alternative fuel and to contribute to the establishment of a new value chain for the production of renewable energy based on microalgae, thus securing a sufficient quantity and quality of biodiesel.

The project looked at every stage of the value chain: selection of microalgae, species identification, cultivation, harvesting and extraction of biodiesel, as well as determination of the properties of biodiesel. Its purpose was to study the available state-of-the-art technologies and provide feasibility studies for potential production. Microalgae by-products and related new business opportunities were also part of the research. The project established several pilot laboratories, and an algae growth unit for biodiesel production, as well as the "Mediterranean Regional Centre for Bioproduction" in Alexandria which would be a training, demonstration, and workshop centre for the region.

In the framework of the Interreg Med MAESTRALE Project, to analyze the potential of all BE forms, MAESTRALE partners (8 countries[7]) reviewed and highlighted the most promising sources in their study areas, taking into account physical, legal, technological, economic, and social contexts. Results showed that marine biomass is considered as one of the most promising blue energy forms for Cyprus and Greece.

[7] Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slovenia and Spain

It can be concluded that plans to use algae as a biofuel are still far from reaching commercial viability and many believe that it is an unrealistic fuel alternative for the future.

3. Best available tools and practices for Blue Energy

3.1 Tools to support Blue energy development

3.1.1 Methodology for BE potential analysis

The MAESTRALE project developed a methodology for Blue Energy potential analysis. The methodology includes: a) a numerical estimation of potential for each BE type, based on morphological and oceanographic data from the Mediterranean Sea basin; b) a compilation of legislation of each country; c) and a SWOT analysis of each selected Blue Energy. The SWOT analysis considers the following aspects: Socio/ Economic; Legislation/ Funding; Environment; Technology; Energy Potential. This process led to the identification of the most promising BE technology.

The detailed results of the Blue Energy Potential Analysis for all Mediterranean countries participating in the MAESTRALE project can be found in the MAESTRALE project deliverable Blue Energy potential in the MED area [40]. All BE forms were highlighted as promising across the Mediterranean countries studied (Figures 16 and 17). However, the most highlighted BE form in the field of study is offshore wind energy, which was selected by all 8 countries and by 9 out of 10 partners. It is worth noting that in some regions the potential of this BE is characterized as low, since the wind speed is not as high as in other regions outside the MED region. This impacts the feasibility of possible investments in such regions.

The second BE form which was highlighted by most partners is wave energy. Wave energy has not been considered by countries in the Adriatic Sea. To increase exploitability of wave energy potential, partners made several suggestions. One suggestion is the use of hybrid technologies, which combine wave-energy extraction with photovoltaic technologies. Another suggestion is to use wave energy extraction technologies along with other structures such as ports or wave breakers to have dual impact.

Marine thermal gradient is highlighted in all central Mediterranean countries and in Cyprus, but not for producing electricity. This BE form is mainly used for heating (winter) and cooling (summer) systems for local businesses and communities. These systems may not produce electricity, but they result in electricity savings. Partners who highlighted this BE form indicated that it has the greatest feasibility compared to other BE forms. The fact that this BE form has been already tested and established in commercial projects increases its perspectives compared to other BE forms in the MED region.

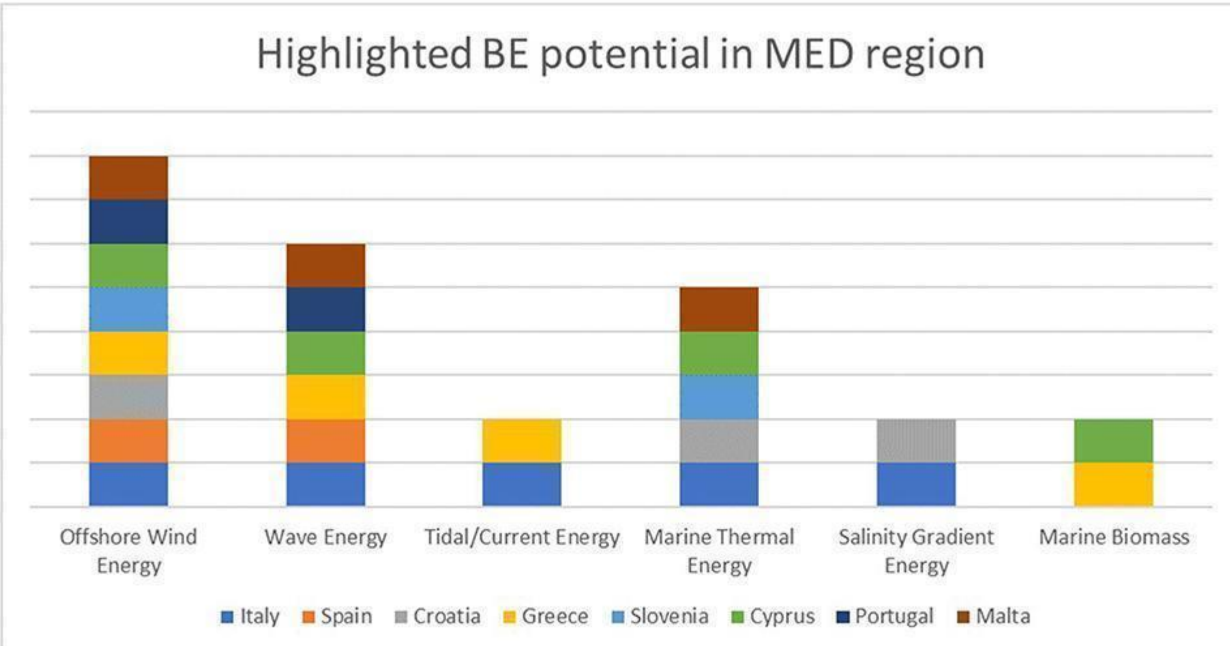


Figure 16. Highlighted Blue Energy forms for each country of study. Marine thermal energy is used directly for heating and cooling rather than for electricity production. Source: Nikolaidis et al., 2019.

Less highlighted BE forms are tidal, salinity gradient, and marine biofuel energies. The expectations for tidal/current and salinity gradient energy in the MED region were not high. This is due to the fact that certain physical conditions must be met for these BE forms to achieve high potential. On the one hand, the salinity gradient energy potential can be high, only if there is fresh water input on the top layer and high salinity water at the water layer below. The major drawback of salinity gradient energy is that the extraction technologies are still in an experimental phase. On the other hand, tidal/current energy potential is in general low at the MED region with the exception of some isolated regions, identified in Greece (Kea, Kithnos, Mytiline, Evoia) and Italy (Straits of Messina). The least highlighted BE form is marine biomass which has been considered only by Greece and Cyprus.

Other factors that may affect the BE potential in the region have been identified by the partners. One factor indicated by many partners is the steep bathymetry, which characterizes most of the MED region and constitutes a major economical barrier. To overlap this barrier, most of the partners recommend floating BE technologies rather than fixed-foundation technologies. Floating structures also give the flexibility of avoiding some high interest areas while remaining in areas of high energy potential.

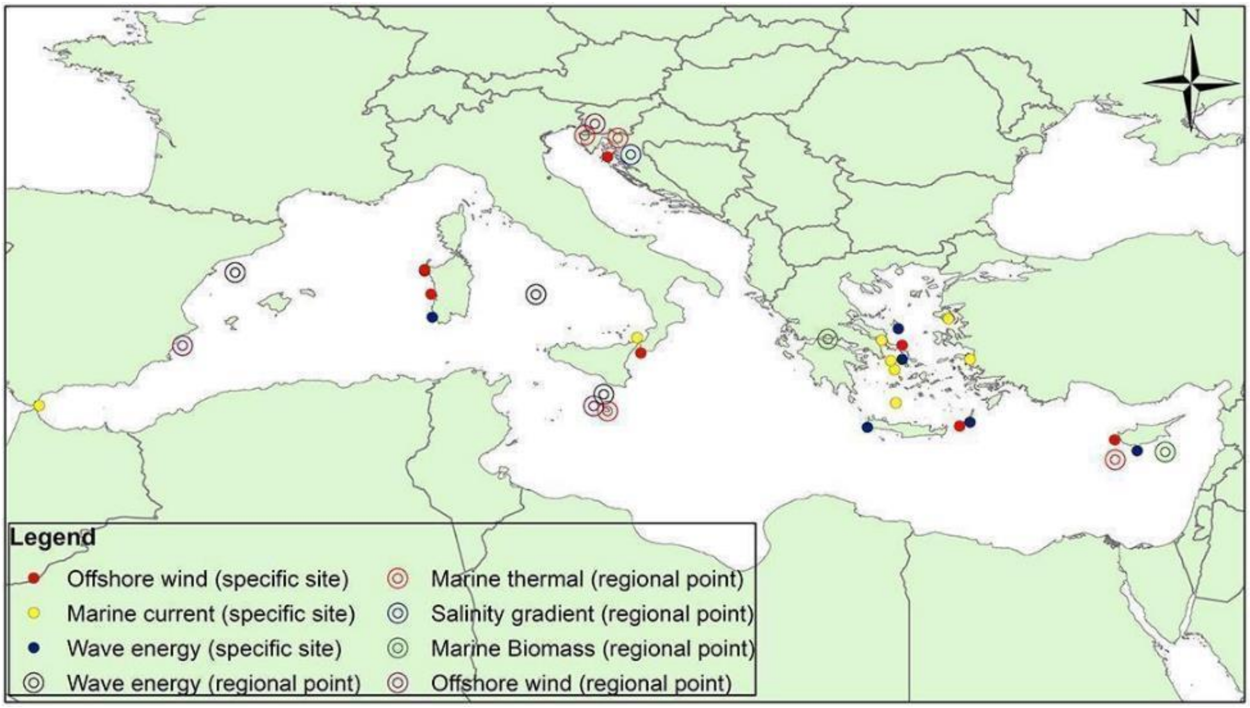


Figure 17. Locations of highlighted BE forms as reported from the partners of the MAESTRALE project. Solid circles represent specific locations, while hollow circles represent general regions. Source: Nikolaidis et al., 2019.

3.1.2 Collaborative platforms

The **Web-GIS for BE** developed under the MAESTRALE project is a support service designed as a tool to drive actions in the Blue Energy sector. It embeds information on blue energy potentials (year-round wave energy, offshore wind, marine current) and existing Blue Energy plants (50 case studies currently uploaded to be further implemented). A stakeholder map is also implemented in the Web-GIS (See Figure18). This allows entrepreneurs to be informed about operating plants and new initiatives (most of these are still at the prototyping stage or are pilot plants); to check energy potentials and plan new pilot initiatives; to collect information for networking with experts and other stakeholders; to increase their company visibility and be involved in design processes for new Blue Energy solutions based on their specific expertise.

This self-service online automated decision-making tool can be used for auditing, assessing and implementing solutions. The users of the online geo-database can access information, check energy potentials, plan new pilot initiatives, and collect information for networking with experts and other stakeholders.

The information embedded in the Web-GIS can potentially be accessed as teaching/learning material for improving knowledge on Blue Energy potential and technologies.

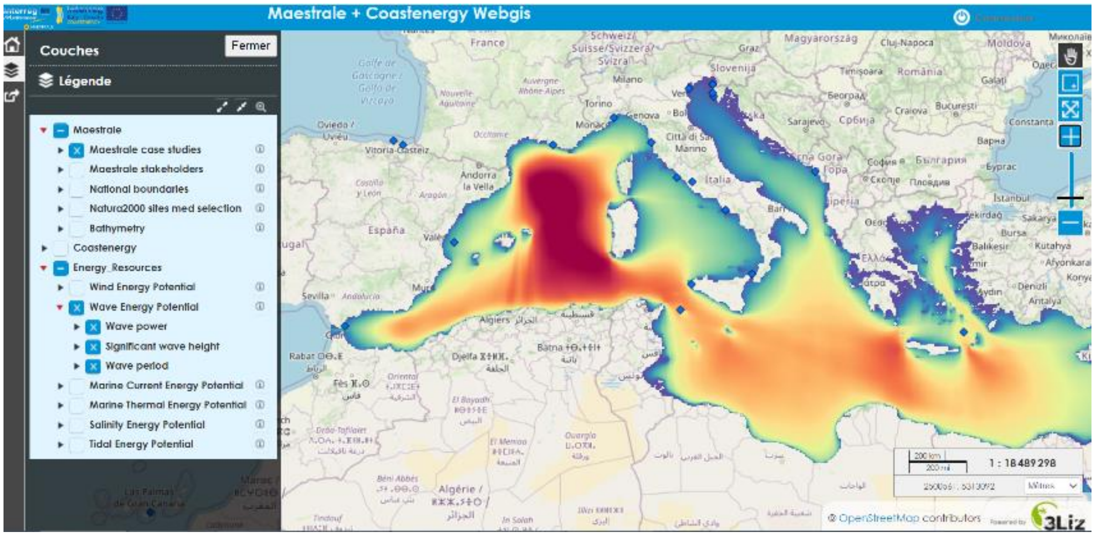


Figure 18. Screenshot of MAESTRALE Web-GIS.

Registration as a stakeholder of a BE community to be included in the stakeholder map is also possible by completing the on-line form, available via the portal.

The Blue Energy Cluster developed under the PELAGOS project is a virtual cluster "gathered" in a platform. It was designed to materialize the Blue Energy Cluster, to provide an environment for collaboration among actors from the Mediterranean, showcasing expertise, products and services, and to develop scientific and/or business cooperation. Its aim is to increase the innovation capacity of its members, support research and innovation in the BE sector and foster ties and collaborations between all the stakeholders of the Quadruple Helix (business – academia – public – citizens).

The platform supports its members to jointly identify opportunities in the Mediterranean marine areas, based on key Blue Energy technology areas, such as offshore wind energy, wave energy, tidal energy etc., in different market sectors including tourism and leisure, aquaculture, shipbuilding and marine transport. For the moment, the Blue Energy Cluster operates under National Hubs in Croatia, Cyprus, France, Greece, Italy, Portugal and Spain. The mission of the Cluster is to assist the development of the emerging sector of Blue Energy in the Mediterranean and to become an important part of the blue economy, fueling economic growth in coastal regions and creating new, high-quality jobs.

Through the aforementioned Hubs of the cluster, the project has coordinated the offering of a consolidated mix of support activities to all relevant stakeholders in the Blue Energy value chain, notably SMEs, by bridging push and pull innovation activities and securing social acceptance. The activities included Knowledge and Market Access, Capacity Building, International Partnering, International Cooperation and Networking, etc.

The 4helix+ Cyber Space, an integrated and collaborative virtual platform developed under the 4helix+ project, which intends to increase collaboration with stakeholders and beneficiaries (blue SMEs, knowledge providers, policy makers, research institutions and universities, society). It is designed as an instrument for constant dialogue, coordination, brokering and consultation, in support of the 4helix+ initiative. It includes several collaborative spaces and tools, such as the Knowledge Provider Gallery (database of registered talents and experts), the portal for Applicants (dedicated to online applications for Knowledge Providers and for innovative funding schemes & opportunities), the Blue Matchmaking Environment (facilitating encounters between the 4helix+ Knowledge Providers and Blue SMEs), and the Transferring Corner (including a series of web-based tools designed to ensure constant dialogue and consultation with concerned regional and national stakeholders to promote the incorporation of 4helix+ concepts and results into the relevant plans and programs at the regional, national and macro-regional levels).

3.1.3 Blue Energy Cluster building methodology

The PELAGOS project has developed a methodology for building Blue Energy Clusters [48] which includes a range of information on establishing and developing the cluster itself, as well as national HUBs. The methodology is described in a guide document (PELAGOS Project, 2017), organized into three sections:

- Section 1 sets the scene for a Blue Energy Cluster defining Clusters and their typical composition, presenting the potential of blue energy, the current technologies, the key players of the blue energy value chain, the key challenges and opportunities of the blue energy sector highlighting the importance and critical factors for establishing a Cluster on Blue energy to address these challenges.
- Section 2 outlines specific particularities and limitations for setting up the PELAGOS Cluster on Blue energy in terms of key characteristics of the PELAGOS project, the anticipated benefits of the Cluster, the anticipated Role of the PELAGOS partners and the key actors to be involved. A standard PELAGOS Cluster development process is proposed and presented under this section, outlining the phases and specific steps to be carried out both on a Cluster and Hub level in order to set up the PELAGOS Cluster on Blue Energy. According to this, guidance and suggestions are provided on what needs to be done and considered while:
  - Establishing the PELAGOS Cluster Governance scheme,
  - Defining the Cluster's Legal Form,
  - Defining its internal communication and information concept,
  - Defining its strategic positioning and
  - Defining its anticipated results, thereby establishing the basis for the implementation of local activities by the HUBs.
- Section 3 provides guidance on what needs to be done and considered by each PELAGOS HUB Coordinator while:
  - Establishing the HUB Team (HUB Coordinator and Focus Group),

- Monitoring the HUB through Focus Group meetings,
- Identifying key actors (Figure 19) and potential members for the HUB,
- Launching the HUB,
- Providing Regional/National HUB services
- And collaborating with the Cluster Management Team under International Cluster level services.

Moreover, for the effective implementation of the activities on a HUB and Cluster level, a proposed time table is also suggested.

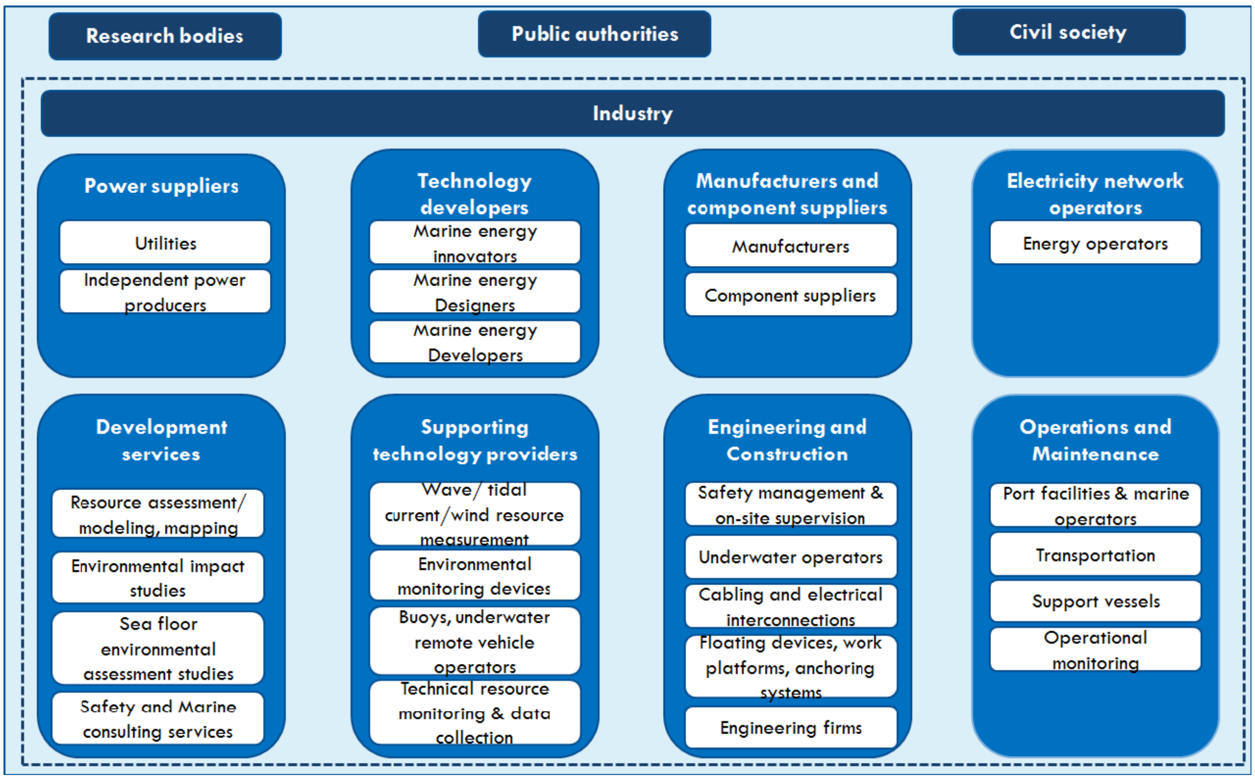


Figure 19. Key actors to be involved in PELAGOS Blue Energy Cluster (PELAGOS project, 2017d)

A suitable environment for cooperation and internationalization of the Mediterranean cluster and its members has been framed through the implementation of pilot activities at the regional and transnational level. Certain services are provided from national HUBs (Figure 20) in an attempt to stimulate MRE development in key market sectors through open innovation, strategic co-operation, MRE technology transfer activities and the sharing of knowledge and experience [17].

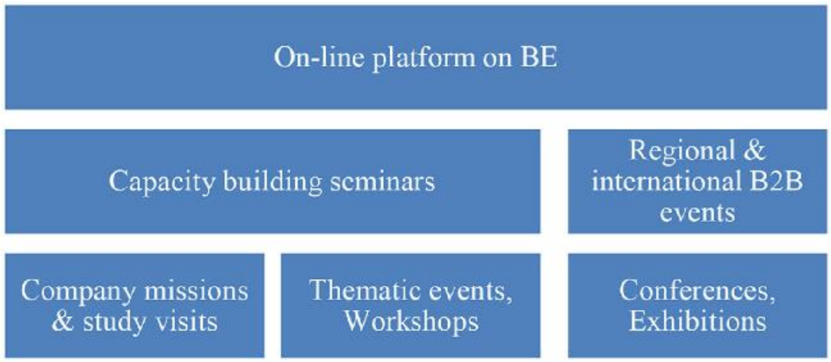


Figure 20. Services provided by each national HUB to its members. Source: Soukissian et al., 2019.

Through this range of services, several opportunities may emerge in terms of knowledge, innovation, networking and business growth such as: capitalizing on and fine-tuning previous experience and knowledge of the BE sector, coordination of pilot activities, development of skills and expertise and identification of new business opportunities, provision of mentoring and coaching services, assessment of environmental impacts and preparation of social acceptance, development of evaluating processes, techniques, models, tools, methods and services. As regards SMEs in particular, a path of successive actions, with associated outputs is planned in order to promote innovation. Among several other duties, cluster coordinators are responsible for ensuring that the cluster will continue to be effective and contribute to the creation of additional value over the long term.

A proposed structure for HUBs was identified: each HUB operates as a National Node of the Cluster so at the HUB level, the Coordinator of each HUB is called a HUB Coordinator and is responsible for the proper implementation and management of the Cluster at the National level with the support of National Focus Groups.

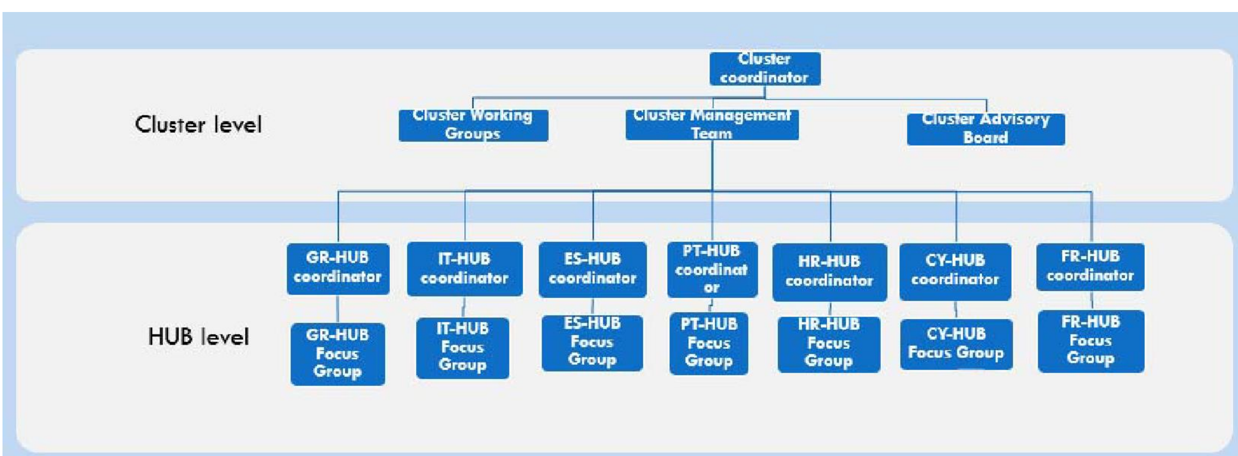


Figure 18. PELAGOS Cluster Governance Scheme (suggested). Source: PELAGOS project, 2017d.

Alternative cluster legal forms are also suggested:

An association (a non-profit organization) is the most commonly used legal form for Clusters within EU member states. This is followed by limited liability companies (organized with the purpose of undertaking commercial i.e. profit-oriented activities) as another relatively common legal form. The hybrid form is a form in which some or exceptionally all Cluster (association) members have been involved and own (owners as members not as association as legal entity) a limited liability company. In the majority of the cases, the hybrid form refers to both: (i) Clusters registered as an association for conducting non-profit activities and (ii) business organizations, primarily LLCs, for conducting profit-oriented activities. Moreover, experience has shown that a hybrid form of registering the Cluster is also the most cost-effective because it allows for a combination of commercial and non-commercial activities.

ALTERNATIVE CLUSTER LEGAL FORMS	
Association (non-profit or for-profit)	This form is used when the focus of Cluster organization is to provide "soft" services to its members, such as support to networking and specialization, training or up-grading Cluster members' skills and capabilities, presentation of a Cluster at international conferences, organization of international conferences to make Cluster known to the international community, lobbying, market intelligence or other not for profit activities. As a non-profit organization, Cluster and Cluster members are eligible to receive national and/or EU grants.
Private limited company	Cluster organization takes this legal form if Cluster members are or would like to be engaged in commercial activities. It is subject to value added tax and taxation. It can access national grants (differs according to the countries' rules) but not EU grants.
Economic interest group	Cluster organization takes this legal form when its activities concentrate on providing "soft" services to Cluster members. Cluster companies remain independent business entities. Economic interest group is registered at a court, activities and operations of Cluster organization and Cluster members are regulated by the founding contract/statute. It is a legal form which provides easy entry of new members into a Cluster and excellent environment for open innovation. Cluster activities can be funded by national and/or EU grants. This form is quite similar with association form.
Cooperative	The focus of this legal form is on the promotion of individual and joint economic interest of all members. Membership is voluntary and open to everyone. It can undertake commercial activities for itself but also for the members. It cannot receive the EU grants when cooperative makes profit. It is VAT liable and subject to corporate taxation.
Partnership	Formally it is not a legal entity but a set of entities.
Hybrid forms	Mix of association and public or private limited company.

3.1.4 Blue Energy Labs

The MAESTRALE project designed the model of Blue Energy Labs (BEL), interactive meetings aimed at facilitating the development of Blue Energy in a given region. During the project, the model was tested through the organization of 40 meetings to select 20 pilot projects. Each BEL involves local businesses, public authorities, knowledge institutions and the public, and operates to support future Blue Energy policies and plan concrete strategies for Blue Growth in the Mediterranean area. The development of pilot projects serves to raise awareness among local stakeholders, facilitate social acceptance, decrease uncertainty and increase feasibility of concrete actions.

The following steps have been implemented to apply the Blue Energy Labs model:

- Organization of a first BEL to explain the project goals and the main achievements made to date by the MAESTRALE project, addressing the stakeholders, explaining their presence at the event and how they can contribute to the BE community, pointing out the legal, economic, environmental and social constraints.
- Organization of a second BEL to focus on and further explore the topics addressed during the first BEL. Start of the process to select the two pilot projects to be implemented further along in MAESTRALE.
- Organization of a third BEL: Presentation of the preliminary results of the potential pilot projects. In this third BEL, it is essential to assess the social perception and the involvement of the social stakeholders in order to test social acceptance.
- Organization of a fourth BEL: Presentation of the results of the energy potential, environmental assessment, legal constraints, social acceptance, economic feasibility, funding opportunities, etc.

3.1.5 BE funding schemes

An Innovation Voucher Scheme was designed and tested under the 4helix+ project. This scheme was designed to support Micro, Small and Medium enterprises (MSMEs) as well as start-ups operating in the blue growth sectors to foster their innovation process.

The Innovation Voucher scheme has offered the possibility to explore business opportunities or solve a small-scale innovation-related problem by acquiring knowledge and coaching services provided by a registered “Knowledge Provider” whose mission is to assist the company in developing an innovative project.

The 4helix+ voucher scheme was characterized by a specific organizational structure:

- Knowledge providers (KPs) were invited to submit an online application form in order to be assessment.
- If they passed the assessment, the KP was registered in the online “Knowledge Providers Gallery”. Its profile and communication details were public and available to Blue SMEs/start-ups seeking collaboration in developing innovation projects.

- SMEs/startups from the blue sector located in pilot partners' areas, needed to select a KP registered in the Gallery. SMEs/startups, in collaboration with the KP, were invited to submit blue-innovation project proposals in the framework of the 4helix+ Transnational Call for Innovation Vouchers launched and promoted in all 8 pilot areas[8].
- Blue-innovation project proposals were evaluated at the regional level by Selection Boards. Boards comprised Local Innovation Committee members (specialists in blue growth and trans-sectoral innovation) and project partners. Each Pilot Partner had €60,000 for allocating six €10,000 vouchers. Awarded SMEs/start-ups and their KPs were given 6 months to complete their projects. Monitoring inspections were carried out during awarded projects' implementation to highlight workflow and resolve potential problems.
- After successful completion of each innovation project, certified by the relevant Local Innovation Committee, the KP were paid for the amount reported on the Voucher by the pilot partner who was responsible for the territory (MED region) where the SME/start-up involved in the project was located.
- Eight awarded projects (one project from each pilot area) were given the opportunity to receive an additional grant of €3,500 after assessment to finalize an application to the European Patent Office.

In order to help SMEs learn and implement crowdfunding campaigns and provide a practical process of knowledge to Public authorities on how to use crowdfunding for civic blue economy projects, the project BLUE CROWDFUNDING designed a toolkit including the following contents:

- SMEs: Regional training in order to build up the capacities of SMEs backed by the online crowdfunding tool.
- BSOs: "Training of trainers" education for BSOs and the establishment of "focal points" to mainstream crowdfunding knowledge.
- Regions: A guided process for changing regulations in order to enable the implementation of a "civic blue crowdfunding experiment" and mainstream it into future 2021-2027 development policies.

The Adopted Crowdfunding Training Tool was prepared based on training material initially used in the "CROWD-FUND-PORT" project (Interreg Central Europe) and updated with new regional data, integrating additional target groups and including information about civic crowdfunding. It can be found online.

[8] Albania, Croatia, France, Greece, Italy, Portugal, Spain/Andalusia, Spain/Catalonia

3.1.6 Business models

iBLUE Interreg MED Modular Project has produced a 3-PBM (3 Pillars Business Model) methodology, which relies on the three pillars of sustainability: economic, environmental and social. The 3-PBM methodology mainly targets businesses related to the yachting sector, but could be easily adapted to businesses of the Blue Energy sector as well.

It is based on the Business Model Canvas and the RPV (Resources-Processes-Values) framework, including the "environmental costs & benefits" and the "social costs & benefits".

By using this business model, the company has to follow different actions through 2 phases. Phase 1 is related to the "analysis of the existing business model from the perspective of the 3 pillars" and Phase 2 is related to the "improvement actions and implementation design". The final scope for each company is to expand its capabilities, confront any challenges and implement innovative plans.

iBLUE has organized training courses in each partner's country for the application of the 3-PBM methodology.

3.2 Best practices

3.2.1 Catalogue of Blue Energy Best Practices

The Catalogue of Blue Energy Best Practices is a combined effort of the MAESTRALE partnership [1] to compile and evaluate examples or uses of different Blue Energy forms and to assess their transferability into Mediterranean surroundings. A total of 50 case examples is provided with several reviewed from different aspects, making the catalogue a compilation of 50 case studies. Most potential variations of Blue Energy were reviewed so the catalogue consists of examples of marine biomass, ocean thermal energy, offshore wind energy, salinity gradient power, tidal stream energy and wave energy. Several transferability aspects were evaluated so the catalogue does not refer exclusively to technological or environmental aspects of the case studies but also to their legislative and administrative surroundings and various aspects of implementation methodologies. Examples already present in the Mediterranean Basin and those with high levels of adaptability can be used as good starting points for determining the overall blue energy use potential available in these regions.

3.2.2 Integration of different BE technologies on multi-functional platforms

The various MREs are at very different degrees of maturity. For example, the wave sector is at an earlier stage of development than the offshore wind sector, and only full-scale prototypes of wave converters have been tested. A way to boost the development of wave energy installation may be to develop promising technical synergies with OWE, reducing the variability of renewable power and lowering the system integration costs [28].

Combined deployment of OWE and other MRE sources, chiefly wave and tide sources, is possible as part of the same physical platform, or as a more indirect connection via the same cable array. Additional synergies can be established through joint operations, monitoring activities or shared monitoring software.

There is already some experience of wave and tide energy combinations in northern Scotland. Moreover, a hybrid wind and wave technology pilot test is to be conducted in Caithness, Scotland, by 2020. In the Northern Atlantic, the MERMAID project in northern Spain (Cantabria) has also explored the feasibility of wave and wind MU. While testing of a wave energy generation device was conducted in Denmark, this combination was never designed to be used commercially in the Baltic Sea, but tested for further use elsewhere (Danish Wave Energy Test Centre) [28].

In the Baltic Sea, major barriers include small waves, winter ice, and the lack of market and suitable technology to address these conditions. In addition, countries have different regulatory and incentive regimes with regards to MRE. For example, UK waters have highly suitable conditions but the government incentive scheme for England, Wales and Scotland, i.e. Contracts for Difference (CfD), does not currently support combined renewable energy technologies. Under the feed-in tariff (FiT), accredited producers whose plants have a capacity of less than 5 MW can sell their electricity at fixed tariff rates established by the Gas and Electricity Market Authority (Ofgem). Under a FiT, eligible renewable electricity generators (which can include homeowners and businesses) are paid a premium price for any renewable electricity they produce. Different tariff rates are typically set for different renewable energy technologies, linked to the cost of resource development, to enable a diversity of projects (wind, solar, etc.) to be developed while investors can obtain a reasonable return on renewable energy investments [28].

Multi-platform projects in the Mediterranean Sea include the ORECCA project Offshore Renewable Energy Conversion platforms - Coordination Action (www.orecca.eu), and the YDRIADA floating platform, which uses wind and solar energy to desalinate seawater and produce drinking water. Ydriada is an offshore floating construction designed mainly for desalination purposes. The platform is equipped with a wind turbine and solar panels capable of producing the energy required for the desalination process. Due to the wind turbine installation, the platform is kept stable even under harsh meteorological or sea conditions.

The desalination unit is theoretically capable of producing 70,000 litres of fresh water per day. The project has been co-financed by the Greek government (through the General Secretariat of Research and Technology) and the EU. The project consortium consisted of several public and private partners including the University of Aegean, LAMDA SHIPYARDS SA, TECHNAVA SA, etc. The project excelled at both the national and European levels. The platform had been installed and operated off the coast of Iraklia Isl. (Cyclades complex in central Aegean Sea) for 2.5 years. However it was considered that it was not capable of meeting the fresh water needs for the island and was shut down.

Moreover, beyond the cost reduction due to common grid connection, power take off technologies and infrastructure for operability and maintenance, it is mostly desirable to foster the development of synergies with other activities such as gas platforms, aquaculture, fish farms and transportation while assessing the social perception of these multi-use platforms [28].

4. How to reconcile Blue Energy with biodiversity protection and other uses of the sea

Various pressures associated with Offshore Wind Farms (OWF) can impact the marine environment. These risks either apply to the entire life cycle of an OWF or only during a specific phase. While the effects of a single wind farm on a particular wildlife population may be negligible, the cumulative spatiotemporal effects of multiple OWFs will cause wildlife population decline [111]. An overview of potential environmental impacts and possible conflicts of MRE with other uses of the sea is compiled in Table 2 with reference to wind energy installations at sea.

Table 2 Overview of potential environmental impacts and possible conflicts of MRE with other uses of the sea

Impacts on marine ecosystems and biodiversity	
Abiotic environment	Changes in wind characteristics and local hydrodynamics, increased resuspension and turbidity, water pollution (metals)
Benthic habitats and species	Loss of habitats, physical disturbance, reef effect with possible establishment of allochthonous species, electromagnetic fields and increased temperature due to cables
Fish	Impacts related to noise during construction, electromagnetic fields due to cables, reef effects (it can also be positive)
Marine mammals	Impact from noise during construction and operation, increased risk of collision with vessels due to increased maritime traffic in the area
Birds	Risk of collision, particularly if structures are illuminated, barrier effect impacting migration and daily routes for foraging, displacement and avoidance, loss of foraging areas
Marine turtles	Impact from noise during construction and operation, increased risk of collision with vessels due to increased maritime traffic in the area
Conflicts with other uses of the sea	
Tourism	Visual impact of wind turbines; restricted access to the open sea limiting sailing routes, windsurfing, diving, recreational fisheries; potential degradation of marine and coastal environment with decreased attractiveness of the location
Fishing	Accidental damage and ship strike; displacement due to access restrictions (particularly impacting for small-scale fisheries; permanent/temporary/seasonal disturbance of mobile species and seabed habitats
Maritime transport	Increased risk of accident due to increased traffic density (for operation and maintenance and reduced sea space); higher insurance costs due to riskier routes; need for diversion with increased travel time and fuel consumption

These potential impacts of offshore installations on the marine environment, wildlife and ecosystems are still under discussion. Conclusions are sometimes very controversial and not always based on scientific evidence or accurate reference environmental data [44]. In general, potentially disruptive interactions between marine energy conversion devices and the environment have not been ruled out. This is true in particular for the sensitive Mediterranean environment, where MRE installations might alter the provision of crucial ecosystem services, particularly for fisheries and biodiversity [45]. It is often argued that device foundations and support structures could act as artificial reefs improving biodiversity. On the other hand, they might also attract invasive species. Trawling bans within the area in question might be beneficial for the marine flora and fauna, but adverse effects from biofouling, such as higher sedimentation rates and eutrophication have not been thoroughly investigated, nor have the impacts from the potential use of antifouling chemicals. Also, the effects of prolonged exposure to noise, electromagnetic radiation, and habitat exclusion on marine animals have yet to be assessed [45].

To date, only a few studies have considered the potential environmental risks associated with the presence of MREs. The fact that many MRE devices are still in the experimental/trial phase is the reason why few data are available on the environmental effects of commercial developments and why it is not yet fully clear how to scale up from the limited observations on individual or small clusters of devices to commercial scale arrays. This despite the fact numerous lessons have already been drawn from the OWE industry regarding monitoring methodologies and key receptors, to establish the baseline conditions of a site in order to evaluate impacts remains the critical point [46].

Thus, the lack of knowledge regarding the type and intensity of environmental impacts from the construction and operation of offshore infrastructure calls for efforts in monitoring and assessment of potential cumulative and long-term negative effects.

The Mediterranean Sea is characterized by important economic activities (coastal tourism, fisheries and aquaculture, maritime transport, etc.) and the strategy for BE development should therefore account for potential conflicts and impacts that may arise. In any attempt for BE development in the Mediterranean, the main priority is to preserve the good status of coastal and marine ecosystems. However, the range of interactions between BE and other marine uses, and the cumulative impacts of their pressure on ecosystems are difficult to determine at first glance. Evidently, it is rational to reinstate the operating principles of the main maritime sectors targeting sustainability and efficiency. This topic has been explored by Soukissian et al., 2019 [17].

Until now, public concern about the environmental impacts of renewable energy projects has been a major factor behind the stalling or rejection of many planning applications for on-shore renewable energy projects. Siting renewables facilities in offshore locations would appear to reduce this tension, but spatial conflicts related to offshore sea uses and demands are on the rise. In this framework, a key role can be played by Marine Spatial Planning (Maritime Spatial Planning according to EU terminology) (MSP). Knowledge on the potential environmental risks that might be associated with the presence of MREs, the prediction of the areas with particularly vulnerable environmental characteristics, and the early identification of conflictual uses could feed the spatial planning process and lay the groundwork for mitigation actions or early negotiations between stakeholders. Spatial decision support systems, through the efficient exchange of information between experts, stakeholders, and decision makers, offer the opportunity to guide the transition from single sector management toward the integrated management of sea uses [46].

4.1 Monitoring environmental impacts

Responsible and sustainable development of MRE requires good knowledge of the environments where turbines or other devices such as kites (for harvesting power from tides or ocean currents) and wave energy converters will be deployed. Regulations often require that early deployments include extensive monitoring to collect sufficient data to understand the potential interactions of devices and systems with marine animals and habitats. The high-energy locations, and often turbid waters, into which MRE devices are placed add considerable challenges to deploying and operating the oceanographic gear and sensor platforms needed to characterize the stressor-receptor interactions that may be occurring. These challenging locations require that boat-based and human observations be kept to a minimum, in favor of *in situ* remote instrumentation. Collecting and interpreting useful information collected at MRE deployment sites poses significant difficulties because of the challenges involved in operating instrumentation underwater, as well as the challenges related to processing and transmitting data for analysis [47].

Recommendations have been made to create a research strategy to identify the most important research questions for monitoring priorities and developing simulations to provide information on the most important effects to be monitored [48]. Standardizing methods for recording and reporting monitoring and data collection would also be useful. Another recommendation is to develop guidance for Passive Acoustic Monitoring (PAM) that provides flexibility to take into account the wide range of animals and specifies the appropriate PAM method under the circumstances (e.g., glider, buoys, or towed).

Monitoring direct effects of stressor-receptor interactions

It is crucial to understand the direct effects of MRE devices on organisms in their natural habitat. Relevant topics include [49]:

- Rates of encounter and effects (injury/mortality rates) of collisions with turbine blades
- Avoidance of moving parts or acoustic fields generated by the device
- Avoidance of or attraction to magnetic and induced electric fields
- Attraction to or aggregation around bottom-mounted or floating structures
- Displacement or permanent alteration of behavior patterns due to new device presence
- Likelihood and effects of entrapment or entanglement of large marine animals because of the

presence of mooring lines, anchors, and export cables.

Studies have been designed to observe specific marine animal behaviors in response to the presence of MRE devices or their acoustic or electronic signatures. These potential effects occur at known or expected locations and/or at times that can be targeted for observation. Many of these interactions can be examined through modelling and other techniques that do not require the in-water study of the physical/biological environment of a specific device [49].

Monitoring the environment where MRE devices are located

A second set of questions deals with the context or vicinity of the device(s). While site-specific, answers to these questions will build an understanding of the biological and physical aspects of (and their links with) the highly energetic environments targeted for wave or tidal power development. It is important to understand the background processes at work at a site before designing a monitoring program that will reliably separate effects from the background natural variability as well as from effects of other anthropogenic activities. The following techniques provide answers to these questions [49]:

- Inventories of organisms that naturally occur in the area and examinations of their normal distribution in space and time, as well as their movement
- Examinations of the amplitude and other characteristics of the MRE stressors, including underwater noise and EMF
- Modelling and validation of hydrodynamic and sedimentation patterns, and their associated variability in space and time
- Modelling of potential effects of MRE systems on ecosystems; although relatively little modelling has been carried out to date, agent-based models and ecosystem models will become useful as the industry moves toward large commercial arrays.

This contextual information can also indicate patterns of device encounter probability, thereby assisting with the siting of MRE developments to avoid or minimize the most likely adverse environmental effects. Combined with information about what occurs when an animal interacts with a device, such as rates of injury or mortality from blade strike, these results can provide insights for regulatory needs to determine likely population-level impacts [49]. A prime example of this approach can be seen in the outputs from several stages of the SeaGen turbine development and operation in Strangford Lough, Northern Ireland [50] that provided information for adaptive management programs. These adaptive management programs helped MRE projects like TideGen in Cobscook Bay, Maine, United States (U.S.) develop effective monitoring and mitigation plans [51],[52].

Monitoring technologies and techniques

Environmental monitoring of MRE devices is made inherently challenging by the harsh conditions under which monitoring must take place, the need to manage power for multiple instruments to assure continued monitoring, and the volume of data generated by the suite of instruments deployed. Conditions at locations suitable for the development of marine energy are inherently challenging for engineering durable and robust systems. Namely, forces from high-energy waves and currents compound the traditional challenges of working in marine environments including pressure, corrosion, and biofouling. In addition, deployment, maintenance, and recovery operations may be limited because of infrequent calm weather windows, short periods at slack tide, short daylight windows in high latitudes, and safety concerns for staff associated with swift currents and large waves.

A variety of integrated monitoring platforms have been developed and deployed for monitoring MRE devices. They include a series of autonomous and cabled platforms that have an array of monitoring instruments integrated for power requirements and duty cycles.

Technological advancements in different instrument classes, the integration of instruments on subsea monitoring platforms, and improvements of methodologies have increased our understanding of the effects that tidal energy turbines and wave energy converters (WECs) have on marine organisms. Despite these advances, monitoring challenges remain with respect to the durability of monitoring equipment in harsh marine environments, power availability/management of integrated monitoring systems, and continuous data collection, storage, and analysis [47].

The most common instrumentation used to document interactions of marine animals and habitats with MRE devices include passive acoustic instruments, active acoustic instruments, and optical cameras, while other instrumentation is used to help define the physical environment in which these interactions may occur [47]. See Figure 19 as example.

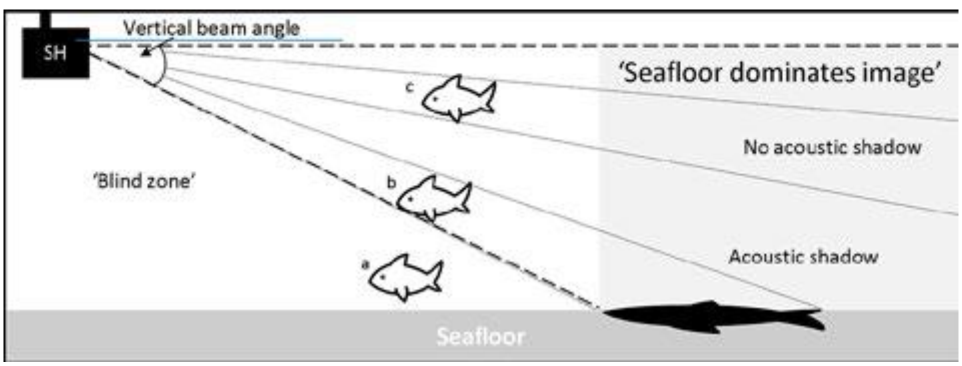


Figure 19. Example of a vessel-based sonar configuration. Source: Parsons et al. 2017

Conclusions and recommendations for monitoring

The collective understanding of the effects of MRE devices on marine animals has improved because of advances made in methodological processes, innovations in monitoring technologies, the integration of state-of-the-art instrumentation on autonomous and cabled subsea monitoring platforms, and their subsequent deployments in harsh marine conditions. These improvements stem from the series of largely undocumented failures and setbacks experienced by those who pioneered monitoring activities for the nascent MRE industry and initially employed standard oceanographic and remote-sensing technologies in this new context. Although the knowledge gained from this process has greatly advanced monitoring capabilities, ongoing challenges remain, including the need to ensure the durability of sensitive equipment; power availability and management for integrated monitoring systems; and continuous data collection, storage, and analysis [47].

Integrated monitoring platforms, as well as other configurations of remotely mounted instruments can help document the most challenging interactions between marine animals and MRE devices, and especially take collision risk assessments beyond a modelling exercise to the collection of empirical data for quantifying the risk. However, there are currently no commercially available "fit for purpose" instrumentation packages, and monitoring still relies on oceanographic, hydroacoustic, and other instruments that are intended for use in more benign marine conditions. These technologies must be integrated, configured, tested, and validated in new ways to suit dynamic marine environments and to detect critical interactions between marine animals and MRE devices [47]. The electronic integration of instruments on a platform is as important as their physical integration, and despite establishing duty cycles, it is important to recognize that interference between instruments is likely, unless engineering measures are adopted to prevent it, and cannot be ignored [47]. The volume of data collected through monitoring activities and the cost of analyzing the data remain important obstacles. The processes for on-board collection of monitoring data need to be weighed against the collection of excessive amounts of data and the concerns about missing rare events and the future potential use of this data [47].

Recommendations on monitoring, studies and assessment are available from the US-Atlantic experiences [54]:

- Impact from noise. There is the need to assess aggregate impacts on species and to focus on the larger scale effects, rather than direct effects such as auditory injury. Other effects (e.g., chronic stress, reproduction, or behavioral shifts) from sound exposure could harm individuals or the population.
- Secondary effects. Look at secondary effects such as increased ship strikes as a result of changing behavior patterns (e.g. a change in migratory routes that coincide with shipping routes is recommended). In addition, piling noise and noise propagation is an area in need of more study, specifically how far sound travels, best methods for mitigating this noise, effectiveness of SRS, and determining the best technology for reducing the impact of sound. Monitoring 50-60 kilometers around a site will help detect changes in habitat use and behavior.
- Aggregating data regarding species abundance, density, behavior, etc. is recommended. Aggregating data allows for results from several methods to be combined and will help reduce uncertainty, as well as compare methodologies.

4.2 Ensuring environmental sustainability, ecosystem protection and biodiversity conservation

Many of the organisms that reside in the energy-rich areas of the ocean are already under considerable stress from other human activities including shipping, fishing, waste disposal, and shoreline development. To achieve sustainable development of MREs it is important that all possible measures to prevent, mitigate (minimize) and eventually offset environmental impacts and negative effects of ecosystems and biodiversity be adopted.

4.2.1 Prevention of impacts: Site selection

Among all mitigation measures, site selection is one of the most important tools, aimed at preventing or limiting environmental impacts. To achieve this, several instruments are available. Marine Spatial Planning (MSP) is one of these instruments. Since the construction of the first OWFs and the expansion of turbines in the sea, increasing attention has been raised to make this use of the sea compatible with other economic interests and environmental protection, through proper planning of the sea space. Unlike the Baltic and the North Seas, there is a large portion of high seas in the Mediterranean Sea, limiting planning under national jurisdiction and regulations. Integrated approaches can be conducted within national territorial waters (12 NM, in some cases only 6 NM) while an ecosystem approach would include protection and sustainable use of the sea beyond these territorial waters [55]. Nevertheless, planning for the first (floating) OWFs in the French Mediterranean already included many features of MSP to investigate the most suitable areas to establish an OWF [56].

Examples are available of the use of MSP to locate areas suitable for OWE production, considering the needs for environmental protection and other uses. The case of the French Mediterranean Sea Basin Strategy (*Document Stratégique de Façade* – DSF), part of the National Maritime and Coastline Strategy (*Stratégie nationale pour la mer et le littoral* - SNML) is illustrated in Figure 20. It includes areas to be dedicated to the development of OWE.

The presence and vulnerability of species in an area may show substantial seasonal variation and impacts may be mitigated by restricting certain activities to periods of low abundance or low vulnerability. For example, in Germany, restrictions for pile driving are stricter in the summer period in areas of importance such as nursing areas of harbor porpoises. Limiting restrictions to certain periods will also make it easier for the industry to accept restrictions. Difficulties occur when considering more than a single or only a few species, since times of restricted activities may otherwise be spread over a large part of the year, making it difficult to plan construction work, for instance.

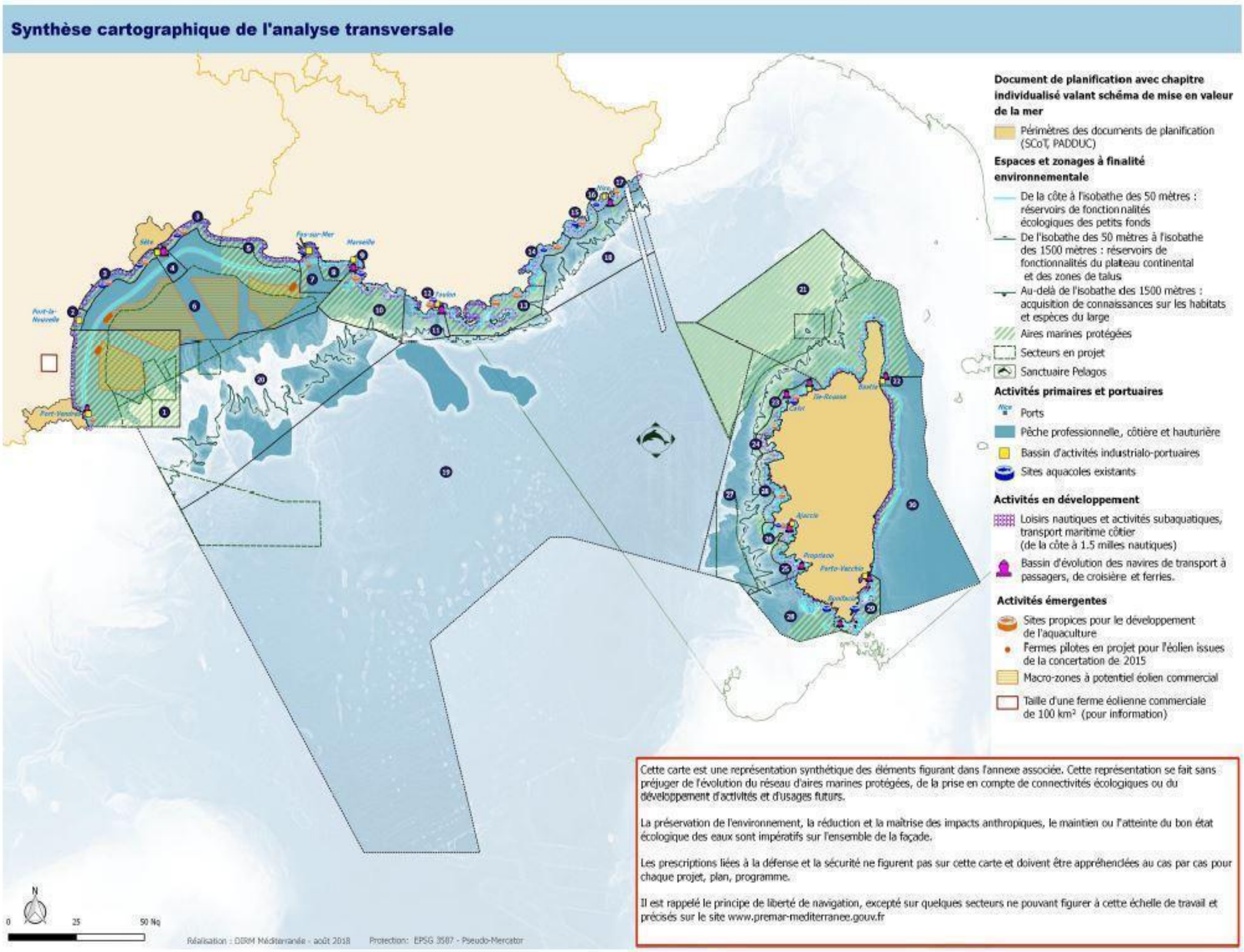


Figure 20. Mediterranean Sea Basin Strategy (Document Stratégique de Façade – DSF).

Future thorough site selection is crucial to avoid or mitigate the negative effects of OWFs on the marine environment and other economic activities. Depending on the potential impacts, the following criteria regarding site selection could be considered [55]:

Table 3 Criteria to be considered for siting OWFs in order to prevent/mitigate impact on the marine environment and other economic activities. From Defingou et al., 2019 (modified).

Prevent environmental impacts	
Habitats	Marine priority habitats, such as *Posidonia oceanica* seabeds and coastal priority habitats like 1150* Coastal lagoons should be avoided. Bundling of cables is recommended to reduce the area that is affected by cable laying.
Fish	Important fish spawning grounds should be avoided.
Birds	Corridors of bird migration and resting/wintering/breeding sites and bird foraging areas should be avoided. Planning offshore wind farms in clusters is recommended to avoid bird population scattering and patchy displacement.
Sea turtles	Sea turtle reproductive sites should be avoided in order to avoid impacts due to light and general disturbance
Monk seals	Monk seal reproductive sites and caves should be avoided in order to prevent impacts due to light and general human disturbance.
Cetaceans	Nursing areas of cetaceans, main migration routes and feeding grounds should be avoided
Prevent conflicts with other economic sectors	
Investigate alternative sites if siting of an OWF or cables is planned:	• in main shipping lanes • in main fishing grounds • in areas of enhanced military use • in areas with known mineral resources • across sites of cultural importance • Investigate the potential for co-use, e.g. aquaculture • Investigate the potential to integrate OWFs in tourism activities or public information

Careful MSP should be used to select appropriate sites for OWF installation, as well as the most appropriate routes for cable laying in order to limit impacts on habitats and benthic communities. This requires good data collection to reduce the uncertainties (mapping of species distribution ranges, spatial and temporal use, etc.) and the mapping of species and habitat sensitivity to OWFs. When sensitive or protected habitats are present, detailed delineation of their distribution and of the seabed in general is needed, so individual wind turbines can be sited to avoid them. This can also help identify the most appropriate cable routes and other micro-scale planning adjustments. It is important to minimize areas needed for OWF construction and operation, either individually or from clusters of projects, due to their cumulative impacts. For example, use the shortest possible area for laying cables, bundle new cables with existing cables, and minimize the number of crossings with other cables to avoid the need for more structures [19].

4.2.2 Impact mitigation

The PHAROS4MPAs project has identified a comprehensive set of recommendations [18] to mitigate impacts from offshore wind farm installation and operation. The measures identified address the main impacts of the sector on marine ecosystems and species.

Mitigation of noise

Regulations on noise mitigation differ between countries depending on the species present and the approach taken by national authorities regarding noise levels. For EU countries, the need to regulate underwater noise from OWF construction is clear under the requirements of Article 12 of the Habitats Directive, which prohibits the killing and significant disturbance of strictly protected species. Projects involving pile driving require a noise prognosis as part of their Environmental Impact Assessments (EIA), and the inclusion of appropriate mitigation measures.

Mitigation techniques [19]

- Choose a suitable time and location to avoid migration/spawning periods and nursery/ breeding areas
- Employ marine mammal observers and deterrence devices to prevent the abundance of animals in noise-impacted areas. Passive acoustic monitoring along with aerial and ship-based surveys can be used to detect their numbers before, during and after construction
- Use special low-noise construction processes (soft-start/ramp-up etc.)
- Consider technical solutions to reduce piling energy: new techniques under development include vibratory piling (if grounds permit) and blue piling (a combustions-accelerated water body provides the energy)
- Use alternative foundation types (e.g. suction buckets, floating foundations and gravity basements)
- Reduce piling noise, e.g. by bubble curtains, noise mitigation screens (NMS) or a combination.

As active noise reduction has proved to be efficient and technically feasible, it is increasingly seen as the best method for noise mitigation. If environmental conditions hinder sufficient noise reduction, other mitigation techniques – e.g. surveillance and deterrence – may be preferable. As marine mammal observers require daylight and calm weather conditions, passive acoustic monitoring (PAM) is the most suitable surveillance method for marine mammals [18].

Sources of continuous noise – e.g. vessel noise – are more difficult to control and minimize, especially during the construction process. Special shipping lanes (e.g. at a fixed distance from Natura 2000 areas and other sensitive sites) and mooring buoys where vessels wait can concentrate the noise in smaller areas and thus reduce its impact. Lower speeds and the use of quieter modern vessels can also reduce ship noise.

Mitigation of light [19]

According to current regulations, OWF turbines are equipped with red lights on top for aviation and white lights lower down for shipping. They should be set to flash with the minimum intensity and frequency permissible under relevant national regulations. OWF lighting usually follows recommendations drafted by the International Association of Lighthouse Authorities (IALA): there are currently few national regulations which limit night lighting.

Mitigation techniques

- 'Light on demand' should be given priority as a mitigation technique for all OWFs, both for aviation and possibly vessel navigation lighting;
- Light color, intensity and frequency: Low-frequency red lights (as well as green and blue lights) seem to attract fewer birds than normal white or red lights. Lights with low frequency and short wavelength radiation are thought to decrease collision risk. Use flashing lights instead of steady lights and keep the luminescent phases as short as possible, the dark phases as long as possible.
- Light emission can be further minimized by not illuminating large areas, or by using inverse LED plates/letters/numbers and other distinctive recognition elements. The radiation angle should be kept as small as possible, upwards radiation should be avoided, and indirect radiation should be preferred over direct radiation.
- Deflectors are recommended: traditionally lit markings may potentially be replaceable by self-reflective imprints.

Mitigation of habitat loss [19]

Direct habitat loss from OWF structures such as turbine foundations covers a relatively small proportion of an overall wind farm area. However, in light of the increasing numbers of OWFs, a general mitigation strategy is needed, especially in relation to protected habitats.

Mitigation techniques

- Construction zones should be minimized and activities should stay within them. Efforts should be made to avoid or minimize the resuspension of sediment and turbidity plumes. How and at what depth cables are buried is also important: appropriate techniques will depend on the type of substrate.

- OSPAR guidelines recommend jetting or ploughing for cable burying. In sensitive habitats (e.g. salt marshes) horizontal drilling could prove to be the least environmentally damaging method, but the timing of the drilling has to be considered – breeding seasons etc. should be avoided.
- If solid rock is present on cable routes and cannot be avoided, horizontal directional drilling may be the most suitable protection method – blasting through the rock would have significant environmental impacts. Further offshore, a rock ripping plough, rock wheel cutter or vibratory share plough may be the best option.

Avoidance and mitigation of bird collisions [19]

The shut-down of turbines in future OWFs in the Netherlands is explicitly written into the license for a specific wind farm area (in Dutch: Kavelbesluiten). For example, in the Kavelbesluit of Borssele I, the current cut-off point is 500 birds/km/h: above this, turbines need to be shut down. In Germany, a threshold based shut-down system is being tested in a near-shore wind farm in the North Sea; and the approach may be rolled out in future projects in the Baltic Sea. However, there is currently no generally agreed best approach for curtailing OWF operations to reduce the collision risk for birds.

Mitigation techniques

- MSP can to an extent reduce the impacts of OWFs on migrating birds and bats by selecting sites outside areas of special importance to either group. Collision risk for seabirds can also be reduced by ensuring OWFs are sited at a distance from breeding colonies.
- For operating OWFs, temporary shutdown during mass migration events (especially in bad weather or poor visibility) has often been recommended as a collision risk mitigation measure. Whenever a dangerous situation occurs – e.g. birds flying in a high collision risk area or within a safety perimeter – the turbines presenting the greatest risk should stop spinning. This strategy can operate year-round or be limited to a specific period. For example, wind turbines on migratory routes could be shut down on nights of poor weather to protect nocturnal bird migration. However, detecting birds at risk requires a real-time surveillance program and significant resources. Although various OWF monitoring systems have been developed, there is no single convincing solution yet at hand.
- The effectiveness of other approaches, such as increasing turbine visibility, has not yet been demonstrated in the field. Various attempts to increase blade visibility have been made by using patterns and colors that are conspicuous to birds (e.g. square-wave black-and-white bands across the blade; single black blade paired with two white blades, ultraviolet-reflective paint).
- Deterrent devices scare birds away from a specific area. However, there is no empirical proof of the effectiveness of deterrents when it comes to wind turbines. Deterrents can be activated by automated real-time surveillance systems as an initial mitigation step prior to blade curtailment.

Although test results are only preliminary, it appears deterrent devices may have an unpredictable effect on the flight path of a bird, so caution is needed if they are used at a short distance from a turbine or within an OWF. Nevertheless, this measure may divert birds from flying straight at a wind turbine.

Mitigation of waste [19]

OWFs should have a waste management strategy to guarantee zero emissions of micro- or macroscopic waste, as well as any contamination with pollutants. Where waste cannot be avoided, it should be taken back to shore and properly recycled or disposed of.

Mitigation techniques

To avoid the use of sacrificial anodes for corrosion protection – and the associated release of (heavy) metals into the water – alternative methods for corrosion control have been suggested or are already in use (e.g. at Trianel Windpark Borkum in the German North Sea). One of these alternatives is the impressed current cathodic protection (ICCP) system, which consists of titan-anodes with a mixed metal oxide coating that gives an estimated lifespan of more than 25 years. Their release of metals is relatively low compared to the use of sacrificial anodes. However, ICCP is a source of electromagnetic fields, and thus has potential impacts on marine biota.

Mitigation of electromagnetic fields and temperature [19]

Cables interconnecting turbines and transferring the energy generated to the shore emit heat and produce a surrounding electromagnetic field. Burying the cables in the sea floor significantly reduces electromagnetic fields but increases seabed temperatures. Regulations concerning burial depth are country-specific and area-dependent. In Germany, for example, the minimum depth ranges from 0.6m within a wind farm to 3m in areas with high traffic. Furthermore, in order to limit the heat emitted by the cables, the so-called '2K-criterion' is a condition to all projects. It states that the increase in temperature must not exceed 2K in the upper 20cm of the seabed. In the UK, a minimum depth of 1.5m is recommended to minimize impacts above the seafloor and in the most active biological upper layer, and to increase the distance between the cables and electromagnetically sensitive marine species.

Mitigation techniques

- Thoroughly plan cable routes and laying techniques to avoid/mitigate impacts on sensitive habitats
- Bundle cables to reduce area impacted by heat and EMFs
- Bury cables to decrease EMFs above the seabed – appropriate burial depth varies with seabed properties.

4.2.3 Compensation of impacts

Even with the use of the aforementioned strategies for avoidance and mitigation, impacts will remain especially on birds and mammals. In Europe, the legal framework that deals with the environmental impacts of offshore wind farms is the Environmental Impact Assessment (EIA) Directive. It requires project owners to take measures to "*avoid, prevent, reduce and, if possible, offset significant adverse effects on the environment*", described in an EIA report. This is known as the Avoid/Reduce/Compensate sequence (or ERC sequence). The objective of this sequence is to obtain no loss of habitats or species ("no net loss" principle). The potential impacts on Natura 2000 areas are covered by the Birds Directive and the Habitats Directive, which member states were required to transpose into national law. If the wind farm development site is part of the Natura 2000 network, the developers must make an appropriate assessment of the impacts on the site. If negative impacts without alternatives are identified, "*the Member State shall take all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected. It shall inform the European Commission of the compensatory measures adopted*" (Article 6.4 of the Habitats Directive). A distinction can be made between ecological and financial compensation measures.

A study conducted by Vaissière et al. in 2013 on 43 offshore wind farms in Europe concluded that the developers of European offshore wind farms had not proposed ecological compensation measures at sea for impacts on the marine environment. The project owners demonstrated that ecological compensation is not necessary because the residual impacts are not significant. The positive effects of the wind farms on the marine environment (mainly the reef and reserve effects) are mentioned as sufficient to compensate for the potential minor negative impacts on fauna, flora and the seabed. They also proposed monitoring as an ecological compensatory measure. Only one report (Prinses Amalia, Netherlands) raised the possibility of monetary compensation for ecological impacts if no other solution is possible. In the Netherlands, Egmond aan Zee is the only offshore wind farm that proposed ecological compensation for impacts produced at sea. However, these were onshore compensatory measures that were proposed for offshore impacts, and some of these measures were for impacts other than those produced by the offshore wind farm project (e.g. Expansion of a bird sanctuary for coastal and migratory birds, Support for initiatives to collect waste at sea) which poses an equivalence problem.

In the marine environment, construction of artificial reefs or rebuilding of former reefs is a common practice which might offset impacts on benthic habitats and fish but can also be beneficial for marine mammals. Further options to compensate for impacts associated with offshore wind energy might be the reduction of other impacts such as from fishing, shipping and sand mining or hunting. In such cases, specific stakeholders (e.g. fisheries, shipping companies) might receive a compensation payment when not using specific sensitive areas [19].

The turbines of the OWF itself can act as artificial reefs and provide the opportunity to reintroduce individual target species to an area. In Germany and the U.S., European target species, e.g. European Lobster (*Homarus gammarus*) were reintroduced in OWF areas [57]. Nevertheless, regarding the entire ecosystem, using newly established artificial reefs on the turbines to generally compensate for destroyed native habitats is not seen as an appropriate compensation measure.

Technical, ecological and governance reasons may explain the absence of ecological compensation measures (Vaissière et al. 2013):

- Residual permanent or temporary impacts are not significant because the implementation of measures to avoid or reduce the impacts on the marine environment have been effective;
- The positive impacts outweigh the negative impacts (according to Environmental Impact studies);
- The technical feasibility of ecological compensation measures in the marine environment seems low;
- The average cost of ecological compensation in the marine environment is too high;
- Compensation for residual impacts is not mandatory for some member states;
- Supporting policies are not clear or do not provide operational guidelines for the implementation of compensation;
- The impacts are acceptable in view of issues such as the reduction of greenhouse gases.

Knowledge of the impacts on the marine environment is still at an early stage and does not provide sufficient experience with underwater ecological compensation.

4.3 Conflict mitigation: Improving compatibility between BE and other uses of the sea

Spatial conflicts arise from direct competition over limited space (two sectors interested in the same location) or one sector negatively impacting the other, which may or may not be in the same location. There are two basic options for addressing spatial conflicts in Marine Spatial Planning: i/ Conflict prevention is the action that seeks to avert spatial competition, usually by ensuring that incompatible activities do not occur in the same space or negatively affect each other; and ii/ Conflict mitigation is the action that seeks to soften the impacts of spatial competition, e.g. by means of compensatory measures negotiated between the sectors affected [58]. More specifically [62]:

1. Strategic solutions can be designed to prevent conflicts as much as possible. This mostly refers to an appropriate and above all, agreed planning framework based on a solid evidence base and stakeholder participation.

2. Solutions that deal with an existing conflict. This refers to situations where offshore wind farms have existed for some time and created difficulties for fishers, such as displacement. Financial compensation for fishers may fall into this category.

3. More localized solutions for mitigating conflicts. This mostly refers to specific offshore wind farm projects yet to be implemented, which may give rise to more localized conflict.

These then need to be dealt with on a case by case basis. Different level solutions are prerequisites for others, or support each other. Strategic approaches, for example, are ideally supported by project level solutions. Solutions that are preventative can also be applied in retrospect as mitigation efforts, so the distinction between the categories can sometimes be arbitrary.

Conflicts between OWFs and tourism

According to available studies [59], impacts on tourism and leisure activities can be negative, positive or negligible, depending on the implementation phase of the offshore installations. In particular, temporary disruption to the tourism sector is expected during the construction and decommissioning phase of an offshore farm. As regards OWFs, during the operation phase, the main threat to tourism appears to be undesirable visual intrusion, which is worst in clearer air and sunshine, while other impacts can be minimal provided mitigation measures are implemented.

Welfare economic impacts associated with spending holidays in the vicinity of an offshore wind farm were evaluated for the Mediterranean [60] (Figure 21). Results showed that tourist community preferences for wind farms that are visible from the shore are likely to be influenced by the information they have on climate change, the real cost of wind power compared to alternative energy sources, the effectiveness of renewable energies and their capacity to replace conventional fuels, and the impact of offshore wind turbines on landscape, noisescape and wildlife. Nationality and education were also showed to matter, most probably because these two factors are likely to influence how informed citizens are with respect to the abovementioned issues.

Figure 21. Conceptual framework of key discourse-based drivers of preferences for wind farm project. Source: Westerberg et al., 2015.

*Variables written in italics have either not been collected for the purpose of the present analysis or were not significant in the final model due to a high correlation with other background variables.

In France, policy recommendations were derived from a study on the impact of OWFs on tourist preferences. The findings of the study indicate that age, nationality, vacation activities and their destination loyalty influence attitudes towards compensatory policies. The recommendations are as follows: wind farms should be located no closer than 12 km from the shore; alternatively, a wind farm can be located from 5 km and outwards without a loss in tourism revenue if accompanied by a coherent environmental policy and wind farm-associated recreational activities.

A combined travel cost – contingent behavior survey of residents and tourists in Catalonia was conducted on-site to examine the effects of an offshore wind farm (OWF) project on beach recreational demand. The survey considered four potential OWF scenarios with different degrees of visual impact. The results showed the importance of the specific location of the OWF project and how the installation of wind turbines would significantly decrease the demand for trips, depending on their degree of visual impacts, leading to a substantial welfare loss. However, the results also showed that the project would mainly result a displacement of trips to other beaches within Catalonia rather than outside Catalonia.

To date, no data are available for sites of particular historical interest and/or located in particularly beautiful landscapes, which are not always included in officially protected areas (Pelagos project, 2017). It is to be noted, however, that while disamenity costs decline as the distance from the coast increases, transmission, construction, and maintenance costs typically rise with distance, therefore posing the crucial question of optimal trade-offs in the economics of near-shore Blue Energy plants [61]. Carefully selected islands could constitute preferred demonstration regions for any innovative MRE projects [65].

A set of solutions to mitigate conflicts between OWFs and tourism have been identified [62]:

Solution 1: Zoning to minimize the visual impact of offshore wind farms
Solution 2: Sensitive siting of offshore wind farms to minimize socio-cultural impacts
Solution 3: Collect data on the coastal tourism and recreation sector
Solution 4: Develop a Tourist Impact Statement and possibly include it as a standard part of the SEA or EIA.
Solution 5: Allow recreational vessels access to offshore wind farms
Solution 6: Design a multi-use offshore wind farm
Solution 7: Use the MSP process to ensure offshore wind farm development benefits local communities
Solution 8: Use the MSP process for clear and transparent communication on the visibility of the OWF
Solution 9: Stimulate and facilitate innovation in the OWF sector to decrease potential conflicts with tourism

Conflicts between OWFs and fishing

Fishing and vessel traffic are usually prohibited in OWFs, reducing the area available for fishing and also creating barriers to navigation. OWFs can jeopardize important fish habitats such as spawning and nursery grounds as their location (shallow areas closer to the coast, on sandy banks) are often also areas particularly suitable for offshore wind farms. However, preserving spawning and nursery areas is likely to be of increasing importance in the face of climate change. At the same time, OWFs can contribute to preserving fish stocks by offering artificial reefs where fish can feed and not be captured.

The main constraint for fisheries is the spatial exclusion in and around OWFs. This has progressively and partially been solved with regards to the transit of fishing vessels. To avoid lengthened routes for other maritime activities, and especially for fisheries, several countries from the North Sea have allowed small to medium-sized vessels (often <24m) to go through OWFs under good weather conditions, either freely or within defined corridors [63]. This is facilitated by the fact that wind turbines are generally spaced more than 1 km from each other, which makes risks very low for mere transit. It is the case in Denmark, Germany and the Netherlands. In the Netherlands, in 2018, after 3 years of study, the government decided to open three OWFs for transit by fishing vessels under 24m. In Poland, where the OWF sector is emerging, the government stated that offshore wind farms should be navigable for ships of up to 50 meters [63].

Nonetheless, most fishing activities have remained excluded within OWFs up to now, except in the UK – where fishermen do not seem to have seized the opportunity, as mentioned previously. However, the design of OWFs compatible with fishing has gained increasing interest in recent years, both from governments and developers, as well as from fishermen themselves. The conduct of static fisheries within OWFs appears to be realistic, with some successful examples of crab and lobster pot fisheries in Scotland and the UK and some promising studies in the Netherlands and Germany. However, sea-bed fisheries within OWFs seems unlikely. In the UK, where it is possible, there is not yet conclusive evidence of significant levels of towed gear fishing activity taking place.

Displacement is a particular issue for coastal and small-scale fisheries as they do not always have the capacity to move to fishing grounds further offshore; nor can they switch to other fishing methods. Due to the many variables in fishing and offshore wind farming, conflicts are usually case specific, depending on the local geological characteristics, types and intensity of fisheries, and the OWF technology implemented. The socio-cultural importance of the fishery for the local community also plays a crucial role in how this conflict plays out [62].

A set of solutions to mitigate conflicts between OWFs and fisheries have been identified [62]:

Solution 1: Use high-level policy to ensure impacts are considered
Solution 2: Acknowledge the special status of fishers in the MSP planning process
Solution 3: Draw on fishers' knowledge to create an evidence base
Solution 4: Choose suitable offshore wind farm locations with care
Solution 5: Set up a liaison group for MSP early on
Solution 6: Use the MSP plan to favor synergies and co-existence
Solution 7: Allow some types of fishing in offshore wind farms under certain conditions
Solution 8: Support fisheries by designating migration corridors
Solution 9: Allow fishing vessels to transit through offshore wind farms
Solution 10: Align construction phases with fisheries seasons

Solution 11: Support collaborative arrangements between sectors	
Solution 12: Use an adaptive approach based on coordinated research and monitoring	
Solution 13: Produce guidance notes and licensing manuals	
Solution 14: Consider technical solutions	

On a more technical level, for a specific project, OWF developers can contribute to lowering the risk of conflict through:

- Careful siting of offshore wind farms (layout);
- Careful timing of construction work;
- Configuration of turbines to allow navigation and fishing in between;
- Adequate cable burial;
- Bunching of cables in corridors;
- Appropriate marking and lighting of structures;
- Adequate early consultation with the fishing industry;
- Associated safety zone proposals.

In situations where conflict with fisheries has not been identified nor addressed during the OWF planning phase, compensation of losses (by OWF developer governments) to individual fishermen or fisheries organizations can be seen as a mitigation measure. However, this solution is not encouraged in most North Sea Countries. In Belgium, Germany and the Netherlands, there are no compensation procedures. In the UK, commercial compensation is considered as the last resort, when there is significant residual impact that has not been avoided through planning. Denmark is the only North Sea country where, according to the Danish Fisheries Act, all fishermen who normally fish in the affected area must be compensated for the loss of income. It is the responsibility of the developer to negotiate compensation with every affected fisherman, and the license to produce electricity from the offshore wind farm (power plant) can be granted to the Developer only if an agreement has been made with all affected fishermen [63].

4.4 From compatibility to synergy: Multi-Use of the sea combining BE production and other maritime activities

The Ocean Multi-Use Action Plan [64], developed by the H2020 Multi-Use of the Seas (MUSES) project, highlights opportunities and experiences across Europe for combining maritime uses, either through joint operations or joint installation. The multi-use (MU) approach is intended to reduce spatial pressures on seas and create new opportunities for socio-economic development, along with potential environmental benefits. BE production is suitable to be combined with other maritime activities. Examples are available where OWFs are combined with other uses – such as tourism, aquaculture, fisheries, and other types of BE.

In 2019, the European Commission approved two other Horizon 2020 projects on MU, focusing on specific aspects such as Multi-Use Platforms (MUPs) and MU in islands titled UNITED and MUSICA. These projects are still in their early stages. UNITED “Multi-Use platforms and co-locatioN pilots boostIng cost-effecTive, and Eco Friendly and sustainable proDuction in marine environments” is led by Deltares, in the Netherlands with a total of 26 participants. The objective is to develop pilot projects in a real environment to enable the large-scale adoption of the multi-use of marine space, including MUP concepts and co-location activities. UNITED focuses on five pillars: technical, regulatory, economic, social and environmental, in five pilot projects across European regional seas in close cooperation with local stakeholders and industrial actors.

MUSICA “Multiple use of Space for Island Clean Autonomy”, is led by University College Cork, Ireland with a total of 15 consortium partners. MUSICA specifically focuses on small islands. Its goal is to accelerate the roadmap to commercialization of its Multi-Use Platform and Multi-use of Space combination for the small island market, and de-risk for future operators and investors. Similar to UNITED, MUSICA's interpretation of multi-use includes both the multi-use of space and MUPs. Sectors covered in MUSICA include renewable energy, energy storage, smart energy systems, and desalination.

The feasibility of combining different sea uses, including MREs, in different locations across Europe, has been analyzed [65] revealing MREs and tourism as the two driving sectors for the advancement of the multi-use concept. Significant barriers affecting combined uses involving OWE concern, for example, a lack of business cases demonstrating the real advantages of MU involving OWE generation, additional financial costs for offshore wind energy developers (e.g. related to foundation types, installation methods, additional protection methods, cable routing, etc.), or high insurance costs for small-scale fisheries companies against possible damages to offshore wind installations. In order to develop MRE-based combinations in the short term, renewable infrastructure should be preferably paired with other technological uses (e.g. combining two types of MRE production). However, to facilitate multi-use development and improvement in the longer term, a key element seems to be the amalgamation of the MRE and tourism industries. Countries which are still looking to develop the offshore MRE sector, and have the potential to co-locate it with tourism activities could benefit from reviewing and tailoring the MRE-based legislative, policy and planning framework put in place by some northern European countries. As the MRE industry further matures technologically, studies should be undertaken to evaluate and quantify the real versus the perceived risks to the health and safety of tourists when integrating tourism with renewable energy production, particularly with respect to offshore location [65].

4.4.1 Offshore wind farms & tourism

Synergies between OWFs and tourism can be developed in several ways (Soukissian et al., 2019; Smart solutions in the Baltic, 2018)[9], including:

[9] “Smart solutions in the Baltic,” [Online]. Available: www.southbaltic.eu/smart/005.

- providing power to local authorities and other infrastructure (hotels)
- sightseeing boat tours (thematic park), sometimes combined with angling
- specially designed platforms around the turbines serving as a resting ground for seals
- designated facilities for divers and offshore restaurants in the vicinity of OWFs
- unique wind farm design and layout can serve as a tourist attraction and regional landmark
- on-land visits to OWF information centers and museums, and platforms for observing the farms with telescopes
- exhibition centers, such as marine museums, aquariums, etc., can be constructed near the OWF areas, building on the availability of habitats developed under the installation
- boat tour operators can be involved in OWF-related monitoring activities
- helicopter flights around OWFs.

Examples of this combination already exist [64] in all countries where OWFs have been installed (North Sea and Baltic Sea). In Belgium, there are boat tours to the first national OWF, Thorntonbank (owned by C-Power), situated 30 km from the coast. For business groups, the tour operator collaborates with the visitor center of C-Power in Ostend, where a representative from the wind farm operator gives a presentation about the OWF. The tour boat does not cross the 500 m safety zone yet, despite the distance, but visitors are able to experience good views of the wind farm. In Germany (North Sea), in addition to boat tours (outside the 500 m safety zone), there is also an on-land observation platform in Bremerhaven with an information board and multimedia terminal. In the UK, the safety distance is usually only 50 m, allowing vessels to be in close proximity to the turbines (Smart Solutions in the Baltic, 2018). Some examples can be found in Brighton, East Sussex in Southern England (visits to Rampion OWF[10]); Ramsgate, Kent (visits to Thanet OWF) and Great Yarmouth, Norfolk (visits to Scroby Sands OWF) in Eastern England[11]; Llandudno, Wales in the Irish Sea (visits to the Gwynt Y Mor OWF). In Middelgrunden OWF in Denmark, tourists can even climb the 60 m tower of one of the turbines and open the nacelle (if the weather conditions are suitable[12]). This OWF also provides a good example of an attractive OWF layout and the benefits of early engagement of the local community in a co-design process. The wind farm layout follows a single curved line, continuing the Copenhagen city structure which has the shape of a superellipse, characterized by the old defense system west of Copenhagen[13]. This MU is also initiated on a temporary basis, usually as part of the OWF developer's corporate social responsibility (CSR) local outreach campaigns[14]**.** These are undertaken especially during the pre-planning stage when local acceptance needs to be secured for the OWF project to continue [64].

[10] Tourist touching the OW turbine in Rampion OWF," [Online]. www.youtube.com/watch?time_continue=23&v=Rqp-60RkL-0.
[11] Go 2 Sea and Sea searcher," [Online]. Available: http://go2sea.co.uk/leisure/ and www.seasearcher.co.uk/trips/offshore-windfarm.
[12] Julia Fchozas," [Online]. www.juliafchozas.com/expertise/middelgrunden-wind-farm-guided-tour/
[13] WWEC 2017," [Online]. wwec2017.com/wp-content/uploads/2017/06/Middelgrunden-Offshore-Wind-Energy-Farm-15.06.2017.pdf
[14] Offshore-windindustrie," [Online]. https://www.offshore-windindustrie. de/bildung/besichtigungen

One of the main drivers for this combination of uses is the fact that it can potentially overcome issues of OWF project acceptance by offering socio-economic benefits to local communities in the form of new jobs and income from OWF operation, transforming the potentially negative OWF image into a positive tourism experience. The combination may therefore also reduce negative costs to OWF operators, associated with planning delays and conflict resolution, as well as contributing to the positive image of OWF by increasing knowledge about the importance of green energy. Furthermore, if the OWF has a unique design and layout, it can become a symbol for the local region, building a sense of pride among locals and stimulating regional development in remote areas [64]. Despite these potential synergies, there are still barriers to the development of this combination: complicated licensing, high insurance premiums and uncertainties over who should cover these costs (OWF or tourism operators) are among the main regulatory obstacles affecting its economic viability. Natural barriers relate to distance from shore, weather and tide conditions and seasonality. Moreover, despite the existence of good practices, it is not common practice to consider this combination from the outset of an OWF planning process [64].

The following objectives to sustain this type of combined activities have been identified [64]:

1. Improve involvement of the local tourism sector early in MSP and planning processes for a specific OWF (consider involvement of local clusters and tourism sector representatives);
2. Facilitate transfer of good practices across Member States/sea basins, acquired from existing MUs;
3. Support the development of viable business models and capacity building for local tourism operators;
4. Mainstream these solutions in local development policies, cohesion policies, and as part of broader project development guidance for OWF developers (especially with regards to consultation and mitigation processes).

4.4.2 Offshore wind farms & aquaculture

Combining offshore wind and aquaculture can entail [64]:

- Direct attachment of installations (i.e. fish cages or mussel/ seaweed long-lines) to offshore wind turbine foundations or development of new infrastructure solutions (i.e. in the form of fully integrated multi-purpose platforms);
- Co-location of aquaculture installations within the security zone of the OWF farm. For instance, seabed cultivation of mussels within the vicinity of the OWF.

Multiple research projects ranging from conceptualization studies to pilots in the real environment, mostly in North and Baltic seas, have played a major role in conceptualizing this MU. These projects have analyzed different technological solutions (TROPOS and MERMAID projects), assessed environmental and economic feasibility (EDULIS project), examined interaction between the two activities in terms of operations and maintenance (Coastal Futures project), and identified the most suitable type of aquaculture for the given site (Offshore Aquaculture project).

In the North Sea (NL, UK, BE, and DE) existing cooperation between research institutes and relevant commercial actors plays an important role in developing this combination. In the Baltic Sea, theoretical concepts were developed in Kriegers Flak, southern Sweden, within the scope of the MERMAID project [66] while tests in the real environment were conducted at the Rodsand 2 offshore wind farm off the south coast of Lolland, Denmark as part of the SUBMARINER project.

However, this kind of multi-use has also been considered as a viable concept in the Mediterranean: in France, for combination with future offshore wind farms [73] and in Cyprus, as a feed management system powered by a stand-alone renewable energy system [68].

The main driver behind this combination of uses [64] is the lack of suitable space in inshore sheltered areas to reach the targets given for increased aquaculture production (60% for finfish and 25% for shellfish by 2020). The multi-use approach may provide an opportunity to move aquaculture offshore to further exposed sites and create cost savings through joint development and shared operations and maintenance. Moreover, using energy from the OWF for aquaculture operations could potentially ensure green credentials and allow aquaculture products to be marketed at a premium.

Barriers to development of this multi-use are [64]:

- Insufficient technology readiness level, especially for harsh conditions in offshore areas, and compatibility of technologies used for different types of aquaculture (e.g. cage vs line) and OWF (e.g. floating vs jacket vs monopile);
- Unknown cumulative effects: especially with regards to combinations with fish aquaculture;
- Unassessed risk and unclear permitting processes/ insurance implications, as well as a lack of planning and financial incentives, needed to enhance the commercial drive for such multi-uses.

Moreover, it is difficult to further develop this MU by adding aquaculture installations to an already operational (or even only licensed) OWF in places where OWF operators are able to veto any kind of development deemed detrimental to their activities.

Objectives to facilitate development of this combination of uses have been identified [64]:

1. Increase awareness of all relevant actors about multi-use opportunities and the benefits achieved to date from existing ventures;
2. Ensure the strategic research agenda corresponds to the needs of current decision-making systems and supports continuous improvement;
3. Support the development of full-scale pilot projects and encourage the involvement of established businesses to address the low investment capacity of the small-scale aquaculture sector;
4. Address the power imbalance between the two sectors through facilitation policy and regulation.

4.4.3 Offshore wind farms & fisheries

Despite the conflict illustrated above, there are examples of compatibility between OWFs and fisheries where fisheries are not excluded from either the OWF development area (which can include a maximum 500 m safety zone during OWF operation) or along the offshore export power cable corridor. It may also include access to the same staff pool, equipment (vessels) or infrastructure (port facilities). Monitoring may be conducted by fishermen as a service, and the same emergency system may be shared by the two activities.

Different regulations across EU Member States apply to the safety zones around OWFs, as well as different cable laying laws and practices (including burial and other protection measures) directly affecting certain types of fishing.

In some EU Member States (NL, DE, BE), fisheries are displaced from the 500 m safety zone not only during the OWF development, but also during operation. Where law does not require connecting cables to be buried, bottom-contact gear (a large proportion of the total commercial fishery activity) cannot be used as it can cause damage to cables and to fishing gear (e.g. the Netherlands and Germany) [63]. In Denmark, fishing is excluded from the entire OWF area and in a buffer zone of 200 m along each side of the export cable. The United Kingdom is an exception, as fishing in OWFs is only prohibited during construction or maintenance phases. Although there are no legal restrictions, a study conducted by the National Federation of Fishermen's Organisation (NFFO) in 2016 showed that fishermen - especially with trawling gear - tended to avoid OWF and their surroundings because of the risks involved for themselves and their gear and vessels.

The main benefit of including a fishery within OWF areas is the potential resolution of conflicts between these two uses, facilitating public acceptance of the OWF. Small-scale fishermen in particular may experience loss of income by changing fishing grounds. Moreover, studies indicate that OWF foundations are particularly valuable fishing grounds as they serve as artificial reefs. Environmental impacts and safety risks of fishing within the wind farms are perceived differently by the actors involved (authorities, developers, fishers) from country to country, resulting in different regulatory frameworks. Moreover, there is a lack of strategic support facilitating the transfer to other types of fisheries (changing fishing gear, replacing fishing quotas) [64].

4.4.4 Offshore wind farms & environmental protection

Restricting maritime activities, such as certain types of fisheries, in the MRE zone could provide or enhance conservation benefits and habitat protection inside the zone and in the surrounding areas [69],[70],[71],[72],[74],[75]. Restrictions on certain types of fisheries can create positive second order knock-on effects for other more environmental friendly fisheries, such as certain types of commercial and recreational fisheries [72]. However, certain offshore wind constructions create an artificial reef effect that can also result in incompatible biodiversity [79]. Another benefit of MRE and Marine Protected Area (MPA) coexistence is that it does not decrease the available marine space for other uses [76]. This benefit is deemed crucial, particularly in countries where marine space is scarce.

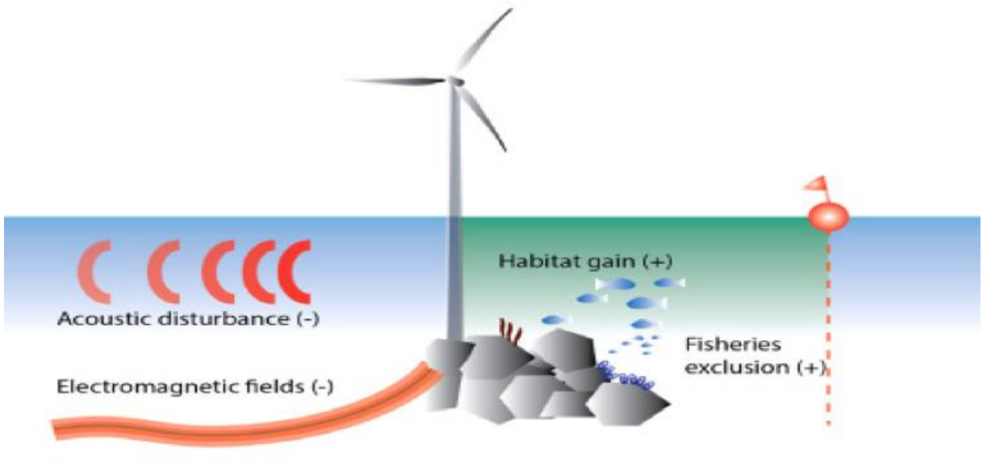


Figure 22. Main pressures from OWFs during the operational phase. Expected effect on the local abundance of marine organisms is indicated as (+) aggregation/increase and (-) avoidance/decrease. Source: Bergström et al. (2014).

Kyriazi et al. (2016) [77] examined a number of potential policy objectives that might affect MRE-MPA coexistence, and how and why the attitudes and interactions of the MRE developer and the MPA authority as key players might influence this coexistence. When MRE-MPA coexistence is pursued, the issue of the uncertainty regarding the extent of damage and hence the appropriateness of compensatory measures might become important. Proposed compensatory measures (when required) might not be acceptable for the MPA authority and/or the MRE developer, resulting in either no applications of MRE projects in MPAs, delays in their approval or even their rejection. More precisely, the MPA authority may be more reluctant to agree on coexistence if the compensatory measures proposed do not ensure a net gain objective that should be required, especially when the conservation goal of the MPA is the enhancement of the ecosystem.

Bergström et al. (2014) [78], based on field work in the Baltic, pointed out that whereas the construction phase was consistently associated with negative impacts, pressures during the operational phase may result in both negative and positive effects, depending on local environmental conditions as well as prevailing management targets (Figure 22). They recommend undertaking long-term, holistic monitoring to be able to clarify the real effects of MRE installations. Sangiuliano (2018) [79] investigated the possibility of co-locating developments in environmentally sensitive areas and pointed out the opportunity of combining MRE installations with environmental monitoring, for the benefit of environmental protection.

4.4.5 Combining different BE types

Combining MRE sources (offshore wind, wave, tidal or solar energy) can be achieved by installing them on the same integrated platform, or just sharing the same marine space in a co-location scheme, where wave energy converters may, for example, fill the gaps between offshore wind turbines sharing the cable array and grid connections (Ramos et al. 2022) [64]. Additional synergies can be established through joint operations, monitoring activities or shared monitoring software.

There is already some experience of wave and tide energy combinations in the northern part of Scotland while others are under evaluation. Moreover, a hybrid pilot test of wind and wave energy converters has been programmed in Scotland (Caithness), whose long-term aim is to deploy a commercial scale project. In the Northern Atlantic, in northern Spain (Cantabria), the MERMAID project has also explored the feasibility of wave and wind multi-use. While testing of a wave energy generation device was conducted in Denmark, this combination was never designed for commercial use in the Baltic Sea, but tested for further use elsewhere (Danish Wave Energy Test Centre). In the Baltic Sea, major barriers include small waves, winter ice, and the lack of a market and suitable technology to address these conditions.

In 2021, a contract was signed to advance the deployment of the first full-scale hybrid floating wind and wave platform, at the PLOCAN test facilities off the coast of the Canary Islands. The agreement was signed by the technology developer Floating Power Plant (FPP) and the PLOCAN-site at Gran Canaria. The platform will use the local supply chain to build the world’s first commercial scale floating submersible platform to combine wind and wave technologies together, thus contributing to the Canary Islands’ firm commitment to boost the blue economy sector. While combining resources, the technology itself also provides an opportunity to exploit new resource areas within the Canary Islands, distributing generation capacity and reducing the visual impact of the planned offshore wind developments. The platform will be able to generate over 5MW of power from the wind turbine and wave energy converters[15].

The main driver for this multi-use is its ability to generate maximum energy per nautical space, with the additional benefits of reducing operational, maintenance and investment costs. It also mitigates potential conflict by allowing space for other maritime uses. The simultaneous production of different MREs can improve the quality of power output and have a positive impact on levelling the power output delivered to the grid (Ramos et al., 2022).

The challenges hindering the development of this MU are less technical and more related to the separate permitting and regulatory processes, the high levels of uncertainty regarding the economic return, different tariff rates and the lack of incentive schemes which limit the competitiveness of this MU.

As reported in Section 2, the opportunity of combining offshore wind and wave energy technologies has arisen and hybrid systems are currently being researched (see Pérez-Collazo et al., 2015 [80] for a review of the different concepts). Thanks to a series of synergies, installation, and operation and maintenance

15 Source: https://www.oceanenergy-europe.eu/industry-news/site-secured-for-worlds-first-multi-megawatt-wind-and-wave-system/

(O&M) costs may be decreased, making the combined harnessing of offshore wind and wave energy a promising sector. To date, the most recent relevant patented technology was developed by the Danish company Floating Power Plant, consisting of a single WT (5-8 MW) mounted on a floating platform also capable of producing 2-3.6 MW of wave power [17].

Objectives to facilitate development of this combination of uses have been identified [64]:

- Disseminate the benefits and viability of existing initiatives, as well as wider interest from industry for these types of solutions, to increase the chances of receiving policy and regulatory support.
- Conduct comparative case study analysis to identify suitable conditions for commercial deployment and upscaling.
- Facilitate communication between different developers on environmental impacts in an open process that can provide recommendations for future EIA requirements.
- Design and support planning and financial incentive schemes that cater to this type of MU where multiple energy resources are combined. This will involve working closely with industry and regulators to ensure appropriate support which considers existing regulations, the marine environment and capacities of the private sector.

5. Addressing enabling conditions for Blue Energy development

Blue Energy development depends on a variety of factors, from physical and geographical factors, to those that are technological, industrial, and capacity-related. Social factors also play an important role, as social acceptance is also an issue for the authorization and permitting processes for Blue Energy installations. Moreover, policy and legislation are key aspects for any sector development, including BE. In the case of BE, policy and legislation can facilitate development in different ways:

- Promoting research and innovation, easing field testing of prototypes,
- Addressing social consensus through educational and communication activities,
- Making public funds available for early-stage research and facilitating private investments for more advanced technological stages,
- Simplifying and speeding up authorization procedures.

In this chapter the role of policy for BE development in the Mediterranean is analyzed and recommendations for creating a better environment for BE are discussed, together with other types of key actions.

5.1 Policy framework for Blue Energy in the MED and the EU

The Mediterranean context

Under the Barcelona Convention system, the Mediterranean Strategy for Sustainable Development 2016-2025 (UNEP/MAP, 2016) aims to provide a strategic policy framework to secure a sustainable future for the Mediterranean region. The rationale behind the Strategy is the need to harmonize the interactions between socio-economic and environmental goals, to adapt international commitments to regional conditions, to guide national sustainable development strategies, and to stimulate regional cooperation between stakeholders in the implementation of sustainable development. In this respect, sustainable development translates into the need to consider environmental, social and economic goals in decision-making at all scales and across all sectors.

Objective 4 of the Strategy "*Addressing climate change as a priority issue for the Mediterranean*" is linked to Sustainable Development Goal (SDG) 13 "*Take urgent action to mitigate climate change and its impacts*". Within Objective 4, to contrast the growing trend of greenhouse gas emissions within and beyond the energy sector, institutional, policy and legal reforms for the effective mainstreaming of climate change responses into national and local development frameworks, particularly in the energy sector is recommended. In addition, mobilization of resources and support for the development of trans-Mediterranean power grids for efficient utilization of renewable energy sources in the region, including solar energy is envisaged. Objective 5 of the Strategy "*Transition towards a green and blue economy*" is also relevant, foreseeing promotion of sustainable consumption and production patterns and encouraging environmentally-friendly and social innovation. The Strategy is complemented by the UNEP/MAP Regional Climate Change Adaptation Framework [81].

MRE, and especially OWE, has been recognized as a strategic asset for the blue economy in the Mediterranean [82] and has been associated with a specific indicator (Offshore wind capacity installed) among the core set of indicators for the Mediterranean blue economy dashboard.

The Protocol on Integrated Coastal Zone Management in the Mediterranean (ICZM Protocol) also provides relevant recommendations for BE development. Article 9 (Economic activities), states that the coastal and maritime economy should be adapted to the fragile nature of coastal zones and ensure resources of the sea are protected from pollution. Regarding infrastructure, energy facilities, ports and maritime works and structures, should be subjected to authorization procedures so that their negative impact on coastal ecosystems, landscapes and geomorphology is minimized or, where appropriate, compensated by non-financial measures. Maritime activities should be conducted in such a manner as to ensure the preservation of coastal ecosystems in conformity with the rules, standards and procedures of relevant international conventions.

The Naples Ministerial Declaration [89] confirmed that responding to climate change is one of the four priorities for the Mediterranean policy (together with tackling marine litter pollution, strengthening and expanding the Marine Protected Areas (MPAs) network, and supporting sustainable blue economy and an ecological transition). Specifically, the Declaration sets recommendations for collecting scientific findings in an easily accessible form on behalf of decision-makers at any level and developing transdisciplinary research and inter-sectoral policies to address climate change through a cross-cutting approach, particularly in the water-food-energy nexus.

As highlighted by the State of the Environment (SoED) 2019 [84], fossil fuels in general dominate energy supply in the Mediterranean region, with heavy environmental and health impacts (e.g. CO_2, water acidification, particulate matter). SoED 2019 stated thta an energy transition is imperative, focusing on energy efficiency and larger shares of renewable sources in the energy mix, in line with international agreements. Shifting towards energy efficiency and reliance on low-carbon energy solutions is also key. SoEd 2019 also indicated that the energy sector is too often supported by considerable fossil fuel subsidies, going well beyond those needed for social purposes. Its environmental impacts are to be addressed at energy facilities, including primary production, electricity production plants, and refineries. SoED 2019 also recommends the implementation of Marine Spatial Planning and Integrated Coastal Zone Management to allow for a sustainable blue economy compatible with the restoration of the health of strained ecosystems and halting the relentless encroachment on the marine and coastal environment.

Regional cooperation on offshore renewables in the Mediterranean is organized under the Barcelona Convention (environment) and the WestMed initiative. Recently, the MED7 Alliance also specifically referred to support for the development of offshore renewable energy in the Mediterranean Sea and in the Atlantic[16]. The Central and South Eastern Europe Energy connectivity (CESEC) High Level Group could foster regional cooperation initiatives, from the Adriatic Sea eastward.

The European context

The EU has a strong track record of commitment to renewable energy. In December 2018, the Renewable Energy Directive 2018/2001/EU entered into force, as part of the *Clean energy for all Europeans* package, helping the EU to meet its emissions reduction commitments under the Paris Agreement. The recast directive sets a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023, and comprises measures for the different sectors to make it happen. It also improves the design and stability of support schemes for renewables, pursues streamlining and reduction of administrative procedures, raises the level of ambition for the transport and heating/cooling sectors; and includes new sustainability criteria for forest biomass, aimed at minimising the risk of using unsustainable feedstock for energy generation in the EU.

The *Regulation on the Governance of the Energy Union* (Regulation (EU) 2018/1999) sets common rules for planning, reporting and monitoring and ensures that EU planning and reporting are synchronized with the ambition cycles under the Paris Agreement. Under the Regulation, EU countries are required to draft

16 www.diplomatie.gouv.fr/en/french-foreign-policy/europe/news/article/ajaccio-declaration-after-the-7th-summit-of-the-southern-eu-countries-med7-10

national energy and climate plans (NECPs) for 2021-2030, outlining how they will meet the new 2030 targets for renewable energy and for energy efficiency. Most of the other elements in the new directive needed to be transposed into national law by Member States by 30 June 2021, when the original renewables directive was repealed.

With the policies already in place, key EU targets for 2030 include: at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy, at least 32.5% improvement in energy efficiency. Particularly, the 40% greenhouse gas target is implemented by the EU Emissions Trading System, the Effort Sharing Regulation with Member States' emissions reduction targets and the Land Use, Land Use Change and Forestry (LULUCF) Regulation.

As part of the *European Green Deal*, in September 2020, the Commission proposed to raise the 2030 greenhouse gas emission reduction target, including emissions and removals, to at least 55% compared to 1990. The Commission started the process of making detailed legislative proposals by June 2021 to implement and achieve the increased goal.

With specific regard to marine renewable energies, other policies are already in place. The Ocean Energy Strategic Roadmap, produced by the Ocean Energy Forum and submitted to the European Commission in November 2016, estimates that under favorable conditions, the installed capacity could reach 100 GW by 2050, thus covering 10% of the EU's power demand (Ocean Energy Forum, 2016) [85].

Directive 2014/89/EU is also relevant, which establishes a framework for the implementation of maritime spatial planning and integrated coastal management by Member States aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources.

To ensure that offshore renewable energy can help reach the EU's energy and climate targets, the Commission recently prepared a dedicated strategy, the *EU Strategy to harness the potential of offshore renewable energy for a climate neutral future* (COM(2020) 741 final) that proposes ways forward to support the long-term sustainable development of this sector.

The Strategy proposes to increase Europe's offshore wind capacity from its current level of 12 GW to at least 60 GW by 2030 and to 300 GW by 2050. The Commission aims to supplement this with 40 GW of ocean energy and other emerging technologies such as floating wind and solar by 2050.

To maximize ORE impact, the strategy goes beyond a narrow definition of the factors of energy production and addresses broader issues such as access to sea-space, industrial and employment aspects, regional and international cooperation, and the technological transfer of research projects from the laboratory into practice. While reinforcing the role of ORE in the energy mix, sustainability and, more specifically, the protection of the environment and biodiversity are key concerns for all dimensions concerned.

To promote the scale-up of offshore energy capacity, the Commission will encourage cross-border cooperation between Member States on long-term planning and deployment. This will require integrating offshore renewable energy development objectives into the National Maritime Spatial Plans which coastal states were due to submit to the Commission by March 2021. The Commission will also propose a framework under the revised TEN-E Regulation for long-term offshore grid planning, involving regulators and the Member States in each sea basin.

Given the emphasis placed by the EU on renewable energy, it is safe to assume that Blue Energy will develop into an important industry and will therefore lay significant spatial claims into the sea in the near future [86]. This will add to the pressures of already established maritime activities such as tourism, fisheries and aquaculture, maritime transport, etc., whose cumulative impacts are becoming increasingly hard to accommodate under the current regime of sectoral management. However, the highly spatial character of industries like Blue Energy facilitates the shift to more spatial approaches to regulating, like Maritime Spatial Planning (MSP).

The Commission estimates that investment of nearly €800 billion will be needed between now and 2050 to meet its proposed objectives. To help generate this investment, the Commission will provide a supportive legal framework, will help mobilize all relevant funds to support the sector's development and will ensure a strengthened supply chain. The Strategy underlines the need to improve manufacturing capacity and port infrastructure and to increase the appropriately skilled workforce to sustain higher installation rates. The Commission plans to establish a dedicated platform on offshore renewables within the Clean Energy Industrial Forum to bring together all actors and address supply chain development.

Policy and legislative framework in EU Mediterranean countries

Current reference policies and strategies mostly target renewable energies as a whole, without making any distinction on the type of energy. There are very few policies specific to MREs at national levels. At the regional level, the large majority of smart specialization strategies in the Mediterranean target the development of renewable energies including marine renewable energies [88].

Existing national strategies are derived from European strategies which clearly target the development of MREs as strategic for the European Union. Seas and oceans are considered as drivers for the European economy and have great potential for innovation and growth as declared under (i) Blue Growth: the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole has a specific focus on Ocean and Offshore wind energies; (ii) Climate & Energy package: the 2020 package, mentioned above, is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets: 20% cut in greenhouse gas emissions (from 1990 levels); 20% of EU energy from renewables; 20% improvement in energy efficiency.

Despite the existence of focused strategies at the EU level, national level policy and legislation is of utmost importance in creating a favorable environment for BE development.

The MAESTRALE project prepared a database of regulations and funding frameworks across eight countries [87]: Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slovenia and Spain. Transferability of innovation was the main objective of MAESTRALE. Under this perspective, administrative and legislative background can have significant impact on the transferability of different BE-based technical solutions. Common regulation and funding framework analysis can be used to cross-evaluate legislative and administrative procedures between countries that readily accept or have any kind of barriers that prevent market uptake of these technologies. The PELAGOS project also worked on the legislative framework for BE [88], summarizing the available information on the national implementations of the EU 2009/28/CE Directive in five Mediterranean member states (Croatia, France, Greece, Italy and Spain). The analysis focused on current legislation, applicable regulations and authorization processes relevant for the development, installation and operational set up of offshore infrastructure for renewable energy production.

García et al. (2020) [89] examined the main characteristics of MSP processes in Greece, Italy, Malta, Portugal and Spain relevant for MRE. A comprehensive overview is reported in Table 4.

In the offshore wind sector, where higher Technology Readiness is available, the authors point out that policies concerning MRE are not very ambitious and sometimes erratic in the countries examined [89]. Modifications to the most recent versions of national energy plans have led, in some cases, to reductions in the initial forecasts of installed offshore renewable capacity (e.g. Portugal). In others, it has led to the complete elimination of targets for marine renewable energy. This is the case in Malta, where the government has abandoned targets for blue energy use at sea, opting instead for solar photovoltaic energy, and in Italy, which has gone from targets of 680 MW in offshore wind and 3 MW of ocean energy by 2020. In countries such as Spain and Greece, drastic changes in the regulatory framework and the support schemes for renewable electricity production over the last decade are added to the unambitious blue energy policy: remuneration for renewable energy generation decreased substantially as a result of national support scheme amendments, increasing uncertainty and insecurity for developers, thus hindering development of the sector [90],[91],[92].

Garcia et al. (2020) also note that, according to the SET Plan (2018) [94], only France, Spain, Italy and Cyprus have prioritized action in the MRE sector and allocated public funding, while only Italy and France have implemented government incentives in the form of feed-in tariffs.

Table 4 Summary of the main characteristics of MSP with an impact on marine energy use in Spain, Greece, Italy, Malta and Portugal. Source: Garcia et al., 2020.

Elements to analyze	Greece	Italy	Malta	Portugal	Spain
Maritime policy	There is no maritime policy. Several sectoral documents with strategic provisions relevant to the marine environment in areas such as tourism, aquaculture or marine renewables. Law 4546/2018 transposes D 89/2014/EU.	There is no maritime policy. According to Decree 201 of 2016, the MSP targets sustainable growth of the maritime economy, the sustainable development of marine areas and sustainable use of resources through the application of an ecosystem approach.	Development Planning Act (2016) aims the sustainable land and marine territory planning. According to the Subsidiary Legislation 552.27 Maritime Spatial Planning Regulations, marine planning will contribute, among others, to the sustainable development of the marine energy sector.	The National Ocean Strategy 2013–2020 includes MSP, the compatibility of activities (including the exploitation of marine energy resources) and the simplification of administrative procedures as being key operations.	There is no maritime policy, although there are relevant sectoral policies such as environmental policy. According to the RD 363/2017, the MSP aims to promote the sustainable growth of the maritime economy, the sustainable development of marine spaces and the sustainable use of marine resources.
Energy policy	300 MW of offshore wind in 2020.	55% renewable sources by 2030. The contribution of offshore wind is not quantified.	It does not consider the contribution of marine renewables for 2020, but for later periods (2050).	27 MW offshore wind and 6 MW wave energy by 2020.	750 MW offshore wind and 100 MW wave energy by 2020.
Institutions	The Ministry of Environment, Energy and Climate Change (YPEKA) is responsible for MSP. The appointment of a competent authority to design and implement MSP is envisaged. YPEKA is also responsible for renewable energy and energy policy.	The Ministry of Infrastructure and Transport (MIT) is responsible for MSP. The Inter-ministerial Coordination Board defines the guidelines for implementing MSP, and the Technical Committee is responsible for preparing plans. MIT also manages applications for offshore wind development.	The Planning Authority (PA) is responsible for terrestrial and MSP. Specific committee for the maritime space and a board for the granting of permits. Malta Marittima Agency promotes blue growth. The Ministry of Energy and Water Management manages energy policy and regulates renewables through the Energy and Water Agency and the Regulator for Energy and Water Services.	The Ministry of the Sea manages maritime affairs. The DGRM prepares and develops the Situation Plan. Island governments develop the plans for their adjacent areas. There is a commission to promote issues related to the marine environment. The Secretary of State for Energy is responsible for the authorization of installations of more than 10 MW. Below that threshold, the DGEG is responsible.	The Ministry of Ecological Transition exercises the competences of MSP. The Autonomous Communities have assumed competences in matters that take place in the maritime space. Sectoral platforms and inter-ministerial commissions for institutional coordination (e.g. Commission for Marine Strategies).
Strategic instruments	A National Strategy for the Marine Environment will be developed, as part of the National Spatial Strategy, with strategic guidelines and development priorities for the marine environment, and Maritime Spatial Plans at the regional level.	Management plans that will determine the spatial and temporal distribution of different uses in each of the three maritime areas identified. Possibility of identifying sub-regions.	Strategic Plan for Environment and Development (SPED) identifies a coastal zone (up to 12 NM) and a marine zone (12-25 NM). The renewable energy infrastructure should be enhanced in these areas as a means to reduce the impact on climate change.	The Situation Plan identifies potential areas, appropriate for certain activities, and exclusion areas where certain uses are prevented. Allocation Plans allow the former to be modified to include uses in areas not previously considered.	Maritime Spatial Plans that will define specific development targets for each marine demarcation, taking into account economic, social and environmental aspects.
Operational instruments	The State determines the location of offshore wind farms, the area occupied, and the maximum installed capacity in Spatial Plans approved by presidential decree at the proposal of the ministries responsible for economy, navigation, defense, culture and environment.	Single authorization for renewable offshore granted by the MIT, after approval of the ministries of economy and environment, obtaining the rights of use of maritime waters and examination of the Conference of Services. Necessary environmental impact assessment.	There is no specific procedure. Review of proposals in the process of control of developments of the PA. Larger facilities need permission to build via the Environment & Development Planning Act and approval of the PA. A license from the Continental Shelf Dept. is also required.	Title for the Private Use of the National Maritime Space (TUPEM), issued by the DGRM. In areas not designated for the renewable production of the Situation Plan, amendment is required through an Allocation Plan.	The Strategic Environmental Assessment of the Spanish Coast for the Installation of Offshore Wind Farms defines suitable, unsuitable and suitable areas with environmental conditions, depending on the degree of environmental impact of the offshore wind installations. There is a specific authorization procedure for marine installations for electricity generation in the territorial sea (RD 1028/2007).
Information and knowledge	Database of the Hellenic Marine Research Center with information on physical, chemical and biological parameters in the water column. Geoportal with information on renewable energy projects of the Energy Regulatory Authority.	Integrated MIT information system that supports MSP with social, environmental, economic uses and activities information. There are resources related to offshore wind potential (Interactive Wind Atlas), waves (ENEA) and oceanographic databases (Mediterranean Marine Data).	Geoportal with marine environmental information (PA). Malta Spatial Data Infrastructure allows for the exchange of geospatial data related to the environment. Database with geological information of the continental shelf for hydrocarbon exploitation (Continental Shelf Dept.).	Public online geoportal with reference information on the current use of maritime space (easements, conditions and elements of oceanographic characterization) and the Situation Plan.	Geoportal of Spatial Data Infrastructure of the Spanish Institute of Oceanography with oceanographic data. Atlas of wave energy potential (IDAE). Network of measurements with real-time information from Puertos del Estado.
Public participation	According to Law 4546/2018, MSP plans will have a public consultation, in addition to seeking the opinion of the National Council for Territorial Planning and the ministries involved.	Public participation during the preparation and environmental processing of the plans. Web with information about plans, consultation and follow-up phases is foreseen.	SPED was subjected to different rounds of public participation during its preparation. Malta Marittima Agency promotes dialogue between public and private stakeholders in matters related to the maritime sector.	Consultative Commissions to promote the agreement of multi-sector interests in the development of the POEM. System for resolving conflicts of the socio-economic impact of the project as the main criterion.	Meetings with stakeholders in the framework of the TPEA project. RD 363/2017 provides for public participation from the initial stages for the development of MSP plans.

5.2 Barriers to BE development in the MED

As anticipated above, one of the main difficulties limiting BE development in the Mediterranean is a lack of defined policies for blue energy at the national level, and a general lack of vision for the marine area that determines the national priorities for development of marine space [93].

The shortcomings identified in marine governance of the countries studied by Garcia et al. (2020) are also an obstacle for the blue energy industry. There are no competent bodies that bring together responsibilities related to maritime sectors, so management responsibilities for marine space and its uses are divided into different departments. This creates complex institutional frameworks that hinder decision-making processes and finally translate into confusing and inefficient authorization procedures [93]. Legal gaps and different competencies, at times also conflicting, among national and sub-national authorities have also been identified as barriers.

At the Mediterranean level, the existence of diverse national policies and regulatory frameworks in different countries represents another barrier to BE development.

Complex licensing and authorization procedures are an issue as well. There is an overall lack of knowledge about regulatory processes to be followed to obtain authorization to develop an MRE project. In addition, the procedures in most MED countries are complex, and this prevents the development of various initiatives, which would contribute to the emergence of a strong economic sector in the MED area [13].

Potential conflicts between BE and other sectors (e.g. coastal tourism, fisheries and aquaculture, MPAs, etc.) and issues on how to regulate these interactions while ensuring environmental sustainability are significant challenges.

Issues related to public acceptance may delay the authorization process and consequently commercial development. Social resistance to offshore installations has been growing in some local communities (e.g. along the Italian Adriatic shores). In fact, despite the documented widespread support of renewable energy exploitation, on several occasions local communities have opposed the installation of plants. The Not-In-My-Backyard (NIMBY) syndrome is probably responsible for this apparent contradiction between public acceptance at the local and national level, so that individuals are in favor of the proposed projects only if they are implemented outside their own community [95].

Key challenges affecting the blue energy sector in the Mediterranean have been identified in the framework of the PELAGOS project [96]:

- **Scale-up** from demonstration (pre-commercial projects) to viable commercial projects.
- **Technology costs** - Technology costs are currently high and access to funding is difficult. Most the existing technologies and especially those related to ocean energy still need to demonstrate their reliability and viability in the marine environment. The cost of generated electricity is therefore currently high.
- **Demonstration of devices at sea** is costly and risky and SMEs are often short of the necessary resources to deploy their prototypes.
- **Large-scale deployment** - There is a need for continued technology push mechanisms and market-pull support schemes as well as large-scale deployment.

- **Critical mass of key actors** - The marine energy community needs to acquire a sufficient critical size including all the key stakeholders such as business, academia and research. This also requires information exchange and coordination efforts among the actors.
- **Technological Risk** – For now, utility scale projects may be deemed 'too risky' in the current economic and political climate. The current deployment pathway seems to be taking a technological jump that is larger than investors are able to or wish to support.
- **Complex licensing and authorization procedures** – At present there is a lack of design consensus, particularly for wave energy technology, yet the wave and tidal sector does not have the significant market demand to support the generation of tailor-made solutions for each application or site. Uncertainty about the proper application of environmental legislation may further prolong them.
- **Grid access** – In some cases, the lack of secured access to grid connection points is a significant barrier. Grid connections to onshore grids and thus centers of demand can also be problematic, as in some cases the grid cannot absorb the electricity from wave energy production. Moreover, other infrastructural issues including insufficient access to suitable port facilities and the lack of specialized vessels for installation and maintenance also need to be addressed. For example, the Maghreb region's (COMELEC - Comité maghrébin d'électricité) immediate plans are mainly focused on expanding energy trade and transmission lines with Europe. The regional integration efforts are intimately related to the development of renewable energy as Europe has stronger commercial incentives for this industry [107].
- **Economic impact** – There is a need to bridge the gap between the expectations of investors and those of technology developers. Expectations need to be aligned with realistic deployment trajectories that are within the capabilities of technology developers and with appropriate funding, whether through public or private funding.
- **Environmental impact** – Some in the sector feel that legislators are over-cautious when formulating environmental legislation and call for greater flexibility. Also, when it comes to deployment, coastal management is key to regulating potential conflicts over the use of coastal space with other maritime activities (e.g. fishing, shipping lanes etc.).

The following weaknesses and threats have also been identified:

- **The delay of the Mediterranean companies involved in MRE in general compared to companies in northern Europe**: The cause is principally due to the more favorable natural characteristics (wind, waves, etc.) in Northern Europe except for the offshore wind industry: the floating offshore wind industry has only started in MED Sea through demonstration projects.
- **"Local" supplies (in the sense of supplies by workshops in the Mediterranean) in the value chain make sense only if they are competitive.** It is therefore necessary for Mediterranean companies to compete on bricks which are priorities in the markets for MREs.
- **Competitiveness priorities identification in MRE technologies are essential in all initiatives.** These priorities are identified from the priority of the markets: reducing the Levelized Cost Of Energy (LCOE) of these energies is key (in this regard, see the projected decrease in Capital and Operating Expenses for MREs, foreseen for the Mediterranean, Figure 23).

- **Financial crisis and poor funding are also important issues that should not be neglected.**

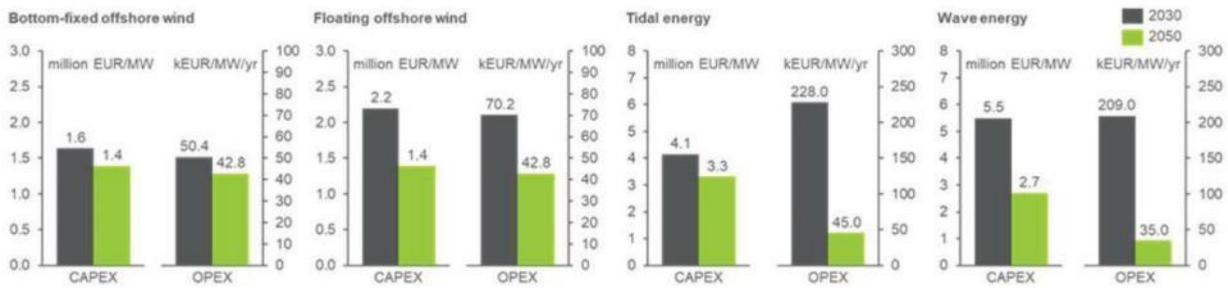


Figure 23. Projected decrease in Capital and Operating Expenses (CAPEX/ OPEX) for Marine renewables (offshore wind, energy and wave). Source: DG-Energy, Guidehouse Netherlands, SWECO (2020) [108]

Specific barriers at country level

The PELAGOS project (2019a) [27] analyzed gaps for BE development at a national level for the following countries: Greece, Croatia, Spain, Italy and Cyprus.

In **Greece,** blue energy may be combined spatially with other marine uses in a sustainable way, offering a number of opportunities for blue growth. Effective MSP is necessary in determining which other marine uses could be compatible or not with BE considering technical, economic, environmental and social factors. It is important to define the design criteria and the location of zoning for BE installations in marine spaces. Combinations of BE types or co-location of BE and other human activities have, in theory, the potential to offer: (1) Environmental savings in the use of space; (2) technical savings in the sharing of infrastructure, equipment and resources; (3) economic savings in the sharing of development, O&M costs and risks; (4) social savings in skill transfer and job creation as well as impact mitigation.

The following gaps are still relevant:

- BE is not a mature type of renewable energy when it comes to technological development and commercialization.
- The BE policy framework of BE needs to become more robust and specific as the existing framework lacks criteria and processes and faces regulatory challenges related to uncertainties regarding permitting.
- Acceleration of MSP in order to avoid conflicts and foster synergies with other human uses.
- Modification of the Act L. 3851/2010 as it impedes the submission of permit applications for OWFs and it refers only to fixed bottom wind turbines without considering the use of floating wind turbines.
- Definition of the exact role and type of authorities involved in the licensing process for OWFs regarding the complicated issue arising from defining the seashore and designating its boundaries (L. 2971/2010) that affect the interconnection of several projects.
- Deployment of a pilot project in order to clarify the obstacles and shortcomings in practice. The project will consider the data collection of several parameters, and monitoring of the installation site during the different phases of the project.

- Consideration about territorial waters and the Exclusive Economic Zone in Greece for the potential exploitation of wind energy.
- Micro-sitting analysis of the offshore project in order to assess the environmental impacts during all phases (pre-construction, construction, operation).

For **Croatia**, a comprehensive approach to blue growth is lacking. This requires that the blue economy be introduced into the strategic documents, while simultaneously entails adjustment of legislation to be in accordance with it. Introduction of a blue economy is especially important for strategies related to innovation and research activities, while legislative change is mainly focused on marine spatial plans. The following gaps are identified:

- Lack of strategy related to the blue economy or blue growth
- Unclear marine spatial plans and Physical Planning Act
- Inconsistent and unclear Maritime domain and Seaports Act (maritime law and seaports)
- The absence of the blue economy concept in RIS3 strategy
- Lack of funds which could foster innovation and research in the blue economy.

Since the blue economy is not officially recognized as a sector, there are no national or government funds allocated for investment in this area. Furthermore, since the blue economy is not presented in any strategic development documents, project ideas related to blue growth are often not in the scope of tenders. Funds need to be allocated with the specific goal of fostering innovation and research to achieve blue growth. If this is not applicable, public authority should, at least, include the blue economy concept into a strategic document. This would enable the submission of the project ideas from this sector with an equal opportunity to be funded as project ideas from the other sectors.

Administrative processes are complex and the legislative framework is flawed in many ways. There is a lack of workflow documents which would simplify the procedure to obtain needed permits. Different public authorities have jurisdiction over different project parts. This often creates confusion and inconsistency in practice, which results in significant delays or investor withdrawal from the project. Lastly, different initiatives can block the project implementation at any stage, even if investors have prepared all the needed documentation. Authorities should keep detailed workflow documents with an overview of what is needed to obtain authorization. Moreover, they should establish a central authority where all communication between potential investors and public officers will be made, and which would be in charge of relaying communication between relevant public authorities.

Maritime spatial planning needs to be carried out. In order to maximize economic benefits and avoid negative environmental impacts for each sector, the operational and multiple-use spatial planning system is used. The objective of this type of plan is to incorporate all planned or potential activities into an integrated map while respecting environmental preservation, public acceptance, and economic viability.

In **Spain**, planning, licensing and environmental permitting needs to be improved to speed up project delivery. Obtaining authorization for an ocean energy project can be time-consuming and costly. Authorization processes need to be tailored and proportionate. A risk-based approach to ocean energy licensing, using the findings from existing studies and deployed projects, should be used. Strategic research should also be initiated to address knowledge gaps and more efficient decision-making. Licensing should also consider the size, socio-economics and environmental context of projects and devices to ensure small-scale projects are not overburdened with irrelevant procedures. Good practice suggests that a one-stop-shop approach to licensing is preferable. Relevant planning and licensing authorities are required to de-risk environmental licensing through an integrated program of measures that will develop guidance on planning, licensing, research, socio-economics and demonstration. This guidance will ensure that best practice and experience in approving ocean energy projects is shared and used to improve and streamline processes.

In **Italy,** the primary gaps relate to regulatory and licensing frameworks and a lack of stable national funding programs. The first two issues are deeply interconnected. Considering the current TRLs of many devices, easy access to deployment in real sea conditions is crucial to test the performance, reliability and viability of the devices, with all elements concurring to the definition of the energy yield. Currently the authorization procedure is based on a single authorization (Autorizzazione Unica), issued by a single authority. However it must undergo a complex administrative process designed to ensure the involvement and coordination of all the authorities and administrative bodies that represent and protect the various public interests involved. In practice, the total authorization process takes at least one year to several years. This kind of timeline is hardly compatible with the requirements of research projects and small-scale testing activities, and specific actions are required in this regard. Despite Italy's scientific achievements, its progress in the ocean sector in terms of industrial roll-out of devices is still underrepresented at the European level. This is partly due to insufficient national investments, which often impairs the participation of Italian actors in co-funded EU programs.

Enabling conditions for BE development in Italy include:

- Legislative and financial instruments. Targeted national policy actions and investment, together with high-skilled job creation can promote strategic positioning of the Italian industry in the competitive global market. Public investments in the form of grants and/or targeted research/operative plans are at this point decisive in boosting the switch from technology push to market pull.

- Modify current permitting and licensing procedures for ocean energy projects. The current regulation on this matter is a complex administrative procedure. The uncertainty of the outcome of the authorization process is also a deterrent for investments in this sector.

- Provide stable funding opportunities. Stable funding is crucial to promoting new technologies. Public investment should be considered for less mature technologies, while public-private partnership would be suitable for mature technologies.

Cyprus. Enabling conditions for BE development include:

- Introduce effective licensing procedures for MRE projects. According to the national MSP currently under development (Section 22), approval of an activity to be executed in the marine waters of Cyprus involves the following procedures: (i) licensing procedure for a maritime activity which is regulated under existing legislation (Section 23); (ii) licensing procedure for a maritime activity which is NOT regulated under existing legislation (Section 24).

- Due to considerably more bureaucratic procedures, it is indeed significantly more time consuming to issue a confirmation of compatibility rather than a confirmation of compliance. To that end, and in order to accelerate the development of the MRE sector, an effective licensing procedure dedicated to MRE projects needs to be adopted and implemented in Section 22 of the MSP law of Cyprus.

- It is also very important to facilitate testing and development of BE technologies. It is therefore essential to implement a provision in Section 22 of the MSP law for direct permission of testing and development of MRE projects with efficient and effective procedures.
- Adopt support schemes dedicated to BE projects. In the context of Law N 33 (I)/2007, a special fund was created for the promotion of Renewable Energy Sources (RES) and energy conservation. The aim of the special fund is to subsidize and support RES and energy efficiency investments in Cyprus. The special fund subsidizes or awards grants for the following major activities: (i) Production or purchase of energy from RES; (ii) actions to promote RES, energy efficiency and to raise public awareness. However, the country's promising legislation for the BE sector has no provision for any form of subsidization or support. Unfortunately, the BE sector is not included at all in the aforementioned legislation. It is therefore mandatory, for an island like Cyprus, to provide effective support and subsidies in order to accelerate the development of the BE sector and contribute significantly to the national targets on renewable energy in the forthcoming years.

Good practices at country level

The MAESTRALE project prepared a regulation and funding framework database [87] that is present across eight countries: Italy, Spain, Croatia, Greece, Slovenia, Cyprus, Portugal and Malta. Several examples of good practices can be highlighted.

Italy. *Incentive for electricity produced from renewable sources, other than photovoltaic energy. Decree of the Ministry of Economy, 23 June 2016.*

The Decree has the purpose of supporting production of electricity from renewable resources by defining incentives and simple access procedures, to promote effectiveness, efficiency and the sustainability of incentive burdens, following the objectives set out in the National Energy Strategy, as well as the gradual adaptation to the relevant Guidelines on State aid for environmental protection and energy issued in the Communication of the European Commission (2014/C 200/01). Offshore wind plants are among the renewable resources that benefit from these incentives. At the national level, the Decree provides for the new support scheme for renewable energy. In general, it grants a fixed tariff, and in some cases, a specific premium, to provide incentives to net electricity fed into the grid. The fixed tariff is different for each source, technology and capacity range considered. Research and demonstration projects could be supported with horizontal R&D support schemes, but no special framework is available at this time.

Italy. *Streamlining and simplifying authorization procedures for renewable energy resources. Note (Circolare) of 5 January 2012.*

The note provides specific guidelines for obtaining authorization for renewable sourced power plants. Regarding the installation of RE plants, this document uses the same authorization procedure for offshore plants under other non-specific legislation i.e. environmental impact evaluation (ref. laws 152 dd. 3/4/2006 and 99 dd. 23/7/2009), maritime concession (ref. Italian Maritime navigation Code), building and operation permits (ref. laws n. 387 dd 29/12/2993 and n. 244 dd. 24712/2007). The procedure is simplified by the application of Law 241 dd. 7/8/1990, which provides for a single reference authority for the authorization procedure. It is in charge of organizing a conference of all the national, regional and local entities required to grant authorization with reference to the above-mentioned legislation.

Italy. ***Regional Law 17/2016 concerning SEA and EIA procedures. Regione Toscana Law 4 March 2016 (LR 17/2016) and 12 February 2010 (LR 10/20).***

According to a note (p. 6) in the guidelines, EIAs for offshore wind systems (the only BE mentioned) are under national authority. These guidelines refer to on-shore wind systems >1MW but these also concern offshore wind systems as guidelines to deliver preliminary assessments by Regions to inform National Authorities.

Spain. ***Regulation of the activity of production of electrical energy in special regime. Real Decreto 661/2007 of 26/05/2007.***

The Decree suspended remuneration procedures and abolished economic incentives for new electric power production facilities, aiming at fostering the development of renewable energies through co-funding provided by the government.

Spain. ***Administrative procedure for requesting authorization to implement generation facilities in the Spanish sea. Real Decreto l 028/2007 of 20/07/2007.***

The purpose of this law is to regulate procedures and establish the conditions and criteria for obtaining the necessary administrative authorizations and concessions for the construction and expansion of electricity generation facilities. If the power capacity installed does not exceed 50 MW (before 10 MW), this law does not apply, as it is considered that it is pointless to deploy a wind farm with less power than this, and therefore, these power capacities are typically associated with demonstration projects.

Croatia. ***Act on Renewable Energy Sources and High-efficiency Cogeneration. Official Gazette 1 00/2015.***

This Act regulates planning and encouragement of production and consumption of energy produced in facilities which use renewable sources of energy and high-efficiency cogeneration, government support for renewable energy, international collaboration in renewable energy, managing the registers of renewable sources of energy for projects, project developers and privileged producers. The act applies for all types of renewable energy sources.

Croatia. ***Decree on Subsidies for Renewable Energy Sources and Highly Effective Cogeneration, Official Gazette 87/2017.***

This Decree determines the amount of subsidies for renewable energy sources and high-efficiency cogeneration, in accordance with the Republic of Croatia's strategic objectives related to the share of renewable energy sources and cogeneration in total electricity consumption, taking into account the state of the energy market of the Republic of Croatia and the costs of electricity production from production plants using renewable energy sources and high-efficiency cogeneration plants. It should be consulted during financial planning of renewable energy projects and investments.

Croatia. ***Tariff system for the production of Electricity from Renewable Energy Sources and Cogeneration, Official Gazette 133/20l 3.***

This Tariff System for the Production of Electricity from Renewable Energy Sources and Cogeneration determines the subsidy amount for electricity produced in a production plant using renewable energy sources and a cogeneration plant or delivered to the power grid, which the market operator pays to the privileged electricity producer and the conditions for obtaining an incentive price. It is applicable to renewables. There is no mention of "blue energy" in particular.

Greece. ***Special Framework for Spatial Planning and Sustainable Development for Renewable Energy. December 3, 2008, 49828 (2464 B/03.12.2008).***

The Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources comprises text and charts that specify or supplement the guidelines provided by the General Framework for Spatial Planning and Sustainable Development.

Its main goals are (a) the formulation of siting policies for renewable energy production units according to type of activity and area, (b) the development of rules and siting criteria that will allow for the creation of viable renewable energy infrastructure, ensuring at the same time their harmonious integration to the natural and human environment, and (c) the creation of an effective mechanism for the siting of renewable energy installations, so that national and EU objectives are met.

The Framework contains specific provisions for the siting of wind farms, small hydroelectric plants, solar farms, biomass/biogas plants and geothermal power plants, as well as an action plan with institutional and administrative measures.

Article 10 of the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources sets special criteria for the siting of wind farms in marine areas and uninhabited islets. With regard to the former, it is provided that the wind farms are allowed to be sited in marine areas where wind power can be extracted and are not under any special institutional status that prohibits the deployment of wind turbines or are not a no-go zone, such as marine parks or shipping lines.

Minimum distances are set in order to ensure the functionality and efficiency of wind power installations. The deployment of wind turbines is prohibited within 1500 m from coasts included in the swimming water quality monitoring program of the Ministry of Environment and Energy, as well as in bays with a mouth width of less than 1500 m. Minimum distances from areas and elements of cultural heritage, agglomerations, and production areas are also set. It is provided that the depth of the foundations or tethering of the wind turbines is defined by the available technology and the respective static and dynamic assessments. Furthermore, adequate connection to the grid and transportation of the generated power should be ensured upon the construction of the wind farm. Finally, the Special Framework includes specific provisions regarding the protection of the landscape.

Article 20, concerning the siting of facilities for new forms of renewable energy, provides that, for the definition of siting criteria for these new forms, including those that are still in the experimental stage, such as energy from the sea (wave power etc.), relevant studies will be carried out within the framework of the action plan that accompanies the Special Framework.

Greece. ***Special Framework for Spatial Planning and Sustainable Development for Aquaculture November 4, 2011, 31722 (2505/B/04.1 l .2011)***

Minimum distances from other types of activities are set. As far as offshore wind is concerned, it is provided that the distance between an aquaculture unit and a wind farm is dictated by the ethological needs of the farmed fish.

It recommends avoiding the siting of offshore wind farms within Areas of Organized Development of Aquaculture. In all other areas, wind farms should be located at least 500 m from functioning aquaculture units. The siting of aquaculture units is prohibited within areas used for the installation of cables or power transfer pipelines. Finally, the production of power from renewable energy sources in order to meet the needs of Areas of Organized Development of Aquaculture or single units is encouraged.

Greece. ***Renewable energy sources to address climate change. Law of June 4, 2010, 3851 (85 A/04.06.2010).***

With Law 3851, an effort is being made to further simplify and shorten the licensing process for new RES projects. It addresses individual steps and removes others. In particular, it provides for direct licensing by the RAE, as well as the establishment of binding and shorter deadlines for public administration.

- Reduce bureaucratic procedures from 36-60 months to 8-10 months: set up an independent authority under the Ministry of the Environment to promote RES investments in the form of a one-stop shop.
- Licensing will be separated from the environmental conditions and will henceforth be part of the second phase. RAE must grant the production license within two months of the submission of the application. Facilities with limited production capacity are excluded.
- The two phases that formed the previous environmental process are integrated into one process

Slovenia. ***Public call for loans for funding environmental investments in local communities 15th April 2016 (Off. Gaz. RS 28/16).***

In Slovenia, various public calls of this type have been launched with the aim of promoting environmental sustainability and contributing to the reduction of CO_2 emissions. Also, installation of systems for heating, cooling and domestic hot water preparation can be supported under this public call for loans. In the case of blue energy — water/water heat pump is supported. Another option for loans is the installation of electricity production power plants/devices. Offshore wind power shall be considered as a blue energy source for electricity production. In some cases, electricity production in connection with sea water (sea current, tidal, wave) can also be part of the public call for loans application, but case to case approval is needed.

Cyprus. ***Promotion and Encouragement of the utilization of RES. N.I 12(I)/2013 n.4405, 20.9.2013 amendments in 2015***

Under the Cyprus Directive 441/2013, a special fund was created in 2013 for promoting and encouraging the utilization of RES and for energy conservation.

The Special Fund subsidizes or awards grants for the following activities:

- Producing or purchasing energy from RES,
- Installing, equipping and other activities involved in Energy Conservation (EC), Energy Savings and Energy Efficiency,
- Programs to promote RES, energy efficiency and combined heat and power, as well as programs to raise public awareness.

It covers small-scale investments relating to:

- Small wind systems for power generation up to 30kW
- Solar systems
- Photovoltaics systems

- Desalination with RES
- Electricity from RES
- Small hydroelectric projects on rivers and streams

And large-scale investments relating to:

- Large wind power systems
- Large commercial PV systems from 21 to 150 kW, connected to the grid
- Large commercial solar thermal systems connected to the grid
- Utilization of biomass and biogas from landfills.

Malta. National Energy Strategy 2012 https://enerqyvvateraqencv.gov.mt/en/Pages/The-NationaI-Energy-PoIicv- for-the-Maltese-Islands.aspx

The Energy Policy addresses complex, shifting, and multiple objectives, the most important being:

- Energy efficiency and affordability
- Sustainability
- Energy security
- Diversification of sources
- Flexibility.

Given that Malta has committed itself to supply 10% of its final energy consumption in 2020 from RES, the Policy defines 6 Policy Priority Areas: (1) Energy efficiency; (2) Reducing reliance on imported fuels; (3) Security of supply; (4) Reducing Emissions from the energy sector; (5) Delivering energy economically efficiently and effectively; (6) Ensuring the energy sector can deliver, along with a number of recommendations/measures to undertake in order to achieve this target.

The following recommendations/measures defined within the Policy directly and indirectly regard marine RES:

- Design public-private investments and public-private investment schemes respectively for large RES projects such as the near offshore wind farm

- Ensure there are stable and transparent incentives/regulatory framework

- Identify onshore and offshore sites (at least one in transitional deep water and one in very deep water) to undertake technical and environmental studies that would eventually be required for authorizing RES projects at such sites. Initially, non-technology-specific baseline studies will be conducted. Technology-specific studies will be conducted at a later stage, once the most appropriate technology has been identified. Environmental impact assessment will be carried out at the earliest appropriate time so that the process leading to the issuance of permits for the development of such farms is streamlined as much as possible.

- Design a legal and financial framework to support marine-based RES solutions, thus removing any ambiguities in Maltese Law

- Direct R&D&I research to Malta’s strengths: solar and marine based technologies (including wind).

5.3 Overcoming barriers: recommendations for BE development in the Mediterranean

Acceleration in the Blue Energy industry has been witnessed globally in regions where deployment targets are coupled with public support for research and development. To maintain this momentum, governments need to lead the way and provide the enabling conditions to accelerate the development of the industry, reducing long-term uncertainty and market risk, and potentially mobilizing private sector capital [97]. Research & Development needs to continue for all relevant BE options, to ensure that subsequent breakthroughs remain possible. In addition to relevant policy mechanisms, incentives schemes and financing options, governments at both the national and international level also need to come up with binding targets, establish an appropriate framework and ensure that policies for marine-based renewable energy technologies are implemented effectively.

All players in the marine-based renewable energy sector have a role to play to ensure that they proactively maintain and bolster civil society acceptance. The birth of a policy community involving technology developers and marine industry, and intermediate levels of decision-making is now necessary to foster the necessary positive environment for the development of BE innovation activities, enhancing synergies among participants [2],[98],[99]. Closer collaboration between all the relevant stakeholders and more constraining targets would in fact foster market acceptance of the technology and be an effective catalyst for innovation and identify existing potentialities [100].

Governments especially need to undertake proactive strategic marine planning to offer concessions in areas with lower risk to ecologically sensitive areas and promote synergies with other marine users [97].

In the Mediterranean, notwithstanding the gaps and barriers described above, the blue economy is recognized as a strategic asset for sustainable development in the region [82]. In order to boost development potential, targeted actions have to be put in place. They are summarized below, according to some main action areas.

Maritime and energy policy. The general EU and national context is favorable to fostering the development of BE. This should be even more streamlined, particularly into climate change mitigation policies [104]. National governments should adopt clear and consistent maritime policies to firmly define national priorities for the future development of marine areas. These policies should reflect specific objectives aimed at the deployment of BE as a means to reduce national carbon footprints and achieve clean energy production goals. For example, The Dutch North Sea Policy Document 2016–2021 [89].

The important environmental benefits of BE need to be highlighted in emerging and future policy, especially with respect to climate change mitigation. The recent recast of the EU Renewable Energy Directive explicitly mentions the need to "*Take into account the contribution of energy from renewable sources towards meeting environmental and climate change objectives*". Governments should provide a clear view on their capacity goals, project pipeline and supporting policies in their National Energy and Climate Plans (NECPs) to 2030 and beyond, as well as within the context of MSP and the emerging national and sub-national Marine Plans. National marine spatial plans should be aligned with the objectives of the NECPs. These plans should be coordinated at the international level, and decisions should be coordinated at the Mediterranean level to optimize the use of marine space [101].

The legal and regulatory frameworks for energy, to be based in the Paris Agreement, need further development to attract private investors, particularly in North Africa and the Western Balkans. Although there are binding targets for renewable energy in most countries, their effective implementation is still uncertain [102].

Legal issues should be carefully taken into consideration, specifically the navigational rights of foreign flagged vessels. States developing offshore BE infrastructure should therefore ensure the preservation of navigational rights as granted under international law. As marine-based renewable energy farms often create *de facto* no-fishing, no-navigation and no-trawling areas, this highlights the need for developers to proactively engage with other stakeholders for the development of marine renewable energy. Furthermore, in cases where maritime zones overlap, governments need to cooperate with neighboring states [103].

Marine spatial planning and other strategic instruments. ICZM and MSP can be used to accelerate BE development by identifying potential areas for MRE development and ensuring co-existence with other economic sectors (multi-use opportunities). National and European regulators could also work on defining ways of solving potential conflicts about use of maritime space. In countries where the MRE sector is not as mature, it would be useful to proceed with mapping and characterization of concessions areas, also in the framework of the national MSP process [104].

Approved marine spatial plans, supported by an appropriate legal framework (law, acts, etc.), should help establish specific areas for the development of renewable energy activity (ocean zoning) [89]. The spatial and time scales of these plans should be adjusted to the characteristics of the marine area. Marine plans should foresee tools that help with flexibility, e.g. multi-use areas, co-location, etc., with the capacity to adapt to technological advances in the field of BE that are anticipated in the short-medium term, such as floating OWFs or commercial wave and tidal devices [89]. Specific instruments should be provided to enable proper coordination between land and marine planning. Cross-border cooperation mechanisms with neighboring countries (EU and non-EU) should be used to allow for concerted action to drive blue energy activity. Pilot areas to test BE pilot devices should be established with the aim of fostering the development of research and demonstration projects in pre-commercial phases (e. g. Galway Bay Test Site in Ireland) [89].

Analysis of potential BE co-activities for designing integrated multi-purpose platforms that can serve both energy and other maritime sectors is recommended, combining green energy production and storage (hydrogen, etc.) with aquaculture, fisheries, other energy sources and defense activities. Exploration and promotion of the coexistence of wind farms and protected natural parks, exploiting the potential of wind energy for restoration and conservation purposes should be undertaken. The possibility of combining natural sanctuaries with energy sanctuaries should be explored so the MPA can also become a renewable energy generation reserve when possible [101].

In summary, it is recommended that MRE development be facilitated through MSP by:

- accelerating MSP and ICZM at the regional/local level in order to establish a holistic approach to management of marine, maritime, and coastal activities in the ocean space
- making use of the MSP process and emerging/future Marine Plans to minimize conflicts and regulate co-existence between ME and other economic sectors (e.g. transport, fishing or tourism)

- fostering multi-use opportunities deriving from joint use of marine space by different MRE types or by MRE and other maritime activities (e.g. aquaculture, fisheries, tourism).

Governance. It is needed to improve coordination and cooperation between authorities responsible for marine planning and renewable marine energy, as well as between different levels of governance. This could be achieved by granting existing authorities with new responsibilities (e.g. IDON[17] in the Netherlands or BSH[18] in Germany) or creating institutions such as the Marine Management Organisation in England, created specifically to facilitate coordination and avoid the adverse effects of fragmentation of maritime governance [89]. Regarding the fragmentation of governance, the system of inter-administrative committees adopted in some countries can partially solve the problem of institutional fragmentation by improving the horizontal coordination of sectoral policies (including that related to MRE). This will help avoid overlaps between the authorities involved and contribute to integrated action in the marine environment (Guerra, 2018). In any event, greater integration between different areas of government, as well as between the different levels of administration, is desirable. This is especially true in countries such as Spain, where there is a high degree of decentralization, resulting in regional governments also having certain responsibilities in energy and spatial planning [93]. In the case of wave energy, with devices installed in areas close to shore, coordination between land and marine management will also be a determining factor for the success of these types of projects [93].

Funding and investments. Policy also has a key role in the development of a promising, fertile environment for MRE investment. The recent economic climate resulted in several governments scaling back financial support for MRE, a condition that stalled the MRE sector's further development and lengthening the timeframe for major projects. It is therefore crucial to ensure financial support for the sector at all stages of development. Giraud et al. (2017) have highlighted the need for investment in the green and blue economy. Traditional and innovative financial instruments and tools provided by Multilateral Development Banks (MDB), the private sector and national financial institutions need to be environmentally oriented to promote sustainable economic activities, including MRE.

In addition, as there is still no level playing field with conventional energy, support schemes for the deployment of renewables are required. For instance, direct and indirect fossil fuel subsidies persist in many countries. Funding and subsidies to the carbon economy could therefore be eliminated. Several key sub-sectors of the marine-based economy (fisheries, transport, tourism, etc.) are artificially supported by environmentally harmful subsidies that create market distortion, privatize economic benefits and externalize social and environmental damages [105]. An exhaustive assessment of price signals in the blue economy sub-sectors needs to be undertaken to phase out "brown" incentives and instead promote greener tax and fiscal policy reforms.

Green incentive mechanisms should follow to support policy implementation. To be most effective, they need to be tailored to the development stage of each respective technology. Incentive mechanisms include [97]:

- *Subsidies*: direct subsidies are particularly effective in early stages of market diffusion. They include investment support and grants to reduce capital costs and operating support.
- *Taxes*: taxes can be used as an alternative to or in combination with subsidies. Tax revenue from

[17] North Sea Interdepartemental Consultation Directorate

[18] Federal Maritime and Hydrographic Agency

fossil fuels or a carbon tax can be redistributed to marine-based renewable energy sources. Additionally, developers of these technologies can benefit from tax exemptions from general energy taxes, or for initial investments.

- *Performance based incentives* or *feed-in tariffs*: feed-in tariffs (FITs) usually take the form of either a fixed price to be paid for renewable energy production or an additional premium on top of the electricity market price paid to RES-E producers. FITs allow technology-specific promotion, as well as an acknowledgement of future cost reductions by applying dynamic decreasing tariffs.

To develop BE in the Mediterranean, substantial and stable public investment is required to commercialize the industry with the objective to reach a production cost of €50 to €60 per MWh to be competitive with other current energy sources (nuclear, land-based renewables (solar/ wind)) [13]. Public commitment will stimulate private investment and foster long-term investors' confidence for the future of the marine energy industry in the Mediterranean. The countries in which investments were first and most important (Germany, Netherland, Denmark, the UK and more recently France) have changed their legislation to facilitate investment in offshore wind farms. This change is mainly about reducing risk for investors. This de-risking is based on the fact that the public authorities give the tender specifications full knowledge of the initial states (soil, wind, environment, etc.). Thus, investors do not take a margin for risks. As BE are at different stages of development, these investments are expected to provide funding from the early stage for devices, pilot tests, large scale demonstrators and commercial farm installation (for example, in France, the cost of each 24 MW pilot project is over €220 M; the state subsidy is nearly €75 M).

Governments should ensure visibility and confidence in funding volumes and mechanisms. Competitiveness should be promoted through designing income stabilization models and auction mechanisms. Other mechanisms should be updated for selling energy and grid services nationally to provide stable revenue. Setting up a large-scale public financing platform with the support of the main European and African development banks to have a pool of collective projects (notably offshore wind turbines or floating energy) has been also suggested [101].

Access to funding should be facilitated. Key European financial institutions (e.g. European Investment Bank, European Bank for Reconstruction and Development) could cooperate to develop a "Mediterranean Renewable Energy Infrastructure Fund" aimed at channeling financial resources or bonds from institutional investors to renewable energy companies in the region, for solar and wind energy projects [102].

Time is needed to decrease the production price as the experience curve demonstrates (Boston Consulting Group): "a company's unit production costs would fall by a predictable amount—typically 20 to 30 percent in real terms—for each doubling of "experience," or accumulated production volume". The cost of offshore wind production has significantly decreased in recent years, reaching a levelized cost of energy below 50 EUR/MWh. For floating technology, a cost reduction is expected due to technical improvements, e.g. using concrete instead of steel for the substructure, and mass production. Other ocean energy technologies may see technological breakthroughs in the years to come [102].

In summary, to ensure financial support for all phases of MRE development, the following is recommended [110], [13]:

- Providing stable mobilization/allocation of public funds/resources for all stages of research, preventing the loss of accumulated knowledge

- Optimizing the use of funds for the MRE sector and concentrating efforts on a limited number of promising technologies;
- Putting in place incentive policies, notably through launching calls for tenders to finance the construction of BE parks.

A relevant example of effective instruments available to ensure financial support for MRE development are the Climate Bond Initiatives. Among the initiatives promoted, the Climate Bonds Standard and Certification Scheme is a labelling scheme that examines and certifies bonds and loans that are consistent with the 2 degrees Celsius warming limit in the Paris Agreement. The Scheme is used globally by bond issuers, governments, investors and the financial markets to prioritize investments which genuinely contribute to addressing climate change. Specific Marine Renewable Energy Criteria are available for certification.

The following EU funding instruments can play a strategic role in the roll-out of offshore renewable technologies[19]:

- The InvestEU program can provide support and guarantees for emerging technologies to accelerate private investment through its different windows.
- The Connecting Europe Facility can be used as a supporting instrument to promote grid infrastructure development, as well as offshore cross-border renewable energy projects.
- As of 2021, the Renewable Energy Financing Mechanism allows Member States to provide financial contributions to renewable energy projects and receive statistical benefits in return.
- Horizon Europe supports development and testing of new and innovative solutions.
- The Innovation Fund under the EU Emission Trading System (EU ETS) can support the demonstration of innovative clean technologies at commercial scale, such as ocean energy, new floating offshore wind technologies or projects to couple offshore wind farms with battery storage or hydrogen production.
- The Modernisation Fund under the EU ETS will also be available to support the development of offshore renewable energy in the 10 eligible Member States.

Authorization procedures. The procedures to implement MRE pilots (connected or not to the grid) and obtain authorizations such as permits, licenses, or other forms of permission should be simplified, explained and promoted to BE project developers [13].

Unnecessary bureaucracy should be removed and coordination between licensing authorities should be improved to reduce authorization deadlines. In this sense, licensing should be tailored to the needs of BE generation activities. A single online system for project promoters following the example of Scotland should be introduced. The best designation methods for specific marine renewable energy zones should be selected according to national marine area characteristics and clean energy objectives: "open door" procedures for large marine areas allow industry to develop their own business (e. g. UK); and "calls for tenders" for short term marine energy developments in smaller sea spaces with high concentration of uses (e. g. The Netherlands) [89].

[19] From: Questions and Answers on the EU offshore renewable energy strategy

In synthesis, it is recommended to ease authorization procedures:

- Ensuring coordination of all authorities and bodies that represent various national public interests (environment, landscape, cultural heritage, etc.)
- Providing instruments to accommodate very different legal obligations arising from domestic, EU and international policies.

Public participation and social acceptance. Policy is recognized as a key enabler for overcoming BE social acceptance issues. Especially in the Mediterranean, public support has been recognized as a crucial factor for BE development, as demonstrated by the examples of relevant projects being postponed due to public opposition. As such, policy should play an active role in supporting local involvement and set forward sound consultation procedures. BE stakeholders also stress the need for sub-national, local administrations to be more actively engaged in the process [101].

It is key to ensure early stakeholder involvement though transparent information procedures and effective participation mechanisms. Additionally, the participation of key actors during the marine plan implementation stage should be promoted. Stakeholder integration processes for offshore energy, with special focus on participation in sensitive sectors (such as tourism or fishing) should be ensured. Synergies should be encouraged (e.g. offshore wind farms co-located with aquaculture). Additionally, multi-sector development scenarios should be considered for stakeholder integration. Specific tools to manage conflict and improve the acceptance of local communities should be put in place [101].

Social acceptance of BE should be tested and resistance to it explored. Society's concerns should be taken seriously and decisions should not be imposed. Challenges associated with BE should be presented transparently and proper solutions to address them should be sought in accordance with social views. Cooperation between companies and local communities and systems of external “management auditors” could greatly facilitate these approaches which are most needed for making the Mediterranean an important source of clean energy. Sub-national, regional and local administrations should be more actively engaged in the consultation process prior to the development of BE projects and be allowed to participate in final decision-making while evaluating true socio-economic impacts on local communities and the environment [101].

It is important to implement a multidisciplinary effort in public debates about BE proposals, in a context of a mature participatory decision-making process that weights the social and economic impacts of development and conservation. The relevant policies should deal with the problem of social acceptance of MRE projects. Therefore, the contribution of government support should produce highly educated citizens. Information campaigns and training platforms must be designed in an attempt to increase awareness about the benefits provided from BE exploitation through education, campaigns and actual public engagement in BE processes [13].

Knowledge, Research & Innovation, Pilot projects. A dedicated national and regional R&I strategy should be developed, alongside a visible and reliable post-2020 project pipeline, for driving the industry towards full market maturity. Early-stage research and further development of MRE should be facilitated and the position gained so far by the MED Mediterranean players should be reinforced.

First, information and knowledge are essential. For this, it is key to improve coordination between organizations performing marine data collection to avoid duplication and ensure format compatibility. In this sense, advances in the application of the INSPIRE Directive contribute to international marine data management initiatives (EMODnet, SeaDataNet, etc.). Available marine information from different sources should be integrated and organized in an open-access, online data portal (e. g. German marine data infrastructure portal, MDI-DE). Availability of valid and useful data for MRE promoters should be ensured, including accurate energy resource mapping and environmental impact data gathering [93].

Implementation of demo/pilot projects should be facilitated. Projects and activities at the regional level should focus on "demo" sites which might be more effective and realistic than theoretical research. The development of offshore test sites in the Mediterranean Sea should be promoted in order to facilitate the scale-up of marine renewable energy prototypes adapted to Mediterranean Sea conditions. Collaboration between energy developers and stakeholders such as ports, marinas, holiday resorts, desalination plants, etc. should also be promoted in order to deploy marine renewable energy devices for small-scale production (e.g. power supply for a marina) [101].

Research should be focused on optimizing device design to achieve low-cost energy production, to promote the offer of the MED region's ports in order to set up industrial sites and to maximize environmental compatibility.

Regarding environmental compatibility, offshore wind farm planning should reflect conservation priorities and aim to avoid ecologically valuable and protected areas and involve a comprehensive stakeholder consultation process. Impact assessments of offshore wind farm projects should promote the exemplary nature of the avoid-mitigate-compensate approach and consider cumulative impacts. Data collection, research on species and ecosystem functioning should be widely promoted to achieve a better assessment of the impacts of offshore wind farms [101].

At the European level, the EU strategy on offshore renewable energy calls for a systematic in-depth analysis of the potential cumulative impacts on the marine environment and the interactions between offshore renewable energies and other sea activities. In this context, the Copernicus Marine Environment Monitoring Service and the European Marine Observation and Data Network (EMODnet) will be helpful tools. In 2021, the Commission proposed the creation of a community of experts from public authorities, stakeholders and scientists to analyze, evaluate and monitor the environmental, social and economic impacts of offshore renewable energy[20].

Supply chain and energy infrastructure. Lack of sufficient infrastructure could be a significant barrier to later mass deployment of marine-based renewable energy technologies. This is linked not only to support infrastructure in terms of construction vessels and equipment, but also to the transmission of energy and integration of marine energy into wider energy networks.

Cooperation. Cooperation across the Mediterranean is key to support BE development, especially in the early phase of development where small projects are disproportionately affected by higher planning and transaction costs. International cooperation can be strengthened by promoting the establishment of a permanent Mediterranean Cluster of stakeholders to sustain macro-regional strategies and connect key actors of the BE sector, by sustaining and strengthening on-going initiatives to transfer scientific information and export best practices to southern Mediterranean countries (e.g. MEDENER, OME, ADEME), and by promoting the implementation of a regional platform to enhance knowledge exchange

[20] From: Questions and Answers on the EU offshore renewable energy strategy

on energy efficiency and renewable energies with the overarching aim of complementing the industrial cooperation effort undertaken through the European Climate Change Program.

The Ministerial declaration on Sustainable Blue Economy of the Union for the Mediterranean (2021) has confirmed the need for cooperation on research and innovation towards the development of technologies capable of fully exploiting the potential of MRE sources in the Mediterranean, including combining different marine activities (i.e. renewable energy, aquaculture, fisheries, bio-resources, environmental conservation and restoration, maritime transport, and tourism services) in the same marine space.

For example, a concrete joint initiative of establishing an offshore bidding-zone would be best suited to a large scale-up of offshore renewables, as it ensures that renewable energy can be fully integrated into the market. This approach would ensure that renewable electricity can flow to where it is needed and improve regional security of supply. In addition, in order to address the practical, physical challenge of connecting projects to several markets with different connection rules, a common approach to grid connection requirements for high-voltage direct current (HVDC) grids should be developed, based on experience in the North Sea basin[21].

6. Further steps forward: Research, Innovation and Transfer across the Mediterranean

In view of all that has been said in this report, it can be concluded that, in general, **environmental concern, social acceptance and integration of BE in Maritime Spatial Plans are common priorities for all blue energy technologies in the Mediterranean, while the development of mooring systems is a common issue when it comes to technological priorities**. This is not surprising considering the particular morphological and bathymetric characteristics of the Mediterranean Sea. From a more technical point of view, in all BE sectors, (offshore wind, wave and tidal) the development situation is similar: there is a large variety of concepts and the resulting competitiveness represents an added value fostering faster improvement of technologies. However, this slows down the achievement of standardization goals [106].

The whole sector needs to focus on concepts that can ensure scalability and industrialization. Given the current status of development (mostly around TRL6-7) [112], **the access to programs and facilities for testing devices in the operational environment is capital to finally prove performance, viability and reliability** and for the selection of “winning” technologies. In any case, effective development of BE cannot be achieved without adequate investments. Fundraising mechanisms remain an open challenge for all the sectors involved, even for those now at the pre-commercial stage. Therefore, sufficient public investment in the field remains essential [112].

Research & Innovation is one of the priorities for BE development in the Mediterranean, identified by the PELAGOS project. The overall objective of the Research & Innovation community in the BE sector is to meet the target of driving down the Levelized Cost of Energy (LCoE), while reinforcing the European industry position on a global stage.

[21] From: Questions and Answers on the EU offshore renewable energy strategy

The offshore wind sector is at a much more mature level than the ocean energy sector, so specific targets are different for these two technologies. The former has a quantitative target for LCoE of 5-€7ct/kWh by 2030 and the technological challenges mainly concern the development of floating devices, advanced anchoring and mooring systems, and lowering of operation and maintenance costs [13]. The latter has the quantitative target of €10/15 ct/kWh in 2030 for tidal/wave technologies respectively, and the significant challenge of reaching technological convergence [13].

Both objectives can be achieved by greatly improving the yield, which ultimately depends on the volume of energy produced, performance, viability and reliability of the prototypes at the demonstration and pre-commercial stage. Cost-effective deployment of MREs should be encouraged, as well as strengthening natural laboratories for testing marine energy devices. The upgrade of low TRL technologies to more advanced levels should be supported in order to favor technological convergence [13].

To achieve all this, the PELAGOS Action Plan has identified the following priority actions for Research and Development [13]:

Recommendation: Encouraging cost-effective deployment of MREs

Actions:

- Support technology development aimed to reduce operation costs of MRE farms. For example, development of fewer large sized turbines and infrastructure with the same project capacity/ design tools (biofouling, behavior of structure/ components in fatigue).
- Support the development of new technologies for floating wind turbines (floaters, anchors) capable of operating in deep waters and/or far from shore.
- Support the development of energy storage (Hydrogen)
- Co-location of MRE infrastructure (floating wind turbines, wave energy converters, solar panels). Substructure technologies supporting the new schemes associated with deeper waters to be innovatively designed with materials and geometries that simplify manufacturing and installation operations.
- Support R&I projects aimed to lower manufacturing and/or installation and/or maintenance costs by adopting new materials and new design concepts;
- Support R&I projects for the development of multi-use platforms;
- Use of HVDC (high-voltage direct current transmission) grids that have much lower losses and improve the availability of power. (https://cordis.europa.eu/news/rcn/129564/en)

Recommendation: **Strengthen natural laboratories for testing marine energy devices**

Actions:

- Reinforce the role of existent natural laboratories for testing systems in the operational environment;
- Promote the creation of a network of natural laboratories with the same standards, for optimal use of resources;
- Adopt simplified procedures for short-term deployment of devices at sea for testing/experimental purposes.

Recommendation: **Support the upgrade of low TRL technologies to more advanced levels**

Actions:

- Support demonstration projects to accelerate the development of the sector;

- Support projects and activities in numerical modelling to simulate the hydrodynamic properties of new concepts in realistic operating conditions;
- Support the development of IT systems capable of gathering, storing and managing all the information obtained during testing in indoor laboratories, in natural laboratories, and measurement campaigns in order to enhance the sharing and use of the huge amount of data already available (Big Data, Data Mining).

In addition**, technology transfer across the Mediterranean countries is definitively needed** and could also significantly contribute to technology development and maturation.

In this sense, Blue Energy Cluster platforms (cf. Chapter 3.1.2) can solve gaps in the lack of innovation and cooperation in the rising field of blue energy. In particular, these platforms may offer organizations cooperation opportunities in the field of MRE, and showcase innovative technologies and services in this sector. The PELAGOS project identified the need for developing a Transnational Mediterranean Blue Energy Cluster [43].

National webGIS platforms, such as the MAESTRALE geodatabase, could also help as other open access databases, by providing information on marine renewable energy potentials, existing technologies (in the form of case studies) and stakeholders maps, and may be highly useful at a Mediterranean level. They can also be widely used as an educational tool for students in the blue energy field.

Creation and adoption of educational schemes (e.g. BLUE DEAL labs) can also contribute to transfer of innovation, through participative processes and use of concrete outputs concerning feasibility studies from pilot projects.

7. References

[1] European Commission 2014. Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Blue Energy. Action needed to deliver on the potential of ocean energy in European seas and oceans by 2020 and beyond. 11 pp.

[2] Pisacane, G., Sannino, G., Carillo, A., Struglia, M.V., Bastianoni, S. 2018. Marine Energy Exploitation in the Mediterranean Region: Steps forward and challenges. Frontiers in Energy Research, 6 (109), 17 pp. doi: 10.3389/fenrg.2018.00109.

[3] MAESTRALE, 2017. Deliverable 3.1.1. Blue Energy regulations and funding framework. 188 pp.

[4] DeCastro, M., Costoya, X., Salvador, S., Carvalho, D., Gómez-Gesteira, M., Sanz-Larruga, F. J., et al. 2018. An overview of offshore wind energy resources in Europe under present and future climate. Ann. N. Y. Acad. Sci. doi: 10.1111/nyas.13924.

[5] Piante, C., and Ody, D. (2015). Blue Growth In The Mediterranean Sea: The Challenge Of Good Environmental Status. WWF Report. Available online at: http://d2ouvy59p0dg6k.cloudfront.net/downloads/medtrends_regional_report.pdf

[6] Zodiatis, G., Galanis, G., Nikolaidis, A., Kalogeri, C., Hayes, D., Georgiou, G. C., et al. (2014). Wave energy potential in the Eastern Mediterranean Levantine Basin. An integrated 10-year study. Renew. Energy 60, 311–323. doi: 10.1016/j.renene.2014.03.051

[7] Monteforte, M., Lo Re, C., and Ferreri, G. B. (2015). Wave energy assessment in Sicily (Italy). Renewable Energy 78, 276–287. doi: 10.1016/j.renene.2015.01.006

[8] Besio, G., Mentaschi, L., and Mazzino, A. (2016). Wave energy resource assessment in the Mediterranean Sea on the basis of a 35-year hindcast. Energy 94, 50–63. doi: 10.1016/j.energy.2015.10.044

[9] UNEP/MAP (2012). State of the Mediterranean Marine and Coastal Environment. Athens: UNEP/MAP - Barcelona Convention.

[10] Fotiadou A and Papagiannopoulos-Miaoulis I (2019). Introduction of Blue Energy in the Mediterranean: The Conceptualization of the Sea as “Space” and Emerging Opportunities for Greece and Mediterranean Countries. Front. Energy Res. 7:59. doi: 10.3389/fenrg.2019.00059

[11] IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. eds. Core Writing Team, R. K. Pachauri and L. A. Meyer (Geneva: IPCC) 151.

[12] UNEP/MAP and Plan Bleu (2020). State of the Environment and Development in the Mediterranean: Key Messages. Nairobi.

[13] PELAGOS project, 2019a. Blue Energy Action Plan in Med. Deliverable 4.3.1.

[14] Union of the Mediterranean, 2021. Towards a Sustainable Blue Economy in the Mediterranean region.

[15] BLUENE project, 2015. BLUe ENErgy for Mediterranean, Value chain scheme for cooperation.

[16] PELAGOS project 2017a. Deployment potential assessment of Blue Energy technologies for MED key maritime industries. Deliverable D.3.1.4.

[17] Soukissian TH, Adamopoulos C, Prospathopoulos A, Karathanasi F and Stergiopoulou L 2019. Marine Renewable Energy Clustering in the Mediterranean Sea: The Case of PELAGOS Project. Front. Energy

Res. 7:16. doi: 10.3389/fenrg.2019.00016.

[18] PELAGOS project 2017b. Diagnostic study of the Mediterranean marine energy resources potential. Deliverable D.3.1.2.

[19] WWF-France (2019). Safeguarding marine protected areas in the growing Mediterranean blue economy. Recommendations for the offshore wind energy sector. PHAROS4MPAs project. 68 pages

[20] Dornhelm, Esther, Helene Seyr, and Michael Muskulus. "Vindby—A Serious Offshore Wind Farm Design Game." Energies 12.8 (2019): 1499.

[21] ZHENG C.W., PAN J. “Assessment of the global ocean wind energy resource”. Renewable and Sustainable Energy Reviews 33 (2014) pp.382-91.

[22] UNEP, 2015. Green economy in a blue world.

[23] DUPONT, C., HERPERS, F., & LE VISAGE, C. (2020). Recommendations for positive interactions between offshore wind farms and fisheries

[24] Wind Europe, 2019b. Our energy, our future - How offshore wind will help Europe go carbon-neutral. 80 pages.

[25] Pantusa D. & G.R. Tomasicchio (2019) Large-scale offshore wind production in the Mediterranean Sea, Cogent Engineering, 6:1, 1661112

[26] Plan Bleu (2020). Blue economy in the Mediterranean: case studies, lessons and perspectives. Plan Bleu Paper n°19.

[27] MAESTRALE project, 2016. Update international catalogue of Blue Energy best practices and Case Studies.

[28] PELAGOS project, 2017c. EU Blue Energy Technologies Portfolio. Deliverable D.3.1.1.

[29] Titah-Benbouzid, H.; Benbouzid, M. 2014. Ocean Wave Energy Extraction: Up-to-Date Technologies Review and Evaluation. In Proceedings of the 2014 IEEE International Power Electronics and Application Conference and Exposition (PEAC), Shanghai, China, 5–8 November 2014; pp. 338–342.

[30] Pérez-Collazo, C., Greaves, D. D., and Iglesias, G. 2015. A review of combined wave and offshore wind energy. Renew. Sustain. Energy Rev. 42, 141–153. doi: 10.1016/j.rser.2014.09.032

[31] B.G. Reguero et al. Applied Energy 148 (2015) 366–380.

[32] Walker, Stuart RJ. "Barriers to the deployment of a 100 MW tidal energy array in the UK." International Journal of Energy Engineering 3.3 (2013): 80.

[33] A. Hossain, A. Azhim, A. B. Jaafar, M. N. Musa, S. A. Zaki & D. Noor Fazreen (2013) Ocean Thermal Energy Conversion: The Promise of a Clean Future.

[34] EDENHOFER O., PICHS-MADRUGA R., SOKONA Y., SEYBOTH K., KADNER S., ZWICKEL T., ET AL., editors. Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (2011).

[35] Pecher, A., & Peter Kofoed, J. (2017). Handbook of ocean wave energy. Springer Nature.

[36] Sannino, G. & Pisacane, G. (2017). Ocean energy exploitation in Italy: ongoing R&D activities. Position paper/September 2017. Enea.

[37] NIHOUS G.C. 2007. A preliminary assessment of ocean thermal energy conversion resources. Journal of Energy Resources Technology 129(1) pp. 10-17.

[38] RAJAGOPALAN K., NIHOUS G.C. 2013. Estimates of global Ocean Thermal Energy Conversion (OTEC) resources using an ocean general circulation model. Renewable Energy 50 pp. 532-40

[39] Alvarez-Silva, O. A., Andres F. Osorio, and Christian Winter. "Practical global salinity gradient energy potential." Renewable and Sustainable Energy Reviews 60 (2016): 1387-1395

[40] MAESTRALE project, 2018. Blue energy potential in the MED area. Deliverable 3.3.2.

[41] ARENA, F ROMOLO, A. MALARA, G. FIAMMA, V. LAFACE, V. – 2016 – The first worldwide application at full-scale of the REWEC3 device in the Port of Civitavecchia: Initial energetic performances. In Guedes Soares, Progress in renewable Energies Offshore, Proceedings of the 2nd International Conference on Renewable Energies Offshore (RENEW2016), Lisbon, Portugal, 24-26 October 2016

[42] Nikolaidis, Karaolia A, Matsikaris A, Nikolaidis A, Nicolaides M, Georgiou G C 2019. Blue Energy Potential Analysis in the Mediterranean. Frontiers in Energy Research 7: 62 DOI=10.3389/fenrg.2019.00062

[43] PELAGOS project, 2017d. Blue Energy Cluster Building Methodology. Deliverable D.3.2.1.

[44] Wilding, T. A., Gill, A. B., Boon, A., Sheehan, E., Dauvin, J. C., Pezy, G. P., et al. (2017). Turning off the DRIP ('Data-rich, information-poor') – rationalising monitoring with a focus on marine renewable energy developments and the benthos. Renew. Sustain. Energy Rev. 74, 848–859. doi: 10.1016/j.rser.2017.03.013

[45] Bray, L., Reizopoulou, S., Voukouvalas, E., Soukissian, T., Alomar, C., Vázquez-Luis,M., et al. (2016). Expected effects of offshore wind farms on Mediterranean marine life. J. Mar. Sci. Eng. 4:18. doi: 10.3390/jmse4010018

[46] Azzellino A. Conley D., Vicinanza D., and Peter J. P. Kofoed, 2013. Marine Renewable Energies: Perspectives and Implications for Marine Ecosystems Volume 2013, Article ID 547563, 3 pages. http://dx.doi.org/10.1155/2013/547563

[47] Copping, A.E 2020. Marine Renewable Energy: Environmental Effects and Monitoring Strategies. In A.E. Copping and L.G. Hemery (Eds.), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). (pp. 19-27). DOI: 10.2172/1632880.

[48] US - Bureau of Ocean Energy Management (BOEM) - Atlantic OCS Region 2018. Summary Report: Best Management Practices Workshop for Atlantic Offshore Wind Facilities and Marine Protected Species. OCS Study BOEM 2018-015

[49] Hasselman, D.J., D.R. Barclay, R.J. Cavagnaro, C. Chandler, E. Cotter, D.M. Gillespie, G.D. Hastie, J.K. Horne, J. Joslin, C. Long, L.P. McGarry, R.P. Mueller, C.E. Sparling, and B.J. Williamson. 2020. Environmental Monitoring Technologies and Techniques for Detecting Interactions of Marine Animals with Turbines. In A.E. Copping and L.G. Hemery (Eds.), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). (pp. 176-213). DOI: 10.2172/1633202

[50] Savidge, G., Ainsworth, D., Bearhop, S., Christen, N., Elsaesser, B., Fortune, F., Inger, R., Kennedy, R., McRobert, A., Plummer, K. E., Pritchard, D. W., Sparling, C. E., and Whittaker, T. J. T. 2014. Strangford Lough and the SeaGen Tidal Turbine. In M. A. Shields and A. I. L. Payne (Eds.), Marine Renewable Energy Technology and Environmental Interactions (pp. 153-172). Dordrecht: Springer Netherlands. https://tethys.pnnl.gov/publications /strangford-lough-seagen-tidal-turbine

[51] Ocean Renewable Power Company (ORPC). 2013. Cobscook Bay Tidal Energy Project: 2012 Environmental Monitoring Report. Report by Ocean Renewable Power Company; Portland, Maine. https://tethys.pnnl.gov/publications/cobscook-bay-tidal-energy-project-20 12-environmental-monitoring-report

[52] Ocean Renewable Power Company (ORPC). 2014a. Cobscook Bay Tidal Energy Project: 2013 Environmental Monitoring Report. Report by Ocean Renewable Power Company; Portland, Maine. https://tethys.pnnl .gov/publications/cobscook-bay-tidal-energy-project-20 13-environmental-monitoring-report

[53] Wilson, B., Lepper, P., Carter, C., and Robinson, S. 2014. Rethinking Underwater Sound-Recording Methods to Work at Tidal-Stream and Wave-Energy Sites. In Shields, M. and Payne, A. (Eds.), Marine Renewable Energy Technology and Environmental Interactions (pp. 111-126): Springer, Dordrecht. https://tethys.pnnl.gov /publications/rethinking-underwater-sound-recording -methods-work-tidal-stream-wave-energy-sites

[54] Parsons, M. J. G., Fenny, E., Lucke, K., Osterrieder, S., Jenkins, G., Saunders, B. J., Jepp, P., and Parnum, I. M. 2017. Imaging Marine Fauna with a Tritech Gemini 720i Sonar. Acoustics Australia, 45(1), 41-49. doi:10.1007 /s40857-016-0076-1 https://tethys.pnnl.gov/publications /imaging-marine-fauna-tritech-gemini-720i-sonar

[55] Defingou M; Bils F, Horchler B, Liesenjohann T & Nehls G (2019): PHAROS4MPAs- A REVIEW OF SOLUTIONS TO AVOID AND MITIGATE ENVIRONMENTAL IMPACTS OF OFFSHORE WIND FARMS. BioConsult SH on behalf of WWF France, p.264

[56] DIRECTION INTERREGIONALE DE LA MER MÉDITERRANÉE (Hrsg.) (2018): Le développement de l'éolien flottant en Méditerranée. Direction Interrégionale de la Mer Méditerranée/Marseille (FRA), S: 69.

[57] Lüdeke, J. Exploitation of offshore wind energy. In Handbook on Marine Environment Protection; Salomon, M., Markus, T., Eds.; Springer International Publishing: Cham (DEU), 2018; pp. 165–188.

[58] Gee K., Lukic I., Schultz-Zehden A-, Ooms E., Onwona Ansong J., Passerello C., 2019. Addressing conflicting spatial demands in MSP. Considerations for MSP planners. https://www.msp-platform.eu/sites/default/files/20190604_conflicts_study_published.pdf

[59] PELAGOS project 2017e. D.3.1.3 Existing Policy and regulatory status on MED Blue Energy development.

[60] Vanja Westerberg, Jette Bredahl Jacobsen, Robert Lifran, Offshore wind farms in Southern Europe – Determining tourist preference and social acceptance, Energy Research & Social Science, Volume 10, 2015, Pages 165-179, ISSN 2214-6296, https://doi.org/10.1016/j.erss.2015.07.005.

[61] Global Insight (2008): "An assessment of the potential costs and benefits of offshore wind turbines", Report, The State of New Jersey.

[62] EU MSP Platform, 2019. Conflict Fish 1. Maritime tourism (including local communities) and offshore wind farms

[63] EU MSP Platform, 2020. Recommendations for positive interactions between offshore wind farms and fisheries - Short Background Study

[64] Schultz-Zehden A. et al., 2018. Ocean Multi-Use Action Plan, MUSES project, Edinburgh

[65] Bocci M, Sangiuliano SJ, Sarretta A, Ansong JO, Buchanan B, Kafas A, et al. (2019a) Multi-use of the sea: A wide array of opportunities from site-specific cases across Europe. PLoS ONE 14(4): e0215010. https://doi.org/10.1371/journal.pone.0215010

[66] European Commission, "Action Plan for a Maritime Strategy in the Atlantic area, COM (2013) 279 final," vol. 13 p, 2013

[67] O. Guiraud, "Pêche et usages professionnels de la mer. Atelier thématique pêche, 2017. [Online]. Available: http://eolmed.fr/wp-content/uploads/2017/02/atelier_thematique_peche.pdf [Accessed October 2020].

[68] Vassiliou Vasso, Marios Charalambides, Michalis Menicou, Niki Chartosia, Eftihia Tzen, Binopoulos Evagelos, Panagiotis Papadopoulos & Alexandros Loucaides (2015) Aquaculture Feed Management System Powered by Renewable Energy Sources: Investment Justification, Aquaculture Economics & Management, 19:4, 423-443, DOI: 10.1080/13657305.2015.1082115

[69] European Commission (EC), 2010. Article 6 - Sector Specific Guidance: Wind Energy Developments And Natura 2000. Available at: http://ec.europa.eu/environment/nature/natura2000/management/docs/Wind_farms.pdf

[70] Inger R.M.J. Attrill, S. Bearhop, A.C. Broderick, W.J. Grecian, D.J. Hodgson, C. Mills, E. Sheehan, S.C. Voti er, M.J. Witt, B.J. Godley 2011. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. J. Appl. Ecol., 46 (6) (2011), pp. 1145-1153

[71] D. Lacroix, S. PiochThe multi-use in wind farm projects: more conflicts or a win-win opportunity? Aquat. Living Resour., 24 (2011), pp. 129-135

[72] O. Langham Artificial reef effect in relation to offshore renewable energy conversion: state of the art. Sci. World J. (2012) Article ID 386713

[73] J.C. Wilson, M. Elliott (2009) The habitat-creation potential of offshore wind farms. Wind Energy, 12 , pp. 203-212

[74] I. Scrase, B. Gove (Eds.), Meeting Europe's Renewable Energy Targets in Harmony with Nature, BirdLife Europe. The RSPB, Sandy, UK (2010)

[75] M.J. Witt, E.V. Sheehan, S. Bearhop, A.C. Broderick, D.C. Conley, S.P. Cotterell, E. Crow, W.J. Grecian, C. Halsband, D.J. Hodgson, P. Hosegood, R. Inger, P.I. Miller, D.W. Sims, R.C. Thompson, K. Vanstaen, S.C. V otier, M.J. Attrill, B.J. GodleyAssessing wave energy effects on biodiversity: the wave hub experience, Philos. Trans. R. Soc. A: Math. Phys. Eng. Sci., 370 (1959) (2012), pp. 502-529

[76] N. Christie, K. Smyth, R. Barnes, M. Elliott (2014). Co-location of activities and designations: a means of solving or creating problems in marine spatial planning? Mar. Policy, 43: 254-261

[77] Zacharoula Kyriazi, Frank Maes, Steven Degraer, (2016). Coexistence dilemmas in European marine spatial planning practices. The case of marine renewables and marine protected areas, Energy Policy: 97: 391-399, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2016.07.018.

[78] Lena Bergström *et al* (2014) *Environ. Res. Lett.* 9 034012 https://doi.org/10.1088/1748-9326/9/3/034012

[79] Sangiuliano, Stephen J. (2018). Analysing the potentials and effects of multi-use between tidal energy development and environmental protection and monitoring: A case study of the inner sound of the Pentland Firth, Marine Policy 96 : 120-132. https://doi.org/10.1016/j.marpol.2018.08.017.

[80] Pérez-Collazo, C., Greaves, D. D., and Iglesias, G. (2015). A review of combined wave and offshore wind energy. Renew. Sustain. Energy Rev. 42, 141–153. doi: 10.1016/j.rser.2014.09.032

[81] UNEP/MAP (2017). Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas. UN Environment/MAP Athens, Greece.

[82] Plan Bleu (2020). Blue Economy. A new frontier for growth and a healthy Mediterranean.

[83] UNEP/MAP (2019). Naples Ministerial Declaration. 21st Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols

[84] UNEP/MAP and Plan Bleu (2020). State of the Environment and Development in the Mediterranean: Key Messages. Nairobi.

[85] Ocean Energy Forum (2016). Ocean Enrgy Strategic Roadmap.Building Ocean Energy for Europe. https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/OceanEnergyForum_Roadmap_Online_Version_08Nov2016.pdf

[86] Fotiadou A., and Papagiannopoulos-Miaoulis I. (2019). Introduction of Blue Energy in the Mediterranean: The Conceptualization of the Sea as "Space" and Emerging Opportunities for Greece and Mediterranean Countries. Frontiers in Energy Research, 7 (59), 5 pp. doi: 10.3389/fenrg.2019.00059

[87] MAESTRALE project (2016). Blue Energy regulation and funding framework. Deliverable D.3.1.1

[88] PELAGOS project (2019b). Survey on national policies and authorization procedures. Deliverable D.3.1.3.

[89] García Q. P., Chica Ruiz J. A., Sanabria J. G. (2020). Blue energy and marine spatial planning in Southern Europe. Energy Policy 140: 111421

[90] Angelopoulos, D., Doukas, H., Psarras, J., Stamtsis, G. (2017). Risk-based analysis and policy implications for renewable energy investments in Greece. Energy Pol. 105, 512–523. https://doi.org/10.1016/j.enpol.2017.02.048

[91] Gabaldon-Estevan, D., Penalvo-Lopez, E., Solar, D.A. (2018) The Spanish turn against renewable energy development. Sustain. Times 10, 1–16. https://doi.org/10.3390/ su10041208

[92] Ibanez-Lopez, A.S., Moratilla-Soria, B.Y. (2017). An assessment of Spain's new alternative energy support framework and its long-term impact on wind power development and system costs through behavioral dynamic simulation. Energy 138, 629–646. https://doi.org/10.1016/j.energy.2017.07.041

[93] García Q. P., Chica Ruiz J. A., Sanabria J. G. (2020). Blue energy and marine spatial planning in Southern Europe. Energy Policy 140: 111421

[94] SET Plan (2018). Ocean Energy-Implementation Plan. setis.ec.europa.eu/system/files/set_plan_ocean_implementation_plan.pdf

[95] Vazquez, A., and Iglesias, G. (2015). Public perceptions and externalities in tidal stream energy: a valuation for policy making. Ocean Coast.Manage. 105, 15–24. doi: 10.1016/j.ocecoaman.2014.12.017

[96] PELAGOS project (2017)f. Blue Energy Cluster Building Methodology. Deliverable D.3.2.1

[97] UNEP, FAO, IMO, UNDP, IUCN, WorldFish Center, GRID Arendal (2012). Green Economy in a Blue World

[98] Borthwick, A. G. L. (2016). Marine renewable energy seascape. Engineering 2, 69–78. doi: 10.1016/J.ENG.2016.01.011

[99] European Commission (2017). Study on Lessons for Ocean Energy Development – Final Report, Directorate-General for Research & Innovation. http://publications.europa.eu/resource/cellar/03c9b48d-66af-11e7-b2f2-01aa75ed71a1.0001.01/DOC_1

[100] Corsatea, T. D. (2014). Increasing synergies between institutions and technology developers: Lessons from marine energy. Energy Policy 74, 682–696. doi: 10.1016/j.enpol.2014.07.006

[101] Union for the Mediterranean (2020). Stakeholder conference on the Blue Economy. "Towards a Sustainable Blue Economy for the Mediterranean Sea basin"

[102] Union for the Mediterranean, (2018). Blue economy in the Mediterranean

[103] UNEP, FAO, IMO, UNDP, IUCN, WorldFish Center, GRID Arendal (2012). Green Economy in a Blue World.

[104] Bocci M., Papaioannou E., Dubreuil C. (2019)b. Blue Economy in the Mediterranean. Policy paper. Plan Bleu. https://planbleu.org/en/publications/blue-economy-in-the-mediterranean-policy-paper/

[105] Jean-Pierre Giraud, Antoine Lafitte, with the contribution of Jeremie Fosse (2017). Blue Economy. Economic activities and sustainable development – Towards a Blue economy for a sustainable Mediterranean: Indicators and recommendations. Plan Bleu Notes #34.

[106] PELAGOS project (2019)c. Strategic Research Agenda towards innovation in Blue Energy. Deliverable D.4.3.1.

[107] ZHANG, XP., OU, M., SONG, Y. et al. Review of Middle East energy interconnection development. J. Mod. Power Syst. Clean Energy 5, 917–935 (2017). https://doi.org/10.1007/s40565-017-0335-7

[108] Directorate-General for Energy (European Commission) , Guidehouse Netherlands B.V , SWECO, 2020. Study on the offshore grid potential in the Mediterranean region

[109] Tagliapiertra S. (2015), Renewable Energy in the Mediterranean: Current Status and Future Prospects, Review of Environment, Energy and Economics, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2603180

[110] Winters J. (2020) The Myth of Algae Biofuels, Harvard Political Review

[111] Bocci, M. & F. Coccon (2021) Using Ecological sensitivity to guide Marine Renewable Energy Potentials in the Mediterranean Region, Interreg MED Mediterranean Biodiversity Protection Community, Deliverable 5.4.3