Project co-financed by the European Regional Development Fund

Promoting innovative nEtworks and cLusters for mArine renewable energy synerGies in mediterranean cOasts and iSlands

Deployment potential assessment of Blue Energy technologies for MED key maritime industries

PMM (leader) CRES, ENEA, UNIZagreb, CRIAUAlg, CTN, UCV, HCMR, MARINEM

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1. Purpose of this document

This deliverable aims to detail and analyse marine renewable energy (MRE) demonstration projects developed and/ or currently under development, in the perspective to their deployment in the Mediterranean Sea.

The document is reviewing the different MREs, their stage of development and their necessary adaptation to the Mediterranean context. The value chain is defined and detailed as well as the technological and non-technological stakes of the MRE sector for its development in the coming years.

As MRE are at an early stage of development, the collection of these current projects will enable to study the blue energy technologies developed and their applications to key maritime industries of Mediterranean insular, coastal & marine areas. Only very few projects are currently developed in the Mediterranean Sea.

The report focuses on different international examples useful to study for the deployment of MRE in the Mediterranean. Transversal projects which gather several sectors (i.e. MRE and marine environment; transport; offshore aquaculture, etc.) are also described and analysed as well as multi-use offshore platforms projects that have been developed these last years, with the support of the European commission.

1 Introduction on PELAGOS project

1.1 The project at a glance

The oceans and seas are the largest and one of the most complex ecosystems on earth, determining the basic characteristics which support life, including the largest quantity of natural resources, fossil, mineral and renewable.

At the same time they also hold a wide range of services, from leisure, such as nautical tourism, to logistics, such as the transport of goods between countries and continents, enabling global trading.

The oceans and seas play an essential role in the present and the future of humanity due to their significance of controlling natural conditions, the services they provided to citizens, and their potential to provide the resources to meet the demands of a growing population.

All this presents the oceans and seas as the source and the next frontier of opportunities and technological challenges, but also as a means likely to be altered and impaired by human activities and their substantial and irreversible consequences on a planetary scale.

Harnessing the economic potential of this energy in a sustainable manner has been highlighted in the Commission's Blue Growth Strategy as one of key areas, where in order to build the necessary capacity and critical mass, it is necessary to involve a wide range of stakeholders.

PELAGOS project aims to increase the innovation capacities and cooperation of blue energy actors in the Mediterranean through promoting a transnational cluster, bringing them together in order to develop a shared understanding of the challenges and collectively devise workable solutions.

The Mediterranean Blue Energy Cluster will promote novel technologies and provide a mix of support activities to beneficiaries such as technology providers, enterprises, financial operators, authorities, NGOs and citizens.

The project will enhance internationalization of the Cluster members through a range of activities that will jointly identify opportunities of Blue Energy in Mediterranean insular and coastal regions.

This will be achieved through fine-tuning of existing know-how, development of skills, the identification of common business opportunities and facilitation of growth by bridging providers and users in targeted maritime industries. The development of this emerging sector can become an important part of the blue economy, fuelling economic growth in coastal regions and create new, high-quality jobs.

1.2 Overall objective

The project aims to establish a transnational Mediterranean Cluster in Blue Energy (BE) to accelerate the development of Blue energy (or Marine Renewable Energy, MRE) sector in Mediterranean coastal, insular and marine regions. PELAGOS will facilitate the deployment of targeted solutions and products tailored to Mediterranean profile.

The project will coordinate the offering of a consolidated mix of support activities to all relevant stakeholders in Blue Energy value chain by bridging push and pull innovation activities and securing social acceptance. More specifically, PELAGOS will design and build a Mediterranean Innovative Cluster by connecting Regions and key actors of the blue energy value chain such as technology and service providers, large enterprises, power distributors, financial operators, policy makers, NGOs and of course citizens.

The project will enhance cooperation and internationalization of the Cluster and its members through the implementation of pilot activities at both regional and transnational levels that will jointly identify opportunities of blue energy in Mediterranean marine areas.

Thus, the use and exploitation of technologies, such as offshore wind turbines, wave and tidal energy converters and ocean thermal energy, in key market sectors such as tourism & leisure, aquaculture, shipbuilding and marine transport is expected to boost economic growth and deliver new, high-quality jobs.

1.3 Results foreseen

Marine renewable energy (Offshore Wind energy, Wave energy, Tidal stream energy, thermal gradient power), presents the EU and in particular Mediterranean with an opportunity to generate

economic growth, enhance the security of its energy supply and foster competitiveness through technological innovation. The position of European industry in the global ocean energy market is currently strong since most of the technology developers are based in Europe. Innovation through R&D can allow the EU to generate export opportunities for both technologies and know-how and ensure that the EU can maintain its industrial leadership. With public support for early stage development, the blue energy sector may be able to play a critical role in the future. Blue energy currently, at the exception of wind energy laid on the sea floor, is at an infant stage with most of the existing technologies still in need to demonstrate their reliability in the seas and innovative SMEs often short of the necessary resources to deploy their prototypes. PELAGOS addresses the above mentioned challenges by engaging actors from the various industries involved, in order to play a facilitating and coordinating role in the exploitation of this emerging technology. The commercialisation of the blue energy sector certainly needs both technical and non-technical advancements. However, given the long investment time horizons for new technologies this project considers blue energy a promising new technology and considers how the EU could usefully support its development.

Increase of transnational cooperation amongst Mediterranean maritime Clusters in Blue Energy offering support services to all relevant actors

The project will establish a Mediterranean Innovative Cluster in Blue Energy sector properly designed to enhance innovation capacities of all key actors involved, with emphasis on SMEs. This cluster will deliver a consolidated mix of innovative transnational services and will foster linkages and collaborations among all the stakeholders of the Quadruple Helix Innovation Model of Blue Growth, in order to achieve the necessary engagement and coordination for the successful deployment of this emerging industry. In particular, PELAGOS cluster will increase SMEs' innovation capacities, support research and innovation in MRE sector, improve the linkages both at regional and transnational level and generate the critical mass that is essential for the deployment of this emerging technology. Cluster actors from the seven participant countries will exchange in a coordinated manner and define common objectives and plans of action. More specifically, with regards to SMEs, the Cluster will support them to identify opportunities for diversification of their products, identification of new markets and trends, cooperation with companies that operate on supplementary products and joint R&D activities. Furthermore, the cluster will assist SMEs to better network with large enterprises and RTOs, connect them with potential investors and financing institutions and expose them to regional authorities and NGOs that act in the local communities.

Accelerated deployment of Blue Energy solutions in key Mediterranean maritime industries by engaging private, government and social sector

Despite its immature stage of implementation, it appears that some blue energies could be suited to the Mediterranean. Moreover, blue energy is a cross-cutting issue that involves other relevant sectors such as tourism, aquaculture, shipbuilding and ship repair, transport activities etc., from which synergies shall be enhanced through the operation of PELAGOS cluster. PELAGOS is expected to ensure that a robust marine renewable energy industry can help create jobs, revitalize abandoned shipyards, and improve the economies of coastal and insular communities. The project will demonstrate that new technologies used in the blue energy field can generate positive externalities and help traditional maritime industries to align themselves with regulations and market pressures. Like other renewable energies, blue energy will benefit from a clear, stable and supportive policy framework to attract investment and secure social acceptance in order to develop its full potential. Complex licensing and consenting procedures can delay projects and raise costs, while uncertainty about the correct application of environmental legislation may further prolong consenting processes. Integrating blue energy into national maritime spatial plans and exchange of information on the environmental impacts, is required to understand and mitigate any adverse effects blue energy installations may have on marine ecosystems.

2 Marine Renewable energies overview

According to the previous deliverables (D3.1.1 and D3.1.2), the marine renewable energies represent different types of technologies which are all solutions for diversifying the energy mix from metropolitan to island territories.

These MRE have many assets, including:

- High potential of development;
- Social acceptability relatively higher at sea compared to terrestrial;
- Different types of application from electricity generation to renewable cooling and energy storage;
- Synergies with other maritime activities.

MRE have the potential to enhance the efficiency of harvesting the European energy resource, minimize land-use requirements of the power sector and reduce the European greenhouse gas emissions.

The Mediterranean bears 30% of global sea-borne trade in volume from or into its more than 450 ports and terminals, and a quarter of worldwide sea-borne oil traffic. Its coasts are home to more than 150 million inhabitants, a figure which doubles during the tourist season.

Taking into considerations these factors and the lack of terrestrial space, MRE are an appropriate answer to address these challenges even if at this stage, the different type of MRE are limited or at early stages of development.

2.1 Offshore Wind Energy

2.1.1 Definition

Offshore wind with fixed foundations (the only commercial offshore wind farms) are now in a phase of sustained growth in northern Europe, with an installed capacity already reaching 2GW, and projects currently under construction exceed 4GW; The annual market could exceed the 10 billion euros next year.

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. The technology of the float allows to address much greater depths, and thus to get rid of a certain number of limits.

The floating offshore wind turbine appears to be the one offering the strong market potential in the short and medium term.

2.1.2 Adaptation to the Mediterranean context

In the Mediterranean, practically no important installations of wind turbines with fixed foundations are possible.

The development of floating offshore wind turbine market responds on the one hand to specific characteristics arising from the technologies currently being developed and on the other hand, to the market potential of the offshore wind laid on sea floor, which is technologically more mature and therefore in the short term economically more attractive.

Floating offshore wind appears to be particularly adapted to the Mediterranean (continental shelf, high depth) but obviously if the potential sites are windy. It is particularly the case of Gulf of Lion.

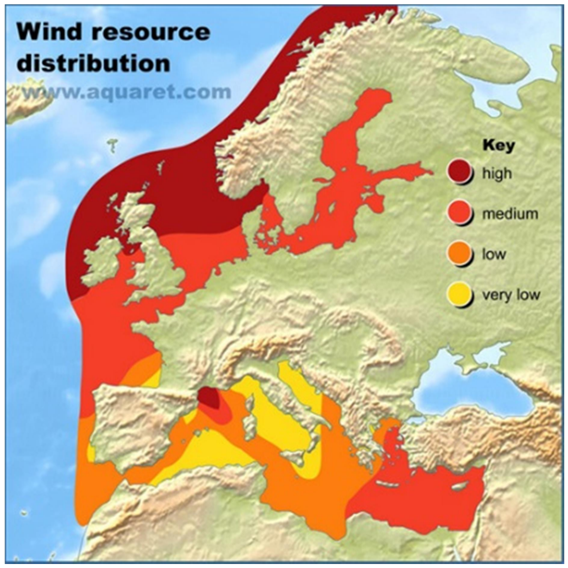

Figure 1 Wind resource potential in Europe
(source aqua-RET project)

On the basis of wind and natural data (speed, duration, depth, etc.), numerous constraints must be taken into account as maritime traffic, air traffic (radar guidance), fishing, etc. To illustrate these constraints, the maps of the Gulf of Lion below show the potential of the wind to the left and the map of the constraints to the right. As a result of this analysis, the selected zones are very small compared to the whole Gulf of Lion which is very favorable to the wind energy at sea. The lesson to remember is that the observation of the natural elements (wind, currents, etc.) is only a preliminary step in determining the potential of these energies.

Figure 3 Wind potential in Gulf of Lion

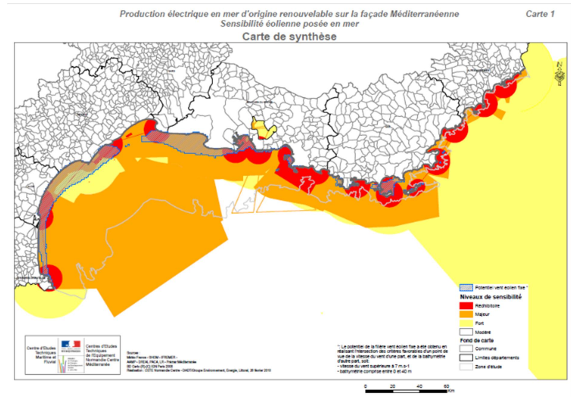

Figure 2 Selected areas for offshore wind in the Gulf of Lion

2.2 Tidal Energy (tidal range and tidal current)

2.2.1 Definition

Tidal energy includes both tidal range and tidal current. Tidal range 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. Although tidal range is proven technology with long-term viability, the environmental implications of any new scheme are prohibitive in the vast majority of scenarios. Tidal range structures are also characterized by high investment costs.

The La Rance Tidal Power Plant in France, with its capacity of 240MW on the estuary of the Rance River in Brittany, France, has been operational since 1966 making it the world's oldest and second biggest tidal power station (after the more recent Sihwa Lake Tidal Power Station in South Korea with a capacity of 254MW) The renewable power plant, currently operated by Électricité de France (EDF), has an annual generation capacity of 540GWh (0,1% of French electricity production).

Tidal current generation involves installing turbines underwater in fast flowing tidal streams. Tidal current technology has been proven technically feasible, although costs must be lowered in order to compete with other renewable energy sources. (E.g. the MeyGen Tidal Energy Project located in Scotland, is currently the world's biggest underwater tidal turbine power project under development with a capacity of 86MW)

Tidal streams are created by the constantly changing gravitational pull of the moon and sun on the world’s oceans. Tides never stop, with water moving first one way, then the other, the world over. Tidal stream technologies capture the kinetic energy of the currents flowing in and out of the tidal areas. Since the relative positions of the sun and moon can be predicted with complete accuracy, so can the resultant tide. It is this predictability that makes tidal energy such a valuable resource.

The highest (spring) tidal ranges are generated when the sun, moon and earth are in line. Water flows in greater volumes when attracted by this combined gravitational pull. The lowest (neap) tidal ranges are generated when the sun, moon and earth describe a right angle. The split gravitational pull causes water to flow in lesser volumes.

Tidal stream resources are generally largest in areas where a good tidal range exists, and where the speed of the currents are amplified by the funnelling effect of the local coastline and seabed, for example, in narrow straits and inlets, around headlands, and in channels between islands.

2.2.2 Adaptation to the Mediterranean context

To allow a realistic implementation of systems in the Mediterranean, tidal turbines need a stream speed of at least 1.5-2 m/s- in order to be effectively operating. As shown in the below illustration, some areas like Dardanelles, Gibraltar and the strait of Messina could have a potential for the exploitation of tidal energy (current). However, some more research and measurement are needed and expected. Tidal range are however not conceivable and adapted to the Mediterranean.

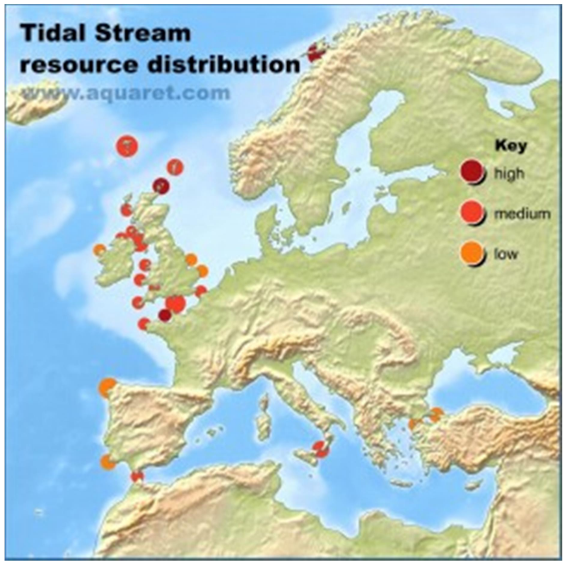

Figure 4 Tidal stream resource distribution in Europe (source aqua-RET project)

2.3 Wave Energy

2.3.1 Definition

Technology in wave energy is still being proven. The optimum technological model is yet to be defined. Several pioneering players have built up prominent positions while new entrants are arriving to the market. The segment is regarded by the European Commission as entering the introductory market stage.

Waves are formed by winds blowing over the surface of the sea. The size of the waves generated will depend upon the wind speed, its duration, and the distance of water over which it blows (the fetch), bathymetry of the seafloor (which can focus or disperse the energy of the waves) and currents. The resultant movement of water carries kinetic energy which can be harnessed by wave energy devices.

The best wave resources occur in areas where strong winds have travelled over long distances. For this reason, the best wave resources in Europe occur along the western coasts which lie at the end of a long fetch (the Atlantic Ocean). Nearer the coastline, wave energy decreases due to friction with the seabed, therefore waves in deeper, well exposed waters offshore will have the greatest energy.

There are many designs being pursued by developers to harness the power of waves:

- **Attenuator:** A floating device which operates parallel to the wave direction and effectively rides the waves. These devices capture energy from the relative motion of the two arms as the wave passes them;
- **Point absorber**: a floating structure which absorbs energy from all directions through its movements at/near the water surface. It converts the motion of the buoyant top relative to the base into electrical power. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors;
- **Oscillating wave surge converter**: It extracts energy from wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves;
- **Oscillating water column**: It is a partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of the airflow. The rotation of the turbine is used to generate electricity;
- **Overtopping/ Terminator device**: It captures water as waves break into a storage reservoir. The water is then returned to the sea passing through a conventional low-head turbine which generates power. An overtopping device may use ‘collectors’ to concentrate the wave energy;
- **Submerged pressure differential**: These 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 in the device. The alternating pressure pumps fluid through a system to generate electricity;

- **Bulge wave:** This technology consists of a rubber tube filled with water, moored to the seabed heading into the waves. The water enters through the stern and the passing wave causes pressure variations along the length of the tube, creating a 'bulge'. As the bulge travels through the tube it grows, gathering energy which can be used to drive a standard low-head turbine located at the bow, where the water then returns to the sea
- **Rotating mass**: Two forms of rotation are used to capture energy by the movement of the device heaving and swaying in the waves. This motion drives either an eccentric weight or a gyroscope causes precession. In both cases, the movement is attached to an electric generator inside the device.

2.3.2 Adaptation to the Mediterranean context

Sea waves and swell are present in the Mediterranean, but the current generated is not favourable enough for the production of energies in large quantities (short wave = not important Fetch) and not very sustainable over the time. However, production systems can be deployed locally, particularly for insular territories in order to provide them with additional energy, as the import of fossil fuels is expensive, but also in addition to other renewable energies such as solar or wind. The potential is however very limited in the Mediterranean.

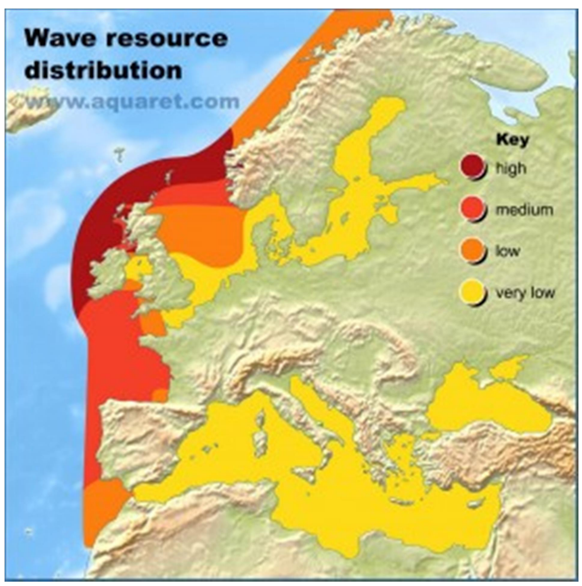

Figure 5 Wave resource distribution in Europe
(source aqua-RET project)

2.4 Ocean Thermal Energy Conversion

2.4.1 Definition

Ocean Thermal Energy Conversion (OTEC) is a marine renewable energy technology that harnesses the solar energy absorbed by the oceans to generate electric power. The sun's heat warms the surface water a lot more than the deep ocean water, which creates the ocean's naturally available temperature gradient, or thermal energy. OTEC uses the ocean's warm surface water with a temperature of around 25°c to vaporize a working fluid, which has a low-boiling point, such as ammonia. The vapor expands and spins a turbine coupled to a generator to produce electricity.

The vapor is then cooled by seawater that has been pumped from the deeper ocean layer, where the temperature is about 5°c. That condenses the working fluid back into a liquid, so it can be reused. This is a continuous electricity generating cycle. The efficiency of the cycle is strongly determined by the temperature differential. The bigger the temperature difference, the higher the efficiency. The technology is therefore viable primarily in tropical areas where the year-round temperature differential is at least 20°c.

2.4.2 Adaptation to the Mediterranean context

Sea-water air conditioning (SWAC) is already developed in the Mediterranean context especially in the French Mediterranean coast.

It is an innovative and environmentally friendly form of air conditioning that uses a renewable source of cold water located nearby. The island's territories, for instance are ideal places for the deployment of this technology. Deep sea water is pumped to the surface. The cold water being denser than the hot water, it masses deeply while only the surface layers are warmed by the sun. The water then passes through a heat exchanger system and cools the water distribution network of the air conditioning. During this stage, the pumped water warms up by a few degrees. 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.

2.5 Salinity gradient energy

2.5.1 Definition

Salinity gradient energy (SGE) is a renewable energy source that can be harnessed from the controlled mixing of two different salt concentration water masses. When a river runs into a sea, the mixing of fresh and seawater occurs. Post stated that from each meter cubic of fresh river water, a 2.3 MJ of work could be extracted. This value is equivalent to the potential energy released by the fall of meter cubic of water of a 225m high dam. The International Energy Agency in its report estimated the theoretical SGE potential at river mouths to be 15,102TWh/year, or equivalent to 74% of the global power consumption in 2011. However due to various physical and environmental constraints it has been shown by Alvarez-Silva et al. that practically 625TWh/year of SGE are globally extractable from river mouths, equivalent to 3% of global power consumption. Although this is much smaller than the theoretical potential, is still a significant amount of clean energy.

Approximately one third of river mouths with an energy density greater than 2.0 MW/m^3 (i.e. energy potential per cubic meter of fresh water) are located in the Mediterranean Sea and one third in the Caribbean Sea and Gulf of Mexico. Therefore these two regions have better oceanographic conditions for harnessing SGE.

More important, as inflowing of rivers into seas is a continuous process, SGE could potentially generate base-load power, if cost-effective technologies can be developed.

The following illustration depicts the global distribution of the extractable SGE resources. As can be seen, suitable river mouths for SGE production sites can be found all over the world.

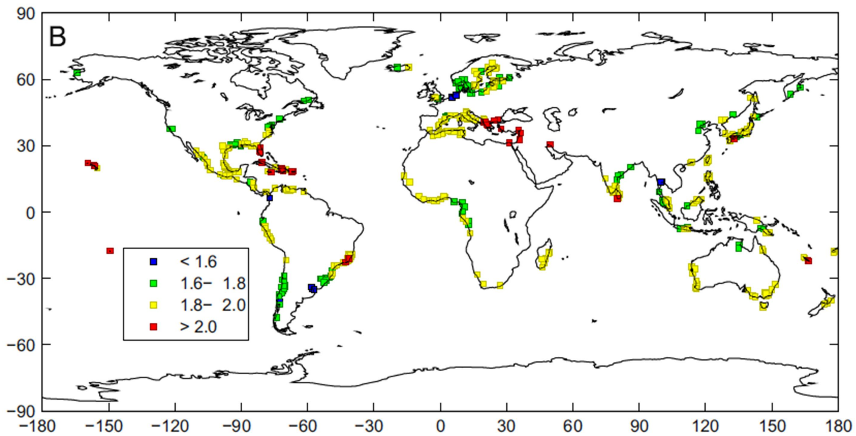

Figure 6 Global map of extractable SGE resources (TWh/y)

2.5.2 Adaptation to the Mediterranean context

Concerning salinity gradient solutions, three potential river mouths located in the Mediterranean Basin of which two on the European soil have a high extractable energy. The two river mouths on the European soil are that of the Rhone River in France and Po River in Italy. However, since salinity gradient energy is still a concept under development, further research is needed for this technology to uptake.

2.6 Technology stakes of Marine Renewable Energies

2.6.1 Withstand rough conditions at sea

To date, the business models for MRE systems define a duration of operation of around 20 to 30 years in an extreme environment. Thus, it is necessary to focus on the resistance of these systems in rough conditions (reliability, choice and design of the adapted materials, means of fight against corrosion and marine biofouling). The valuation of the expertise coming from the oil offshore should be sought. These problems require knowing by the instrumentation the actual loading conditions under operational conditions in order to integrate them into the fatigue dimensioning models, in particular (long-term behavior under cyclic and static loads). Moreover, knowledge of the behavior of materials and their durability in an extreme marine environment must be refined, new materials can also be developed.

It is necessary to take into account of course the phenomena of corrosion and fouling: materials, protection, etc.

2.6.2 Anchors and foundations

In order to reduce the cost of anchoring and installation / recovery systems and the interface between foundation/nacelle, it is necessary to develop solutions to each type of MRE systems, reliable and adapted to the surrounding environment (current, waves, nature of the sea floor, etc.) with solutions allowing rapid and safe interventions. These solutions require a good knowledge of the environment in order to determine the soil / structure interactions, particularly in extreme conditions, and to develop suitable recognition methods.

2.6.3 Processes and means of installation

These demonstrators are not conceived for industrial deployment. The installation of pilot farms, and then their maintenance, will allow an in-depth reflection on the organization of the offshore installation and maintenance works, the dedicated means to implement and the overall economy of this phase.

2.6.4 Underwater electric architecture

The underwater electrical architecture of farms producing marine energies has been identified as a stake in development of the sector. For example, the few existing solutions in the submarine connector market have been developed for the petroleum sector at costs not suited to the economic models of industrial MREs. In addition, the connectors are limited in voltage. Submarine connectors are used to ensure the interconnection of production systems. It is necessary to have reversible connection solutions adapted to the submarine environment with strong current and strong agitation. In order to facilitate the recovery of the tidal turbines for maintenance, the high-voltage sealed disconnection-reconnection must be able to be carried out under the surface, in very short times (taking advantage of periods of spread, for example for the hydro- favorable Sea. Reliable and economical submarine electrical connection solutions still need to be developed.

2.6.5 Submarine cables

For the development of MRE commercial projects, it will be necessary to develop underwater cable solutions adapted to the environment of the sites in terms of stability to the bottom and protection, in particular to dredging, making it possible to limit the costs of supply and installation. Solutions on dynamic cables and umbilical should be proposed in order to facilitate the recovery of systems.

2.6.6 Performance of production systems

MRE projects are facing major investments, some of which are linked to the connection work which are non-compressible, the cost of electrical KWh produced and its reduction throughout the learning phases is a key element in the development of the MRE sectors. Demonstrators have to reduce their costs in order to take part in the current energy mix. The industrialization of manufacturing processes will also reduce the production costs of MREs.

2.6.7 Operation and maintenance

The operation and maintenance of marine energy farms is clearly one of the major challenges for the development of the sector, which will not be able to use existing solutions from offshore oil sector, which are expensive, not optimized in the MRE context and which are not widely available. They will require solutions adapted to the management of the port infrastructures and the associated logistical means but also tools that will allow to plan optimally the interventions to reduce the costs of preventive maintenance operations for example.

2.7 Non technologic stakes

Non technologic stakes are related to the development of tools for the acquisition, validation and analysis of weather-ocean and environmental data and to the integration of MREs in the maritime space as a new use

2.7.1 Estimation of exploitable resources

The evaluation of the exploitable resource and the predictability of electricity production in the short and medium term (from a few hours to a few days) is a major challenge for the location of future marine power generation, for the management of the electricity produced as well as for optimizing its insertion in the energy systems, for the organization of the operation and the maintenance according to the ocean-meteorological windows.

Moreover, with a view to optimal management of the national and international electricity grid, the predictability of long-term electricity generation (from the season to several years) is also a major challenge. The estimation of marine resources is a major challenge because of the potentially high penetration rates of the MREs combined with the fragility of non-interconnected electrical systems in island areas.

The estimation of the exploitable resources in Mediterranean is the object of the Deliverable D3.1.2 Diagnostic study of the MRE resources potential.

2.7.2 Environmental impacts

The effects of the presence of structures (submerged, semi-submerged or floating), in particular on the propagation of currents and waves, have been studied for various applications in the coastal sea. These effects can have strong impacts on sediment transport and on marine ecosystems. Existing tools can be adapted to the specific case of MRE systems. New tools will also emerge due to the specificity of the sites operated by MREs. More generally, the qualification and then the quantification of all the potential environmental impacts associated with the deployment of such systems must be documented by long-term follow-up and must take into account the specificity of the installations and surrounding environments that will require the development of specific instrumentation. It may also be noted that MREs will enable scientists to acquire new knowledge about marine ecosystems through, for example, the development of protocols recognized and implemented during the impact and follow-up studies.

2.7.3 Socio-economic impacts

The MRE represent a new activity in an environment already provided with many other activities (fishing, maritime traffic, yachting, extraction of aggregates ...). Their developments will require:

- To identify the anthropic activities concerned by the implementation of MRE and to define their modalities in space and time;
- To identify the practices of the various actors in the use of a limited maritime space in order to develop a hierarchy of constraints;
- To test systems for monitoring occupational and recreational activities on a limited number of sites;
- To model the course of activities in space and time using digital geographic information processing algorithms and modelling tools;

- Propose methods for assessing the impacts of the development of the MRE, the countervailing measures to be implemented, their associated costs and their effectiveness against ecological, economic and social indicators.

2.7.4 Safety and security

The MREs will have to demonstrate that the equipment and installation procedures of the systems guarantee the safety of the workers and the goods during all phases of the project, from construction, maintenance and dismantling. Beyond the problem of safety, the status of the workers on the different stages remains to be defined precisely. The areas occupied by the MRE shall be instrumented so as to reduce to the maximum the probability of collision with other users of the sea (fishing, shipping, boating, etc.).

3 Marine Renewable Energies Value Chain

3.1 Value chain

Figure 7 - Overall Marine Renewable Energy Value Chain

3.1.1 Studies and design

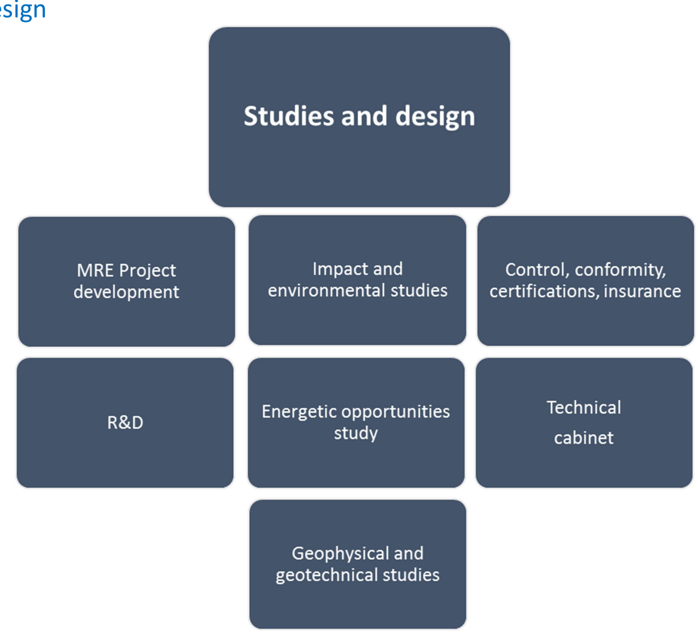

Figure 8 - Studies and Design Phase

3.1.2 Manufacturing components

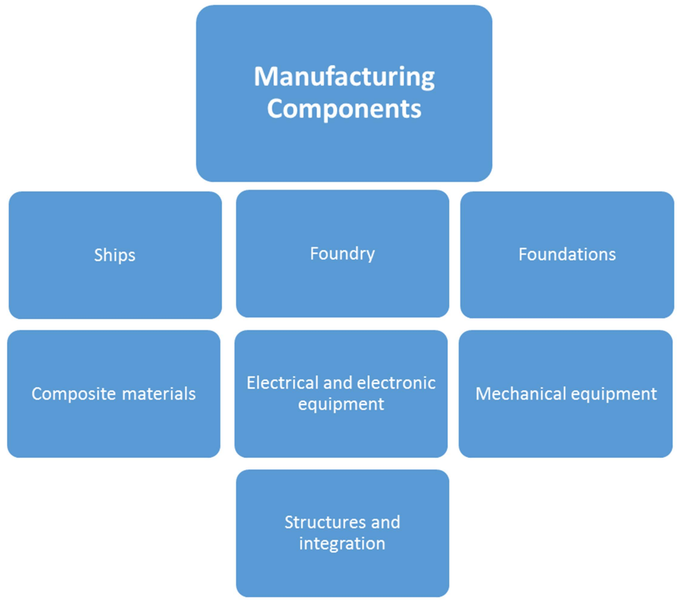

Figure 9 - Manufacturing Phase

3.1.3 Installation and construction

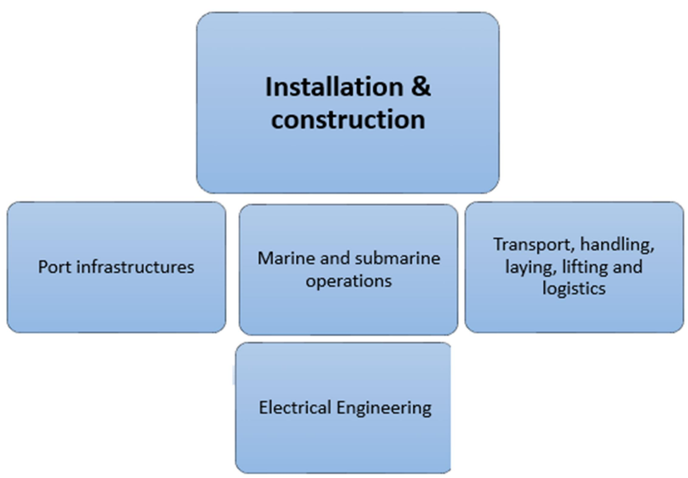

Figure 10 - Installation and construction Phase

3.1.4 Operation and maintenance

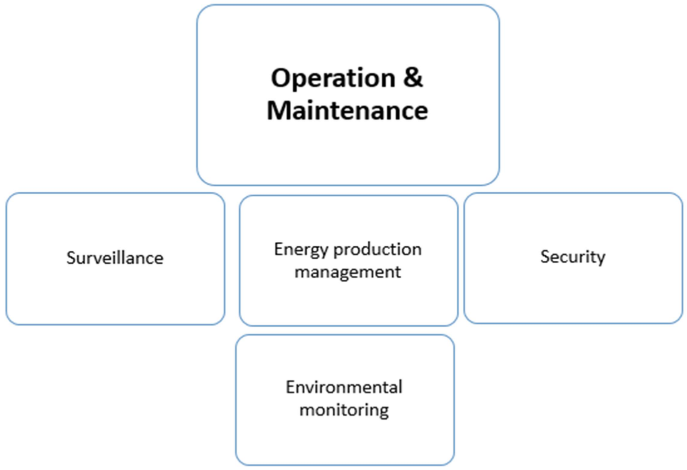

Figure 11 - Operation and maintenance phase

3.2 Key actors

Several key actors are involved in the MRE value chain:

- **Power suppliers**: Utilities and independent power producers;
- **Technology developers:** Marine energy innovators, designers and developers;
- **Manufacturer and suppliers:** Manufacturers and component suppliers;
- **Electricity network:** Operators managing the electricity networks
- **Development services**: Resource assessment/ modeling, mapping, environmental impact assessment, sea floor environmental assessment and related marine safety and supply consults, permitting, approvals planning, marine corrosion consulting;
- **Supporting technology providers**: Wave/ tidal current/ wind resource measurement, environmental monitoring devices, buoys, underwater remote vehicle operators/ owners, technical resource monitoring and data collection;
- **Engineering and construction:** Safety management, work platforms, underwater operators, cabling and electrical interconnect for marine operations, anchoring systems, floating devices, engineering firms, on-site supervision and management;
- **Operations and maintenance:** Operational monitoring, transportation, port facilities and marine operators with related experience (including transport vessels and certified diving teams) with the ability to do deployment/ removal, emergency repair, mitigation strategies and asset management;
- **Research and development**: Academia, private and public research organisations;
- **Policy and industry support**: Government policy development, industry associations and non-governmental associations;
- **Business services**: Legal, financial, insurance, business, communications, market research and training activities.

4 Demonstration projects in Marine Renewable Energy

Demonstration projects all contribute, at different but essential levels, to the maturation of MRE technologies and the preparation of their deployment on a commercial scale:

- Technological brick projects make it possible to test and validate technological developments, essential to improve the reliability and the performance of technologies while reducing their costs;
- The validation of demonstrators allows to continue the process of defining the relevant systems in order to eventually converge towards a limited number of technologies.

4.1 Offshore wind energy demonstration projects

4.1.1 Floating offshore pilot farms in France

Through a participatory process, 3 areas have been selected in the Mediterranean (1 in the Atlantic Ocean) for the implementation of wind farm demonstrators (2014).

A call for the implementation of offshore wind farms was launched in 2015 (M€ 150):

- 3 to 6 wind devices per farm, 5MW minimum
- Be connected to the grid
- Demonstrator for 2 years + 15-20 years exploitation in case of success of the pilot
- Environmental monitoring during the construction phase + 5 years in exploitation phase

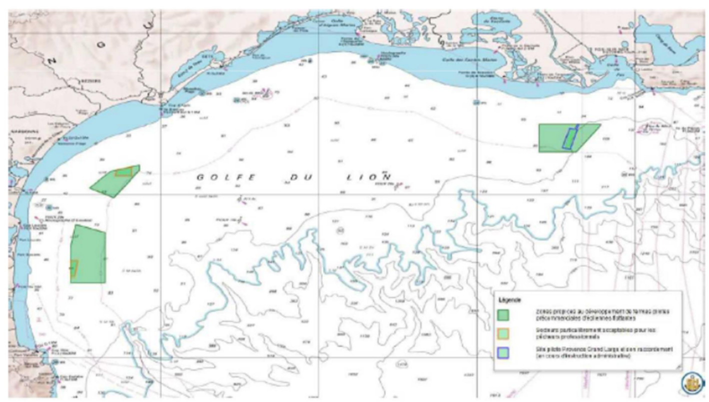

Figure 12- Location of the 3 French pilot wind farms

The 3 pilot projects selected are the following with the ambitious objective to be fully operational in 2020:

- **EOLMED project** in Gruissan led by QUADRAN (partners: Ideol, Bouygues TP, Senvion) 4 wind turbines of 6,15 MW;
- **PGL project** "**Provence Grand Large"** in Faraman area led by EDF EN (partners: Siemens, SBM, IFP EN);
- **EFGL project** "**Les Eoliennes Flottantes du Golfe du Lion"** in Leucate area led by Engie (Partners: caisse des dépôts, Principle Power, Eiffage and General Electric) 4 wind turbines of 6MW.

Eco-design of EFGL project offshore wind energy with integration of ecological engineering solutions

The field of Ecological Engineering is in full emergence in the development of floating offshore wind sector. The environmental approach is fully integrated in the three Mediterranean pilot wind farms.

In the Port Leucate project led by ENGIE, a French SME, Ecocean is responsible to develop solutions to preserve and enhance biodiversity around these MRE devices.

ECOCEAN and its partners have been investing solutions for many years in the marine environment by setting up R&D projects for the preservation of biodiversity and the restoration of coastal habitats especially around solutions for the protection of juvenile fish. This work made it possible to develop solutions to recreate habitats and facilitate the installation of biodiversity on to docks and pontoons in marinas and commercial harbors (solutions today validated scientifically and marketed).

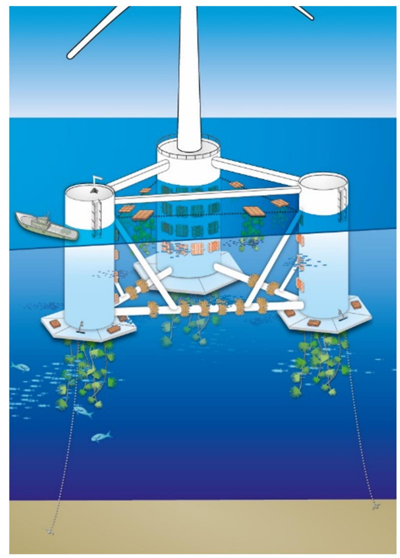

Figure 13 ©Ecocean

Thanks to these initial results, R&D innovations are being carried out today to meet new needs, on other types of maritime infrastructures: dikes, waste water outfalls, mooring lines ... but also on floating platforms of offshore wind turbine. It is thus that reflections are being made which aim at improving the attractiveness of these infrastructures for biodiversity and the development of the biodiversity of infrastructures without affecting the technical characteristics of the float. These reflections are under way in the framework of the project "The floating wind turbines of the Gulf of Lion" (LEFGL), carried by ENGIE, EDPR and the Caisse des Dépôts with the objective to increase the attractiveness of biodiversity and the natural production of fish, particularly the species of fishing interest.

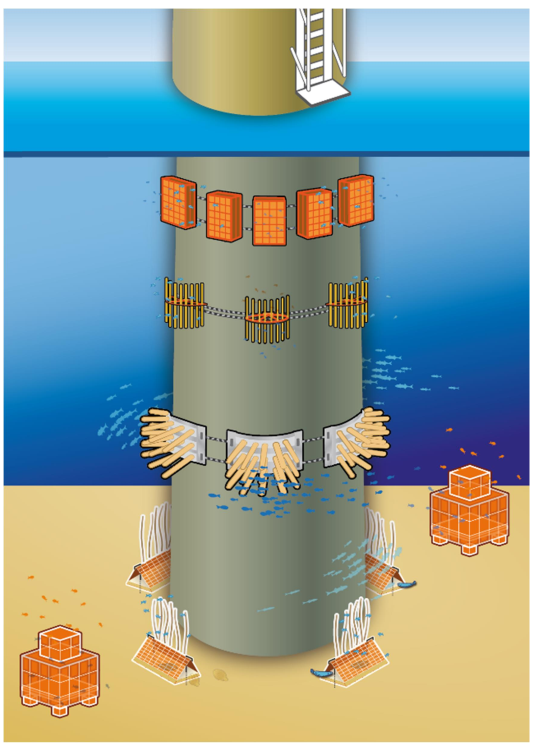

Figure 14 ©Ecocean

4.1.2 FLOATGEN

Budget: K€ 36.339

Funding programme: H2020

Partners: GAMESA INNOVATION AND TECHNOLOGY S.L with IDEOL, UNIVERSITAET STUTTGART, ACCIONA WINDPOWER SA, NAVANTIA S.A., DR TECHN OLAV OLSEN AS, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V., RSK ENVIRONMENT LIMITED, Greenovate! Europe, ACCIONA ENERGIA S.A

Date: 2013-2016

Description: The objective of the FLOATGEN project is to demonstrate the technical and economic feasibility of two different multi-megawatt integrated floating-wind turbine systems in deep waters, never applied before to Mediterranean Sea conditions, in order to extend deep offshore wind resources and demonstrate decrease of costs for electricity generation down to competitive level. The project will also assess, compare and obtain conclusions about performance of such two different combinations of wind turbine and floating structure technologies to get the knowledge to improve performance of the future replication projects of these technologies.

To reach such objectives, the project will join a 10 partnership European consortium, industry led by three global wind turbine manufacturers and wind farm operators, GAMESA and ACCIONA WINDPOWER and ACCIONA ENERGIA, in cooperation with the floating systems developers IDEOL and NAVANTIA, the contribution of OLAV OLSEN and STUTTGART UNIVERSITY for structural design, and supported for monitoring, environmental and dissemination activities by FRAUNHOFER-IWES, RSK GROUP and GREENOVATE.

4.1.3 AEROPITCH

Budget: K€ 900

Funding programme: Provence Alpes Côte d'Azur Regional Council

Partners: EOLFI with Coreti and IRPHE

Date: 2014

Description: The goal of the project is to conceptualize mechanical devices and control systems allowing the monitoring of the energy produced by a VAWT (Vertical Axis Wind Turbine). The project aims to develop a system allowing the start-up of vertical axis wind turbines without intervention of the generator, improving their aerodynamic performance, regulating the efforts on the generator for strong winds. It consists of the definition of the blade profile, of the blade pitch equipment acting on the profile as a function of the position of the rotating blade and of the associated control system. This device is part of VERTIWIND demonstrator.

4.1.4 BLIDAR

Budget: K€ 2.164

Funding programme: FUI & regional authorities

Partners: NKE with EOLFI, Ifremer, IRSEEM

Date: 2011

Description: The BLIDAR project aims to complete offshore measurement missions to predict the offshore wind farm's annual energy yield and assess the profitability of the wind farm. It also aims to provide an alternative means of calculating offshore mast measurements. By reducing the environmental and visual impact, it will show up to an altitude of 200m and can be installed regardless of the water depth at a competitive price.

The BLIDAR project aims at developing a metocean data measurement buoy for the resource assessment (especially wind conditions using a LIDAR) of offshore wind projects. "Floating lidars" can accurately measure wind characteristics from 40 to 200m high, in a broad range of water depths, for the tenth of the cost of an offshore met mast. The BLIDAR project resumed in 2014 for a two-year program. Its last phase will consist in installing a prototype at sea to validate its performance.

4.1.5 VERTIWIND

Budget: K€ 16.800

Funding programme: Phase 1 (budget 3200K€): EUROGIA+ / Phase 2: ADEME as part of AMI EMR

Partners: NENUPHAR Phase 1: ALSTOM Hydro (Spain) - Converteam / Phase 2: EDF EN, EDF RD, Converteam, Seal Engineering, Bureau Veritas

Phase 1 : ENSAM Lille, TU DELF (Netherland), Université du Pays Basque (Spain) / Phase 2 : ENSAM Lille, ISITV

Date: 2011

Description: The VERTIWIND project aims to develop and implement an innovative concept of floating vertical axis wind turbines, which represent a technological breakthrough in the landscape of offshore wind farms, which are almost all designed on a traditional horizontal axis. Perfectly adapted to the marine environment, the concept has the following advantages:

- Fitted with lower masts, these turbines have a lower center of gravity which reduces the cost of the floating structure and the impact on the landscape;
- Robust and simple (neither gearbox nor steering system for the mast or the blades), these turbines are more reliable and therefore more suitable for the marine environment;
- Smaller sizes than conventional wind turbines will facilitate safer industrial deployment by avoiding the main problems in the offshore wind sector (e.g. maritime resources, organization of the construction phase).

This new floating concept eliminates the current limit of 35 meters depths for offshore wind farm foundations. Therefore, the location of the projects will not be constrained by the seabed (e.g. underwater shelves, raised seabed areas) but maintain a balance between use, environmental sensitivity and the stated objective of competitive energy costs . A 2MW floating offshore wind turbine has been built and tested between 2011 and 2012. The aim is to expand the market for offshore wind farming, currently limited to countries with vast continental shelves and with depths less than 35 meters mainly located in the north of Europe.

4.1.6 OCEAGEN

Budget: K€ 19.900

Funding programme: ADEME

Partners: IDEOL with BOUYGUES TP, IFSTTAR

Date: 2014

Description: Oceagen is a research and development project dedicated to the qualification of new components for the mooring system. Ideol is the pilot for this and is working in partnership with IFSTTAR (the French institute of science and technology for transport, development and networks) responsible for conducting qualification tests on innovative components (cables, mooring chains and connection parts).

On a wider scale, this project allows the structuring of an industrial sector with a strong technological component and the costs of the floating wind turbines to continue being reduced. Surrounded by industrial partners such as Arcelor Mittal, LeBéon Manufacturing, Areva Le Creusot...

Launched in November 2014, Oceagen is supported by ADEME through the Investments for the Future programme.

4.1.7 SPINFLOAT

Budget: K€ 4000

Funding programme: H2020

Partners: EOLFI with SSP, Gusto MSC, Université italienne Politecnico Di Milano, Institut de recherche néerlandais ECN, Laboratoire allemand Fraunhofer IWES

Date: 2014

Description: SPINFLOAT aims to design and develop a prototype of a multi-megawatts wind turbine with vertical axis and variable pitch blades, mounted on a semi-submersible float. The objective is to validate the "rotor - float" prototype in laboratory.

This ambitious program should be carried out by a multidisciplinary European consortium of at least 6 private or public organizations: the Danish leader SSP Technology, the German Fraunhofer IWES laboratory in charge of the generator, the Dutch naval architect GustoMSC, Dutch research institute ECN for aerodynamic numerical simulation and Italian University Politecnico Di Milano for wind tunnel tests. The project will be led by the French specialist in wind energy EOLFI.

4.1.8 HYDROFAN

Budget: K€ 1879

Funding programme: General council Brittany

Partners: DCNS, Lorient [Project Developer], Coriolis, Quéven, Université de Bretagne Sud, LIMATB (Laboratoire d'Ingénierie des MATériaux de Bretagne) sur l'éco-conception des matériaux, Lorient/Ploemeur

Date: 2014

Description: The HYDROFAN project involves developing an innovative wind-turbine blade from composite material, produced using automated fibre placement and resin transfer methods. The exploitation of wind energy will ultimately require several tens of thousands of turbines to be installed worldwide and this means that wind-turbine suppliers must be capable of offering mass-produced, high-performance, low-cost products.

The HYDROFAN project needs to provide the technological breakthrough required to perfect automated draping processes, originally developed for aeronautical construction, and resin transfer impregnation in mass-production applications. The object of the HYDROFAN project is therefore to successfully manufacture a wind-turbine blade demonstrator, which is suitable for mass production and is cheaper than those currently available, using an innovative manufacturing method. The results will provide the basis for deploying a tool for mass-producing wind-turbine blades.

4.1.9 Floating environmental friendly desalination unit

Budget: 2.872.312 €

Funding programme: European Regional Development Fund

Partners: UNIVERSITY OF THE AEGEAN, LAMDA SHIPYARDS and Marine Services B. & N. S.A, TECHNAVA S.A., REGION OF NORTH AEGEAN, ALGOSYSTEMS S.A., REFLEXION S.A., INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS, CENTRE FOR RENEWABLE ENERGY SOURCES, I. KOUIMANIS & ASSOCIATES, HELLENIC REGISTER OF SHIPPING S.A.

Date: 20/11/2003 - 30/6/2007

Description: This project involved the study, design and construction of a floating autonomous system for seawater desalination powered by renewable energy. The system was designed in order to operate in an off-shore environment and is anchored off Iraklia in the Aegean Sea. The reverse osmosis desalination unit is powered by a 30 kW wind turbine and a photovoltaic system and is able to deliver up to 70 m^3 of fresh water per day to the nearby island of Iraklia via a pipe. No chemical additives are used in the desalination process. The whole plant works on a special floating platform that measures 20 x 20 meters. The system is adapted to operating with varying power input for maximum exploitaiton of wind energy. Furthermore, it can remotely controlled and operated via a SCADA system.

4.2 Tidal Energy demonstration projects

4.2.1 URABAILA

Budget: K€ 5000

Funding programme: FUI

Partners: BERTIN Technologies, EDF, K-EPSILON, UFO-Boat, CERENIS, Energie de la Lune, ICNERGIE, GPMB, EPOC, M2P2

Date: 2013

Description: Hydrokinetic Generator using one or more cross-flow marine turbines. The project is structured around two phases and a network of regional players in the PACA and Aquitaine areas.

As part of Phase 1, it will carry out the industrial research on technological components (rotors, flow accelerators, gearboxes, generators) for eco-designed, sustainable, high energy efficiency. The different technology options considered will be implemented on low kilowatt models and tested at SEENEOH (one of the trial sites of France Energies Marines) in a perfectly designed environment representative of a natural setting.

As part of Phase 2, the technological solutions adopted will be implemented in two pilot sites with a dozen or so kilowatts. It will aim to narrow down the choices from the point of view of performance and dependability for two specific configurations (channel, estuary). For the Gironde sites scientific knowledge will be brought to bear on understanding the turbines' effects on the sedimentation of a natural estuarine environment. The feedback garnered during this phase will:

- Establish the operating range of the machine architecture;
- Establish regulatory, financial and insurance recommendations necessary for the implementation of the project.

4.2.2 MARENERGIE

Budget: K€ 900

Funding programme: Ademe, Conseil régional de Bretagne, Brest métropole, Quimper Communauté, Conseil départemental du Finistère

Partners: Hydrohelix Energies, Quimper [Project Developer], Dourmap, Brest, InVivo Environnement, La Forêt-Fouesnant, Sofresid Engineering, Guipavas, EGIM, Marseille, IRENav, Lanvéoc, UBO, Brest

Date: 2005

Description: Using tidal power to produce electricity is the concept behind the Hydrohelix Company which has brought together eight businesses and research centres under the umbrella of the MARENERGIE/SABELLA project. The project partners are preparing to instal the first 200 kW hydro generator – a large-diameter turbine linked to an electric generator – which will transform the kinetic energy of tidal currents into electricity and then convey it by cable to the coast. After a trial period, it will be possible to connect a 1megawatt production unit comprising five hydro generators to the network.

The use of tidal currents, which produce predictable levels of energy as they are influenced by the phases of the moon and not subject to the vagaries of the weather, is just one response to the issues of declining fossil fuel stocks, diversification of energy sources and exploiting forms of renewable energy which do not generate greenhouse gases. The MARENERGIE/SABELLA project aims not only to develop new French technology for use along our own coasts, but also for deployment abroad.

4.2.3 MEGAWATTBLUE

Budget: K€ 4 535

Funding programme: ERDF Brittany region

Partners: Guinard Energies, Brest [Project Developer], Bernard et Bonnefond, Saint-Étienne, ENSTA Bretagne, Brest, Ifremer, Brest

Date: 2014

Description: MegaWattBlue® is a 2nd generation marine turbine with a free-slewing ducted current nozzle.

- Focusing on the cost price per MWH :
  - The cost of industrial equipment being mainly due to weight, we therefore need a machine with a lower Kg / kWh ratio than that of existing equipment. To achieve this, it is essential for us to aim for the best reasonable energy efficiency, and optimal reliability and productivity.
- Minimizing risks and costs (CAPEX and OPEX)
  - By using as many well mastered technologies as possible, in Brittany in particular: mechanical and naval engineering, electrical manufacturing, boilermaking, offshore, maritime works…
- Offering a range of modular solutions to suit the consumer's energy requirements
  - Marine turbines built in partnership with the specialists of various "energy converters", by using their available standard products and by offering system integration engineering on the basis of the "one stop shop" concept

One of the technical advantages of this technology is, for example, the use of a nozzle. Without a nozzle, the theoretical recoverable power is 59 % of the available hydrodynamic power at the most (Betz limit). The nozzle enhances the energy harnessed by a factor of 1.4. Yet the produced kinetic power depends on the cube of the speed: the power is thus multiplied by 2.7.

4.2.4 ORCA

Budget: K€ 27 949

Funding programme: ERDF Brittany

Partners: Alstom France, Nantes, Grenoble et Paimpol [Project Developer], EDF, Paris et Paimpol Bréhat, Nexans, Lyon, Sector, Lyon et Paris, Stat-marine, Nîmes et La Seyne-sur-Mer, STX France Solutions, Nantes et Lorient, CETIM, Nantes, École Centrale de Nantes, Nantes, ENSAM, Chambéry, Ifremer, Brest, INP, Toulouse, IUEM AMURE, Laboratoire "Aménagement des Usages des Ressources et des Ecosystemes marins et littoraux", Brest, IUEM LEMAR, Laboratoire des sciences de l'Environnement MARin (LEMAR), Brest, IUEM, Laboratoire Domaines Océaniques (LDO), Brest

Date: 2011

Description: The aim of the ORCA project is to trial, at a pre-selected site at Paimpol Bréhat, a full-scale version of all the principal elements needed to create high-power tidal turbines. The project comprises the study, design, manufacture, installation, testing and maintenance of the equipment, as well as studies of environmental conditions. Creating such a machine poses considerable technological challenges in terms of design, logistics, manufacture and installation, as well as non-technological obstacles that are only likely to arise with full-scale demonstration projects. The stakes are extremely high, as success means the development of a wholly innovative form of marine renewable technology, capable of offering tidal farms with an energy output in excess of 100MW.

4.2.5 Magallanes

Budget: N/A

Funding programme: N/A

Partners: Sagres SL, ABB and LEASK MARINE

Date: 2007

Description: The Magallanes project was launched in 2007 in Redondela (Galicia, Spain) with the challenge of developing a technology capable of extracting energy from the tides.

The project was in the final phase of assembly and construction of a full scale prototype of 350 Tm in weight. Sea trials began in late 2015 or early 2016.

Following a research and development phase, Magallanes built and tested in 2014 a first 1:10 scale model, which successfully concluded official trials at the European Center for Marine Energies (EMEC) in the Orkney Islands (Scotland).

The project was based on getting the most efficient and cost-effective method to obtain energy from the tides: a robust and simple installation, capable of producing in any area of the world and with the easiest maintenance system.

4.2.6 KOBOLD

Budget: N/A

Funding programme: financed by the Ponte di Archimede Company and by the Sicilian Region Administration in the framework of EU Structural Funds.

Date: installed in 2001

Partners: ADAG (Aircaft Design & AeroflightDynamics Group) della Università di Napoli "Federico II"

Description: The Enermar Pilot plant is located in the Strait of Messina, along the Sicilian coast, at a depth of 18-25 meters in a site where the expected current velocity is around 2 m/s. The Enermar Plant has been installed in 2001. At 2 m/s the power produced was about 25 kW (the design power is 80 kW). The system consists of a buoyant support platform and the patented Kobold turbine.

The Kobold turbine is a rotor mounted on a vertical shaft, which produces mechanical energy by exploiting marine currents. The platform, designed by the Ponte di Archimede Company, houses the gearbox, a 160 kW synchronous generator and the necessary electrical equipment. The Kobold turbine has a diameter of 6 m and is equipped with three blades with a span of 5 m.

4.2.7 GEM

Budget: N/A

Funding programme: Regione Veneto

Date: 2015

Partners: SeaPower scrl, ADAG (Aircaft Design & AeroflightDynamics Group) della Università di Napoli "Federico II"

Description: GEM is an ocean current energy conversion system, using two horizontal axis hydro turbine mounted on the side of a supporting submersed structure. A first full-scale prototype has been deployed in the Venetian Lagoon, the expected power is about 20kW with lagoon maximum current speed of 1.5 m/s. A full-scale prototype of 500 kW will be installed in the Strait of Messina.

4.3 Wave Energy projects

4.3.1 PYWEC

Budget: K€ 2850

Funding programme: FUI

Date: 2016

Partners: PYTHEAS TECHNOLOGY with GEPS TECHNO, DCNS, ECN (LHEEA), ECN (SEM-REV), ENSTA BRETAGNE, CEA

Description: The project will provide an efficient solution for the recovery and transformation of primary marine energies into electrical energy, by developing a highly innovative piezoelectric generator according to a process patented by the SME PYTHEAS, leader of the project. The generator was identified as the main missing technology brick for the large-scale deployment of the wave energy sector. The demonstrator is currently built and will be tested with a wave generator already in operation on the site SEM-REV at Croisic.

4.3.2 BILBOQUET

Budget: K€ 1 407

Funding programme: FUI & PACA & Bretagne regional authorities

Partners: D2M with CERVVAL, ADENEO, OCEANIDE, BV, JEUMONT, IFREMER, ENIB, AMPERE

Date: 2011

Description: The "Bilboquet" system consists of a guided float which moves with the force of the waves along a floating anchored column. The float is equipped with racks which actuate the gear generators located in a capsule at the top of the column. The lower part of the column is equipped with a weighted part with vertical hydrodynamic damping to provide three anchor points which contribute to higher vertical stability.

The "Bilboquet" is robust and efficient and can be anchored in various depths. A suitable anchoring system allows the construction of power generation farms. The size of the "Bilboquet" can be adapted to environmental conditions (waves and water depth) and the optimization of energy efficiency which ranges from 1,500 to 3,500 kW, with a demonstrator to 120 kW. The project concerns the development of a reduced power "Bilboquet" whose production and sea trials will validate the R&D to date. In addition, the partners will develop a performance simulation method for a "Bilboquet" farm that could be adapted to other sets of renewable energy devices (e.g. offshore wind turbines).

4.3.3 SABELLA

Budget: K€ 13 500

Funding programme: ADEME, ERDF

Partners: Sabella with Bureau Véritas and IFREMR

Date: 2009

Description: The SABELLA technology aims to exploit the hydrokinetic energy of tidal currents to produce electricity from submarine hydrojets. The "D10" project consists in the design and realization of a pre-industrial hydroelectric demonstrator, whose main characteristics are a rotor 10 m in diameter and a power of 500 kW to 1 MW for the hydrokinetics of the site envisaged in the Passage of Fromveur, with a connection on the isolated network of Ouessant.

A prototype worked in the Odet for nearly a year in 2009, demonstrating its reliability and its robustness in the marine environment, while proving via an underwater camera its safety with respect to fish.

These results enabled SABELLA SAS to be selected in 2011 following a call for expressions of interest from Ademe specifically dedicated to marine energies.

A scale 1 machine, the D10, weighing less than 450t was submerged in May 2015 in the Fromveur between the islands of Ouessant and Molène, and connected to the ouessantin network in September 2015. The generator with a power of 1 MW is in direct engagement on the axis of the rotor, without multiplier: it is a guarantee of robustness. Since November 2015, the first kWh produced by the D10 are injected into the ouessantin network.

4.3.4 NORMANDIE HYDRO

Budget: K€ 112 000

Funding programme: ADEME and PIA (Programme d'investissement d'avenir)

Partners: DCNS with EDF EN

Date: 2009

Description: The installation and operation of a 14MW Pilot farm of 7 turbines at Raz Blanchard for 20 years.
The schedule for the project is as follows:

- Study phase (2015): finalization of the technical design of the project and the development of the site, continuation of the consultation, obtaining the necessary administrative authorizations;
- Construction and installation phase (2016/2018): construction and installation of turbines, construction of the farm and connections to the ground electrical network;
- Operation phase over 20 years: operation and maintenance of the farm.

4.3.5 Buoy (Santoña)

Budget: NA

Funding programme: NA

Partners: Cantabria, Iberdrola.

Date: 2008

Description: The 2011-2020 Renewable Energy Plan will include waves as a new clean source such as solar or wind. Tides and currents can be used, the thermal energy of the ocean - the difference in temperature between the surface and the sea floor - or the movement of the waves. Spain focuses on this last option, with great potential in the Cantabrian and the Atlantic. This technology could be also used in the Mediterranean Sea. In Cantabria, it was placed in Santoña (Cantabria) a buoy of 12 meters in diameter, but barely visible from the shore. The waves will make the buoy moving up and down with power. This pendular movement will cause a mechanical energy that will be transferred to a hydraulic pump and from there through pipes until making an alternator to move. The current will be sent to the outside through a cable.

4.3.6 Pelamis

Budget: NA

Funding programme: NA

Partners: E. ON, Scottish Power Renewables

Date: 2004

Description: Great articulated cable, which is tied to the sea floor and produces energy thanks to the movement of the pieces' joints. IDEA forecasted that by 2020, it could be reach a power installed between 300 and 500 megawats. In 2004, Pelamis Wave Power (formerly Ocean Power Delivery) created a full scale WEC prototype for testing at the Orkney site of Billia Croo at EMEC. This Pelamis machine was the first WEC to supply electricity to the national grid from offshore wave power. After implementing design improvements to the prototype, Pelamis returned to the Orkney test site in 2007 in advance of deploying three P1 machines in Portugal in 2008. In 2010, E.ON UK began testing of the Pelamis P2, a second-generation device developed, manufactured, and operated by Pelamis Wave Power. A second P2 device was deployed by ScottishPower Renewables on an adjacent berth to E.ON's device as part of a unique joint working arrangement between the two renewable energy developers to maximize learning from operating and maintaining the machines as a wave farm.

4.3.7 BIMEP

Budget: NA

Funding programme: NA

Partners: Basque Country

Date: 2014

Description: A marine infrastructure under construction and completion which is located off the coast of Armintza in Bizkaia with a capacity of 20MW, at a distance of about 1,700 m off land and occupying an area of 5.3 km^2. The project aims to improve the systems for catching energy from the waves in the open sea. The favorable characteristics of the Cantabrian Sea create the necessary conditions to test the efficiency of new technologies that take advantage of the wave energy. Companies from all over Europe conducted their experiments in these installations as soon as they were operational, for that there are submarine infrastructures with connection to the terrestrial electricity network.

4.3.8 WAVEPORT –Wave Energy 7PM Project

Budget: € 8 million

Funding programme: NA

Partners: Degima participates in the European Waveport project, in which, along with other European partners such as the University of Exeter, the Wave Energy Center (Wave EC), the Norwegian company Fugro Oceanor, the English technology center ISRI

Date: 2014

Description: Project 7th Framework Program, which consists of the demonstration and development of a tradable wave energy converter (with Power Buoys) with a new wave-tuning system that activates in real time (AIMS) that refines the natural harmony of the section with the frequency of the waves.

The Waveport project is the main commitment that Degima is making in the field of Marine Renewable Energies. It consists of the manufacture of a wave-buoy of power generation from the waves with a new tune-up system that consists of a buoy receiving information about the characteristics of the waves (height, period ..) which allows to adapt the resistance of the generator (Power-Take-Off) to maximize the power generation. Sensory buoys send the information via radio, and this allows to optimize the capture of the energy of the waves. In addition, the University of Exeter has developed algorithms that allows predicting - in terms of sequence - the characteristics of the waves, receiving the feed-back with the data recorded.

Degima is the company responsible for the construction of the structural metal elements of the buoy. The Anglo-American company Ocean Power Technologies is developing point collectors capable of obtaining up to 150 kW of energy by developing buoys that capture energy through the waves.

4.3.9 SINNPOWER wave energy converter at Heraklion Port

Category: Wave energy

Budget: NA

Funding programme: German Government - Federal Ministry for Economic Affairs and Energy

Partners: SINN Power, Port of Heraklion

Date: December 2015 – ongoing

Description: In December 2015, SINN Power started operating the first wave energy converter module on the Greek island of Crete. The module was installed at the breakwater wall at the port of Heraklion and was run in test mode for two days and then removed again for the stormy wintertime. In May 2016, the wave energy converter module was re-installed at site for long-term tests to measure the generated electricity and evaluate the long-term functionality of the components. By analyzing data from long-term tests in Heraklion, SINN Power was able to improve the reliability and energy efficiency of the wave energy converter technology. In December 2016, the engineers took the module off the wall to upgrade the wave energy converter module to the third generation. The upgrades reduce costs, increase performance and improve structural stability. Among others, they include:

- New generators with more power output
- More efficient power electronics
- Cost-improved, shock-absorbing generator mounting
- Improved end-stop buffering to absorb the impact of high waves

After the winter break, the third-generation wave energy converter module will be reinstalled for another round of long-term tests. These advanced tests serve as preparation for the planned installation of the floating wave energy converter array, also planned to take place in the Heraklion area after coordination with the local authorities.

4.3.10 REWEC3

Budget: N/A

Funding programme: INEA -Ten-T Pogramme 2007-2013

Date: full-scale prototype installed in 2015

Partners: Port of Civitavecchia, Wavenergy.it srl. NOEL (Natural Ocean Engineering Laboratory, Università Mediterranea of Reggio Calabria)

Description: Civitavecchia is the major port of Rome. The Port Authority of Civitavecchia has recently decided to upgrade its infrastructure and adopted the REWEC3 technology for the new caisson breakwaters. 17 out of the 27 breakwaters constituting the breakwater protection are of REWEC3 type.

Each REWEC3 caisson is 33.94 m long and includes 8 independent absorbing cells. The total length of REWEC3 caissons is 578 m. First turbines Wells of 20kW have been installed and the total installed power will be of 2.7 MW.

4.3.11 OBREC

Budget: N/A

Funding programme: National Operational Programme for Research and Competitiveness 2007–2013 (NOP for R&C), RITMARE project (National Research programmes funded by the Italian Ministry of Education, University and Research)

Date: 2015

Partners: Seconda Università degli Studi di Napoli

Description: A device denominated OBREC (Overtopping BReakwater for Energy Conversion) embedded into a breakwater and based on the wave overtopping process has been developed. The device consists of a rubble mound breakwater with a frontal reservoir designed to capture the wave overtopping from a sloping ramp in order to convert wave energy into potential energy. Water stored in the reservoir produces energy by flowing through low head hydraulic turbines, using the difference in water level between the reservoir and the main sea water level. A pilot full-scale prototype of OBREC has been installed at the port of Naples (Italy) in 2015. It consists of two configurations with different dimensions of the reservoir and of the frontal ramps. The total length of the prototype along the breakwater direction is 6 m.

4.3.12 ISWEC

Budget: N/A

Funding programme: Regione Piemonte, Regione Sicilia, ARIS spa, Landra S.r.l., UP Design s.r.l, Sirius Electronic System s.r.l., Miwt s.r.l., Power Evolution s.r.l., University of Catania, Asa impianti s.r.l, Enel Green Power

Date: 2015

Partners: Politecnico di Torino, Wave for Energy, Enel Green Power

Description: ISWEC (Inertial Sea Wave Energy Converter) device consists of a sealed hull that contains a flywheel that rotates generating a gyroscopic torque, the PTO converts such torque in electrical power. An advantage of ISWEC is the absence of parts in relative motion immersed in the water, as the whole conversion group is allocated inside the hull. A full-scale prototype has been deployed in August 2015 and moored 800 m from the coast of Pantelleria, Italy. The device is 8 m width and 15 m length and 4.5 m height. The installed prototype has a nominal power of 100kW.

4.3.13 40SouthEnergy

Budget: N/A

Funding programme: N/A

Date: 2014

Partners: Enel Green Power, 40SouthEnergy

Description: 40SouthEnergy is developing wave energy converters since 2007. A family of point absorber devices has been designed with different sizes. A prototype named R115/150, a 150 kW wave energy converter, has been installed during March 2014 in Punta Righini test site in Tuscany. Next generation of machines will reach 500kW and 2MW.

4.3.14 BUTTERFLY

Budget: K€ 600

Funding programme: ERDF and CDTI

Date: 2015

Partners: Rotary Wave S.L.

Description: WAVE ENERGY CONVERTER TO PRODUCE ELECTRICITY FROM THE WAVES - Rotary Wave, a Valencia (Spain) start-up, has been researching for the last four years in the design, construction and setting up devices to obtain electricity from waves and currents and desalinized water with no external energy consumption. We have studied, experimented and tested, and patented some devices that have better properties than the devices that already exist. In 2015 a research device was installed in the Mediterranean sea, up north of Valencia, financed with ERDF funds (European Union), where the device was working for more than three months, producing energy in the device, not sending energy to land and not connected to grid. Results obtained in this test where very positive and far exceeding our expectations.

4.4 Ocean Thermal Energy Conversion demonstration projects

4.4.1 NEMO

Budget: €72M Euro

Funding programme: European NER 300, one of the world's largest funding programmes for innovative low-carbon energy demonstration project

Partners: DCNS and Akuo Energy

Date: 2014

Description: NEMO "New Energy for Martinique and Overseas" is an offshore ocean thermal energy project off the west coast of Martinique in the Caribbean Sea. A moored barge will be installed housing four turbo-generators. Each will be driven by an Ammonia closed Rankine cycle utilising the circa 20°C temperature difference between the cold seawater at 1.1 km depth and the warm surface waters. The cold water is pumped via a single large diameter riser. Each turbine will produce roughly 4 MW resulting in a total nominal installed capacity of 16 MW with a maximum available capacity of 10.7 MW. The net generated power is exported to the grid via a subsea cable and a substation at an existing conventional fossil fuel power plant.

This project falls within the scope of the partnership agreement signed in January 2013 between DCNS and Akuo Energy to combine their respective skills with a view to marine renewable energy developments. First application of this cooperation, the offshore OTEC plant project in Martinique will benefit from the complementary know-how of the two partners, which will work together during the construction and operation phases.

This technology will benefit all overseas island territories, non-connected to continental power grid, and therefore help isolated areas achieving energy self-sufficiency.

4.4.2 THASSALIA

Budget: K€ 35 000

Funding programme: N/A

Partners: ENGIE Cofely

Date: 2016

Description: Located in the heart of Marseille, the Thassalia marine geothermal plant will use the ocean's geothermal energy to supply heat and cooling to buildings connected to it. In doing so it transforms the Mediterranean into a sustainable source of energy for an area of almost 500,000 m^2 of buildings in the city.

Thassalia will be the first geothermal power plant in France to operate using salt water, and it will transform the Mediterranean into a sustainable source of energy for nearly 500,000 m^2 of buildings.
The marine geothermal power plant will be situated in the Port of Marseille. A pumping station will draw water from a depth of up to 5 meters, where the water is at a constant temperature. Heat pumps will recover energy from the sea for transfer to the district heating and cooling network. This 3 km-long urban network will cool buildings in summer and warm them in winter. Eventually, the network will service 500,000 m2 of buildings, including the Euromed Center, Les Docks and future Arenc Residential Park.

4.4.3 MARLIN

Budget: K€ 17 088

Funding programme: ADEME

Partners: DCNS with France Energies Marines, Ifremer, Brest, Région Martinique, Région Pays de la Loire, Région Réunion, Université de La Réunion

Date: 2014

Description: Ocean Thermal Energy technology is designed to produce constant renewable electricity. Based on a (steam-driven) thermal motor installed on an offshore or onshore platform, this energy-generating system exploits the natural temperature difference between surface and deep water in equatorial and tropical seas.

Thermodynamic fluid in an embedded closed circuit vaporizes in a heat exchanger (evaporator) as a result of the warm surface seawater. Under pressure, the vapour drives a turbine which, connected to a generator, produces electricity. As a result of the cold seawater, the vapour then re-condenses in another exchanger (condenser) and can thus begin a new cycle. OTEC is therefore a basic renewable energy. The MARLIN project is proposing through laboratory research and testing to develop and describe different materials for piping deep water and to offer a choice of solutions as to the composition of the constituent elements, and will validate their durability. Models of the piping will be validated on mock-ups in tank tests. Real-life tests in tropical seas will then be carried out over 3 years. The MARLIN project will also test innovative solutions for heat exchangers and will describe methods of treating biofouling. A specific test bench will initially be created in Cherbourg before being installed in Martinique for a period of two and a half years to take advantage of the tropical seawater conditions.

4.5 Salinity Gradient demonstration projects

4.5.1 Statskraft Osmotic Power Plant

Budget: N/A

Funding programme: N/A

Partners: Starkraft

Date: 2009-2013

An important osmotic power plant has been tested from 2009 to 2013, the first in the world developed in Tofte, Norway by built by the national power company Statskraft. This plant had a capacity of only 4 kW.

In 2013, Statskraft announced its decision to stop its work to develop an osmotic power technology. The larger planned pilot facility, and the future commercial plant, will finally not be built.

Whilst reliable, this plant was very expensive to install. The permeable membrane is currently too expensive, and in order to have any meaningful energy output, a very large membrane area is required so at this stage, it is not economically feasible.

4.6 Transversal projects

4.6.1 POWER-C

Budget: K€ 2 641

Funding programme: FUI

Partners: COMEX with Nexans, Powersea, Subsea Tech, CNRS – CPPM

Date: 2014

Description: The objective of the POWER-C project is to develop High-Voltage subsea connectors (wet-mate) for Marine Renewable Energies. The concept is based on a development finished in 2013 with a 24kV connection system that features simple terrestrial connectors protected by a housing for subsea application and a dedicated, recoverable connection tool.

The main objective is to develop a 36kWversion of the system and test it in a realistic environment.

The concept developed here allows reducing the costs by using standard, simple terrestrial connectors (with low failure rates) and use a dedicated tool for the connection functionalities.

4.6.2 POWERMATE

Budget: K€ 558

Funding programme: FUI, ERDF & regional authorities

Partners: COMEX with EDF, Subsea Tech

Date: 2011

Description: POWERMATE is a development and qualification project for a totally new concept of underwater wet-mate electrical connection for transmission of high power produced by particular systems of offshore renewable energy, while reducing costs and improving reliability compared to current solutions. Objectives:

- Development of the connector and tool adapted to the needs of Marine Renewable Energy (medium / high voltage);

- Development of installation procedures;
- Validation of the concept by hydrostatic testing, electrical testing and by pool tests in the sea.

4.6.3 CAP ENC

Budget: K€ 3 196

Funding programme: FUI

Partners: IRH Ingénieur Conseil, Vandœuvre-lès-Nancy [Project Developer], Ponsel Mesure, Caudan, Veolia Recherche et Innovation, Maisons-Laffitte, INRA, Laboratoire d'Ingénierie des Systèmes Biologiques et des Procédés (LISBP), Toulouse

Date: 2013

Description: Fouling remains one of the main concerns of industrials in the thermal transfer technology sector and processing industries. It is also a major issue for the marine renewable energy sector and for all forms of underwater infrastructure in the marine environment.

The aim of the CAP ENC project is to develop a sensor able to quantify and identify the nature of fouling, whether organic, mineral or biological. The project is innovative in the way it combines measurement of discrete spectra and electric and thermal stimuli (LOcal THermal and Electric Pulses Analysis: LOTHEPA) to distinguish between different types of fouling in terms of their thermal and electric properties.

By defining the fouling, the operator can employ appropriate remedial treatment, reduce operating costs (energy, chemical products, etc.), optimise production time and limit waste. The sensors need to be easy to adapt on different production lines. They will make networked surveillance possible by being installed at several points on a unit to monitor the kinetics of fouling and/or erosion of surfaces.

The target market comprises cooling towers and agri-business industrial sites in France and worldwide. Market demand in this sector is estimated at several hundred sensors per year. The sensor will be added to the 'Neosens' range of sensors already marketed by Ponsel.

The sensor will also be tested for its applications on underwater objects in the marine environment (MRE, desalination, etc.). This will be a more restricted market in terms of sensor sales but represents an important strategic issue for industrials in the sector.

4.7 Coexistence with other marine activities

The MREs are clearly a new activity in the maritime space which can find synergies with existing activities (for example in the pooling of logistical means used for the maintenance of farms, the advisability of establishing farms in Floating wind farms or the exploitation of deep and nutrient-rich waters from terrestrial thermal power stations in the seas). To date, this coexistence of activities is not framed, which makes it impossible to evaluate its relevance. However, it presents the opportunity to pool certain costs and boost the sectors concerned. Some examples of projects are described in the following section.

4.7.1 Marine environment and MRE

- **SIMEO project - Marine Station for the observation of marine vertebrates and their environment**

It aims to design and implement the first prototype of a range of marine stations associated with new services based on the analysis of unpublished data sets about marine vertebrates and their environment. This project involves the combination of advanced measuring instruments on a single buoy; radar, sonar, video, sound and weather measurements, tidal current measurements, as well as probes to analyse the water (temperature, salinity, etc...).

SIMEO will collect basic information on various species. The station will include an anchoring system adapted to the diversity of the site, character of the seabed (sand, rocks ...), currents, waves, and will consist of three parts: Aerial, Central and Underwater. SIMEO be self-sufficient in energy and ensure the transmission of the data collected back to the land without the scientists having to move offshore to the station.

At the same time, business applications with powerful added value will be developed to obtain relevant data which is immediately useful as decision support tools for impact studies, surveillance and monitoring of Marine Protected Areas.

- **JONATHAN - The development of MRE activities, including wind power, at sea and the creation of Marine Protected Areas (MPA) are increasing the demand for knowledge of the marine environment and for monitoring species over vast distances**

The development of MRE activities, including wind power, at sea and the creation of Marine Protected Areas (MPA) are increasing the demand for knowledge of the marine environment and for monitoring species over vast distances.

The JONATHAN project is aimed at perfecting a numerical technique for large-scale monitoring of marine fauna – birds, marine mammals, turtles, etc., by flying over maritime zones and deploying on-board, high-resolution photographic equipment. Images will be taken based on a previously defined statistical plan and will be subsequently processed. The JONATHAN project will also focus on human activity, notably ships but also micro-waste, oil slicks, etc.

The principle involves taking daytime HD digital photographs, followed by computer analysis, to locate potential targets, quantify them and facilitate their description using semi-automated classification. The main technological barriers lie in detecting the targets in a challenging environment – swell, luminosity and the mobility and size of the objects – as well as in devising a strategy for how to process the considerable volume of data which comes into play in the form of the series of high spatial and temporal resolution images.

4.7.2 Aquaculture/ fisheries and MRE

- **XPRA, Artificial reefs for protecting fishing around offshore wind farms**

As offshore wind farms are developed, installing artificial reefs may provide a suitable means of offsetting the farms' impact on the environment and the fishing industry.

The XPRA project will examine an environmentally appropriate reef model based on fibre-reinforced concrete. It will be designed to withstand the hydrodynamic conditions in the Channel and to be economically sustainable.

What makes the project particularly interesting is that it will provide concrete results from a pilot study carried out in the Channel close to future wind-farm sites. Equally important is the impetus it will give to developing collaboration between scientists and fishing industry professionals at various stages of the reef creation process.

Using numerical modelling tools, studies will focus in particular on the stability and the resilience of these constructions in areas of rough seas. The project will perfect a decision-making tool for establishing the reef mass dimensions, immersion depth and sea state. It will identify a proven method for scientifically monitoring conditions in the Channel by adapting methodologies, which have already been tested in the Mediterranean, and will put innovative protocols into practice.

Thus the project is aimed at offering ways, on the one hand, to improve the design, manufacturing and positioning processes for artificial reefs and, on the other hand, to establish and test appropriate methodologies for scientifically monitoring artificial reefs in the environmental conditions of the Channel.

4.7.3 Naval and MRE

- **WINDKEEPER - Support and maintenance ship for offshore wind farms**

With the development of Marine Renewable Energies and offshore wind farms in particular, there is now a demand for a fleet of ships designed to install, maintain and protect these structures.

The aim of the WindKeeper project is to design an economical, clean, reliable and intelligent ship capable of operating in complete safety for up to 300 days a year. To reduce operating costs, a small-scale craft of less than 50 m in length is needed, with dynamic positioning and sea-keeping abilities akin to those of much larger vessels.

As regards energy-saving, the project will incorporate an electric generator into the propulsion system, while the hull's shape and coating will be designed to minimise resistance to forward movement. The ship will also be equipped with an energy recovery system and will incorporate on-board systems for treating emissions and reducing the volume of waste.

As regards safety, the architecture of the WindKeeper hull and the method for integrating the propulsion system will reduce the vertical impact of the swell. The hull will also be equipped with a dynamic system to stabilize the vessel's motion when approaching wind turbines and when positioning personnel and equipment close to them. The safe transfer of personnel and goods to wind turbine platforms will be ensured by a stabilized gangway system which will also operate a nacelle to control the turbine blades on site.

Particular attention will be paid to the safety and ergonomics of the working and living space so that the 8-member ship's crew and 20-member maintenance teams can live side-by-side during missions lasting 2 to 3 weeks.

This intelligent ship will be equipped with surveillance and transmitting systems enabling it to communicate securely with other vessels on the farm site as well as with bases on land. The ship will also communicate with the wind turbines to anticipate preventative maintenance measures.

- **AMARYLLIS – Asset management system for navigational safety in and around offshore wind farms**

The AMARYLLIS project aims to offer a competitive mobile asset management system for craft (vessels, aircraft, personnel) moving within and around an offshore wind farm by providing an effective response to the problems of security and safety which arise during each phase of the life cycle of the field (design, installation, operation, development, decommissioning). Thus, the project proposes the development of a comprehensive control and management system for these new maritime spaces:

- Specific marker buoys;
- Specific maritime traffic controls;
- Specific supervision;
- Specific surveillance;
- Specific method for action procedures.

This will also take into account:

- current and potential future constraints relating to international regulations;
- technological challenges in coping with the difficulties inherent in the use of existing facilities (accessibility, environmental conditions, MCO, radio frequency and hyper frequency interference (radar), the impact on other maritime traffic).

4.7.4 Algae and Energy production

- **MED-ALGAE - Production of Biodiesel from Algae in selected Mediterranean Countries co funded by ENPI CBCMED Mediterranean Sea Basin Programme**

The project is a new technology project which can contribute to the goals of the EU strategy on "Climate change and energy". The methodology includes all stages in the production of biodiesel from microalgae: sampling of seawater or freshwater, the selection of microalgae, species identification, cultivation of microalgae, harvesting and extraction of biodiesel and determination of properties of biodiesel produced in accordance with Standard EN14214 and its testing. Five pilots will be established in each participating country: Cyprus, Italy, Malta, Lebanon and Egypt.

Lead by THE AGRICULTURAL RESEARCH INSTITUTE – CYPRUS, the partners are Fondazzjoni Temi Zammit, American University of Beirut, National Technical University of Athens (NTUA), National and Kapodistrian University of Athens, The Lebanese Association for Energy Saving & for Environment (ALMEE), Malta Intelligent Energy Management Agency (MIEMA), Mediterranea University of Reggio Calabria (Italy), Alexandria University, Cyprus Energy Agency, National Research Center, ALESSCO

4.7.5 Muti-use offshore platform

The European Commission has launched several initiatives to support the development of a multi-purpose sustainable exploitation of renewable resources and services in the oceans related to energy, food, medicine, shipping, safety or consumer electronics responds to a natural process of knowledge production and essential innovation for the future of European development.

Following this strategy, funding and support to the development of innovative concepts of multi-use oceanic platforms has become a strategic initiative of the European Union. It aims not only to ensure a comprehensive and sustainable use of the marine-maritime environment, but also to boost the industrial development of and job creation in emerging sectors such as renewable energies, offshore engineering, marine biotechnology and offshore exploitation of living resources in a more sustainable way.

Oceans of Tomorrow projects, TROPOS (http://www.troposplatform.eu/) H2OCEAN (http://www.h2ocean-project.eu/) and MERMAID (http://www.mermaidproject.eu/), have responded to this challenge by developing unique concepts for the sustainable use and exploitation of the marine environment. These projects have studied options to determine the most efficient multi-purpose offshore areas through the use of multi-use offshore platforms, at competitive costs compared to mono-use applications, and thus helping to unleash the potential of "blue growth" of adjacent coastal areas. There is a significant demand for these regions to attract industrial development associated with these new concepts for sustainable aquaculture, renewable energy and integrated transport facilities. Therefore, the development and implementation of a continuous innovation process is much needed as well as the testing and validation of prototypes and demonstrators which maybe create synergies and allow for a reutilization of technologies used for offshore oil facilities, but which are fundamentally aimed at the reduction of economic costs and ecological footprints.

Without governmental intervention, the offshore multi-use platforms are not currently economically competitive. There is a significant governmental interest because multi-use platforms promise emissions reductions, increased energy and food security along with economic benefits. There is no single support mechanism that will offer the financial support necessary for its commercialisation. All concepts will require a suite of support actions to access the market from demonstration projects in 2020 to pre-commercial phase in 2025 and commercialisation phase after 2030.

For a deployment in 2020, existing infrastructures can meet the needs of the industry. However and in order to reach the commercialisation stage, the development of built-for-purpose vessels, ports and facilities and grid connections will be required in order to reduce costs, emissions and increase the productivity for the sector.

- **TROPOS** project main objective is to develop a modular floating platform, adapted to deep waters. It focused on Mediterranean, subtropical and tropical regions, in particular on the EU Outer-Most Regions, composed by the Azores, the Canary Islands, Guadeloupe, Guiana, Madeira, Martinique and Reunion. Thanks to its different modules, the floating platform system is able to integrate a wide range of possible sectors: ocean renewable energy and food (aquaculture) resources will be exploited the platform will serve as a hub for maritime transport and innovations in the leisure sector, and will also fulfil functions for oceanic observation activities. The platform is composed of a central unit and functional modules, in particular the floater concept (submersible, floating or deep submersible units), that is adapted to each area where it is implemented.

- **H2OCEAN** is a project aimed at developing an innovative design for an economically and environmentally sustainable multi-use open-sea platform. Wind and wave power will be harvested and part of the energy will be used for multiple applications on-site, including the conversion of energy into hydrogen that can be stored and shipped to shore as green energy carrier and a multi-trophic aquaculture farm.

- **MERMAID** will develop concepts for the next generation of offshore platforms which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. The project does not envisage building new platforms, but will theoretically examine new concepts, such as combining structures and building new structures on representative sites under different conditions.

6 evaluated proposals, 2 funded for M€30 with ENFAIT and OCTARRAY projects and 2 on reserve list (SEAWARD, CAREWEC)

4.8 Demonstration projects and upcoming calls for MRE projects under Horizon 2020 programme

In 2016, two major calls to support the MRE demonstration projects were launched:

- **LCE 13 – 2016: Solutions for reduced maintenance, increased reliability and extended life-time of wind turbines**

Operation and maintenance costs for wind farms are today still too high. There is a need for demonstration of innovative solutions and tools for increased reliability of wind turbines including substructures to reduce the need of maintenance and increase the life time of the turbines.

- **LCE 15 – 2016: Development of a >10 MW ocean energy array**

Scaling up in the ocean energy sector to power plants > 10 MW will be important to be able to reduce the cost of energy.

Several calls for proposals are launched by the European Commission in 2017 to support the development of MRE demonstration projects:

- **BG-02-2017: High value-added specialised vessel concepts enabling more efficient servicing of emerging coastal and offshore activities**

Increasingly business and services are carried out within the marine space. Examples include: offshore terminals, aquaculture, renewable energy, marine biomass, blue tourism, surveying, environmental monitoring, accident response and clean up and clearing of marine debris and other pollutants.

5 evaluated proposals, 1 funded ROMEO project (M€10) and 1 on reserve list CAROLINA proposal

Costs at sea are higher than for equivalent shore based operations and a significant proportion of them are associated with the support vessels which service these activities. Inappropriate vessels can increase costs because they may have limited operational weather windows, high overheads, slow speed, low efficiency and they may be generally ineffective for the task concerned. European yards and their suppliers (often SMEs), are world leaders in high value-added vessels and highly specialised ships. The challenge is to develop novel specialised vessel concepts which are economically viable and environmentally friendly and which will more effectively serve coastal and offshore activities, thereby supporting European growth and employment through development of a blue economy.

- **LCE 7 -2017: Developing the next generation technologies of renewable electricity and heating/cooling**

Wind Energy: Reduction of environmental impact of wind energy: The challenge is to develop potential mitigating strategies or alternative solutions and to increase public acceptance of wind energy, thereby shortening consenting procedures, on the basis of an increased scientific understanding of the social and environmental impact of wind turbines and (clusters of) wind farms both on and off-shore (including floating) and to identify solutions for improved wind turbines/farms with less impact. Innovative mitigation actions could increase the deployment possibilities for wind energy, developing a better understanding of the impact of wind energy on the environment as there are still gaps in the knowledge which result in long consenting procedures and reduced deployment possibilities and secondly, developing innovative mitigation actions. Cooperation with NGOs and civil society groups is essential for further investigation of the roots of resistive behaviour as engaging and involving concerned communities can facilitate addressing this specific challenge.

Ocean Energy: Development of advanced ocean energy subsystems: innovative power take-off systems and control strategies: The challenge is to improve performance of ocean energy devices and reduce the overall cost of ocean energy by means of the demonstration of innovative power take-off systems and control strategies in order to increase power capture and power conversion efficiency, to reduce cost of components in the systems and to increase power quality. For the advanced sub-system an improved understanding of their interaction with energy resource is needed. Further, new system designs and methodologies are needed to enhance reliability and performance levels, making a step change in the sector and introduce as well a certain level of standardisation.

- **LCE 6 -2017- New knowledge and technologies**

The technologies that will form the backbone of the energy system by 2030 and 2050 are still under development. Promising technologies for energy conversion are being developed at laboratory scale and need to be scaled up in order to demonstrate their potential value in our future energy system. These new technologies should provide more flexibility to the energy system and could help adapting to changing climatic conditions. New knowledge and more efficient and cost-competitive energy technologies, including their conventional and newly developed supply chains, are required for the long run. It is crucial that these new technologies show evidence of promising developments and do not represent a risk to society.

- **LCE 14 – 2017: Demonstration of offshore large >10MW wind turbines**

The development of large scale (>10MW) turbines will have intrinsically logistical requirements regarding handling, installation, operation and maintenance, constituting a large part of the levelised cost of energy (LCOE). Improved handling (storage, loading, transport, etc.) on land, in the harbours and/or at sea, as well as improved logistics around operations and maintenance have to be taken into account in this innovation action.

- **LCE 16 – 2017: 2nd Generation of design tools for array development and deployment**

Design tools for array of wave and tidal energy converters have been developed. Single devices have already been deployed and the first arrays are planned for 2016 onwards. Based on the experience with the first ocean energy arrays the design tools can be developed further and a 2nd generation of advanced tools is foreseen which will have a significant positive effect on future devices and arrays. The impact of design on energy yield, survivability and O&M as well as environmental impacts should be taken into account. These tools should facilitate a significant increase in reliability, survivability, performance improvement and cost reduction of devices and arrays.

5 Commercial operations in Marine Renewable Energy

Commercial and Industrial Operations in MRE were launched in France. These most advanced projects will be connected to electricity network around 2020 for offshore wind and tidal current energies as illustrated below.

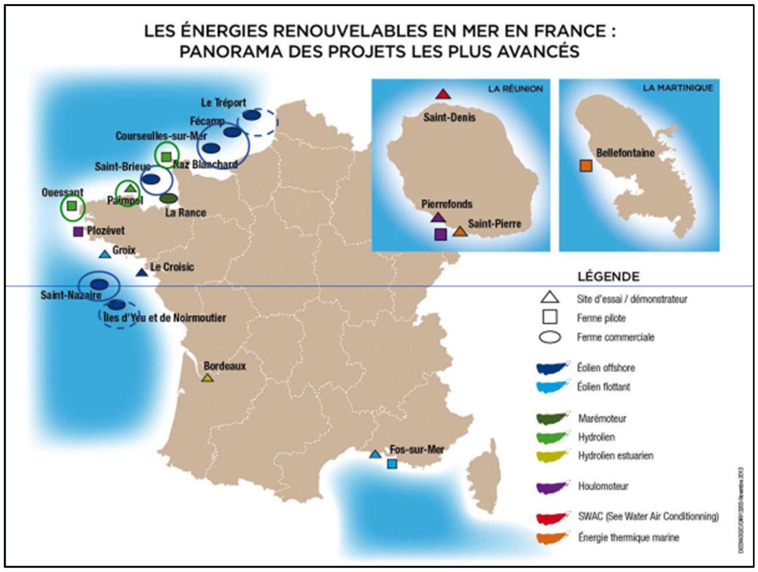

Figure 15 Most advanced MRE projects in France

Offshore wind areas in Channel and NW Atlantic coast: 4 launched in 2011, operational around 2020 = 4X500 MW = 2,000 MW and 2 operation launched in 2013 2X500 MW = 1,000 MW

Tidal current energy in Atlantic with two projects: 14MW Pilot farm of 7 turbines at Raz Blanchard and 4 hydropower devices of Alstom (GE) for 1.4 MW.

6 Conclusions

This report provided an overview of the MRE systems currently developed, their degree of maturity and their level of adaptation to the Mediterranean context. As MRE are at a development stage, the collection of the these demonstration projects enable to study the blue energy technologies developed and their applications to key maritime industries of Mediterranean insular, coastal & marine areas.

Blue energies, at the notable exception of wind energy laid on the sea floor which is broadly deploy in Northern European countries, are at an infant stage with most of the existing technologies still in need to demonstrate their reliability at sea.

Only very few demonstration projects are developed in the Mediterranean Sea. This contrast of the deployment of marine energies between the countries of Northern Europe and Southern Europe is mainly due to the natural characteristics of these two large areas:

- In the North, strong winds, strong tidal currents in certain zones, powerful waves on the Atlantic coast and finally water depths rather low in general;
- In the South, only few areas are windy - especially the Gulf of Lion, almost no tide, few areas of straits - therefore strong current, coastal areas with relatively deep water.

With the necessary caution in any prospective exercise, the main conclusions we can highlight are:

- Wind energy will be probably developed in the windiest areas and will be mostly floating because it is adapted to the depths of the continental shelf;
- The technologies will be adapted from those used for offshore wind turbines laid on the sea floor. The installation of the pilot farms of several tens of MW in Mediterranean Sea is already planned. Remarkable innovations on this type of energy at sea, adapted in Mediterranean context are in progress including eco-design;
- Hydroelectric power in the straits is potentially interesting but it is probably necessary to wait the results for hydroelectric demonstrators which are operating in the zones of strong currents of Northern Europe;
- The energy of the waves could be developed in very specific zones, especially for insular territories;
- The SWACs are very interesting for coastal urban areas for heating or cooling the buildings, saving a lot of energy consumed;
- The industry of the Mediterranean countries is ready to design the equipments for the production of these energies which would be important growth relays, in synergy with key market sectors such as tourism & leisure, aquaculture, shipbuilding and marine transport.

The value chain around the development of MRE projects is well defined and detailed. PELAGOS project will be an important initiative to increase the innovation capacities and cooperation of blue energy actors in the Mediterranean through promoting a transnational cluster, bringing them together in order to develop a shared understanding of the challenges and collectively devise workable solutions. The Mediterranean Blue Energy Cluster will identify and gather the different actors of the value chain, promoting novel technologies and providing a mix of support activities to these beneficiaries.

7 References

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8 Glossary

AEM: Anion exchange membranes

BE: Blue Energy

BG: Blue Growth

CAPEX: Capital expenditure

CEM: Cation exchange membranes

CDLE: Capacitive double layer expansion

CDP: Capacitive Donnan potential

CSPE: Contribution to the Public Electricity Service

CYCOFOS: Cyprus Coastal Ocean Forecasting System

EEZ: Exclusive Economic Zone

EFGL: Eoliennes Flottantes du Golfe du Lion

FUI: Fonds Unique Interministériel (Inter ministerial fund)

kW: Kilowatt

LCE: Low Carbon Energy

MEB: Mixing entropy batteries

MJ: Mega joule

MPA: Marine Protected Area

M/S: Meter/Second

MW: Megawatt

MRE: Marine Renewable Energy

NGO: Non-Governmental Organisation

OPEX: Operational Expenditure

OTEC: Ocean Thermal Energy Conversion

PACA: Provence Alpes Côte d'Azur

PRO: Pressure-retarded osmosis

PGL: Provence Grand Large

RE: Renewable Energies

RED: Reversed electro dialysis

SGE: Salinity gradient energy

SWAC: Sea-water air conditioning

TW: Terawatt

VAT: Value-added tax

VAWT: Vertical Axis Wind Turbine

9 ANNEXES

9.1 Other offshore wind projects

9.1.1 STATIONIS

Budget: K€ 1970

Funding programme: FUI

Partners: Eolfi with Abysscad, Capsim, Innosea, ECN

Date: 2015

Description: Software for optimizing the architecture of the bottom-to-surface links of a floating wind farm. The Stationis project focuses on bottom-to-surface links (anchoring and electrical architecture), which constitute one of the major characteristics of floating wind power. Their impact is important in the use of the maritime domain, compatibility with other users of the sea and cost. The equipment (chain, anchors, cables, flotation and stiffening elements) and their installation account for more than 20% of the total investment cost of a floating wind farm.

9.1.2 GHYDRO

Budget: K€ 122

Funding programme: France Energies Marines

Partners: DCNS, Brest, EDF, CIH, Le Bourget-du-Lac, France Energies Marines [Project Developer] Laboratoire d'écologie benthique, Ifremer, Brest

Date: 2014

Description: The GHYDRO project involves producing a methodological guide to studying the environmental impact of offshore wind-turbine technologies.

The object of GHYDRO is to promote the positive integration of offshore wind farm projects into the environment. Little feedback is yet currently available on the potential environmental effects of these. This methodological guide will offer recommendations on describing the original state, methods for identifying and analysing potential environmental changes and a description of the programme of environmental monitoring. The guide will principally deal with impact on the marine environment and taking usage into account.

The environmental monitoring protocol put in place by GHYDRO will guide developers and consultants in environmental baseline and impact studies and also in ensuring surveillance of wind-turbine test sites.

9.1.3 OceaNET

Budget: NA

Funding programme: NA

Partners: WavEC Offshore Renewables / Coordinator (WAVEC), Instituto Superior Técnico (IST), Uppsala Universitet (UU), Fraunhofer – IWES (Fraunhofer-IWES), Maritime Research Institute Netherlands (Marin), Universidad de Cantabria (UC), Ecole Centrale de Nantes (ECN), The University of Exeter (UNEXE), Tecnalia (TECNALIA) and University College Cork (UCC-HMRC).

Date: 2014

Description: OceaNET is a multinational Initial Training Network (ITN) funded under the PEOPLE Programme (Marie Curie Actions) of European Union's FP7. The aim of the network is to train 13 Early Stage Researcher (ESR) in the area of floating offshore wind and wave energies to support the emerging marine renewable energy sector. The project is coordinated by WavEC Offshore Renewables. It began in September 2013 and will take four years. The network brought together partners from across Europe and offered 13 ESR positions at 10 different host institutions. The OceaNET ITN focused its efforts on the areas of array design, implementation and operation & maintenance. The development of enabling technologies was also explored.

9.2 Other Tidal Energy projects

9.2.1 ACORN – Advanced Coatings for Offshore Renewable Energy

Budget: NA

Funding programme: NA

Partners: SMEs

Date: 2013

Description: Despite considerable development in the field of protective coatings against marine corrosion, a specific development is still necessary to improve the current solutions to this problem. More durable coating systems (+20 years) are required to provide reliable protection against corrosion/biofouling or corrosion/ cavitation, and also avoid the need to include complementary cathodic protection. The need for such coatings is accentuated in the case of fixed offshore structures. The growth of this market is related to the construction of new structures that go from the foundation of the turbines of marine wind energy to the devices of wave energy.

9.2.2 Fahemar

Budget: N/A

Funding programme: N/A

Partners: N/A

Date: 2014

Description: The development of techniques for the use of wave energy and its conversion into electrical energy is now at its dawn and Spain is nowadays the European country with a greater potential for wave energy use, especially in the Cantabrian Sea.

At the moment, the projects that are being investigated (except the one that is done taking advantage of the technology Pipo System, of national patent) in Spain, use North American or British technologies (OPT, Pelamis, Wedge, etc.).

The purpose of the Fahemar Project is the development of a national technology that implies such a qualitative leap in existing technologies and methods that allows leading the generation of this type of renewable energy, creating a hopeful new industry, not only exploitation of this type of energy but also the manufacture of all the goods of equipment and its components (boiler, power electronics, transformers, etc.), which can be a true industrial revolution.

9.2.3 E-WAVE

Budget: N/A

Funding programme: Research Promotion Foundation of Cyprus

Date: 2010-2012

Partners: Oceanography Center, University of Cyprus, Atmospheric Modeling and Weather Forecasting Group, University of Athens, Greece, Ocean Analysis Laboratory, Naval Postgraduate School, USA, Cyprus Energy Agency, Meteorological Service of Cyprus

Description: Integrated High Resolution System for Monitoring and Quantifying the Wave Energy Potential in the EEZ of Cyprus

The development of an integrated, high resolution system for monitoring the energy potential from sea waves at the Exclusive Economic Zone (EEZ) of Cyprus coupled with the well-established Cyprus Coastal Ocean Forecasting System (CYCOFOS)

The new system will include:

- A complete, high resolution digital atlas containing detailed maps for the coastal and offshore areas of the EEZ of Cyprus in which sea wave and wind climatological characteristics as well as the distribution of the wave energy potential will be monitoring;
- Novel models for the prediction and quantification of wave energy in short and long forecasts horizons, a tool of significant value for grid designers and regulators;
- A state of the art wave prediction model will be employed targeting at the high resolution estimation of the sea state characteristics, essential for the energy potential;
- Novel advanced statistical models will be developed for the estimation of energy distribution;
- The results of previous EU projects that the partners participated – especially those of MARINA platform, CIRCE (Climate Change and Impact Research: the Mediterranean Environment), POW'WOW (Prediction Of Waves, Wakes and Offshore Wind) and MyOcean – concerning high resolution studies and systems in Mediterranean will be used;
- The CYCOFOS system and local observations for sea parameters will be utilized for the optimization of the results.

9.3 Other OTEC projects

9.3.1 OPTIMA PAC

Budget: K€ 1 630

Funding programme: FUI

Partners: Dalkia France with ACRI In, ACRI St, Barriquand, Crudelli, VEOLIA, Villefranche Oceanology Observatory, ECOMERS – University of Nice, Principality of Monaco

Date: 2011

Description: The Sea is a source of non-intermittent renewable thermal energy. Seawater heat pumps use a thermodynamic system making use of hot or cold seawater to produce energy from the ocean's depths to provide both heating and cooling networks to the end user within a radius of several kilometers.

Suitable for high density coastal areas, this marine energy technology is developing in the Mediterranean area with its high water temperatures, lack of tides and favourable water depths.

Optima Pac is an integrated research project which aims to develop a working industrial sector gathering together players in the Ocean Thermal Energy Conversion (OTEC) value chain. The purpose of the project is the optimization of OTEC technical and environmental performance in its entirety, taking into account the potential effects on the marine environment and conditions for the favourable development of ocean thermal energy conversion.

The project is based on three major complementary actions:

- Modelling thermal plumes in existing OTEC projects and the dispersion effects in the marine environment and integrating hydrological and oceanographic data;
- Study of the effect of existing OTEC projects on organisms and marine communities;
- The development of efficient technological solutions adapted to seawater using the results acquired from the above and integrating range of services for the end user.

9.3.2 IISIS

Budget: N/A

Funding programme: N/A

Partners: FCC Servicios Ciudadanos, Acerinox, Aqualia, Berenguer Ingenieros, FCC Construcción, Grupo Cementos Portland, Obeki, Vinci Energía, IMDEA, UHU, UV, Instituto Eduardo Torroja, UPV, Tecnalia, OBEKI and IH Cantabria.

Date: 2014

Description: Aimed to carry out an advanced and ambitious research on the elements, materials, technologies and systems necessary to develop buildings in a marine environment, habitable, built by structures and prefabricated modules that can be assembled, demountable, transportable and durable over time without disturbing the surroundings (energy, water, basic food, treatment and recycling of waste), equipped with all kinds of integrated facilities and a system of intelligent management and control. New knowledge of sustainability and self-sufficiency will be generated, focused on optimizing the available primary energy resources, minimizing the environmental impact on the environment through the development of novel integrated energy production and storage systems that meet the needs of habitability and service of "IISIS".