Maestrale Project – Sustainable Blue Energy in the Mediterranean

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ABSTRACT

Maestrale is an Interreg MED 2014-2020 Programme co-financed by the European Regional Development Fund. The University of Siena, (UNISI) coordinates a consortium of 10 partners from Italy, Greece, Malta, Spain, Portugal, Croatia, Slovenia and Cyprus (Oceanography Centre, University of Cyprus). The Maestrale project intends to lay the foundation for a Maritime Energy Deployment Strategy in the Mediterranean. Based on a thorough study of existing and innovative technologies, hindrances and potentials in participating countries, Maestrale aims to widen knowledge sharing among scientists, policy makers, entrepreneurs and citizens to support blue growth development. So far there has been limited progress regarding concrete initiatives and operating plants in the MED area despite the plethora of academic and technical studies already available in the field of offshore renewable energy. To assist in this effort, project partners cooperate to analyse and report the maritime renewable energy potentials in participating countries with regards to their physical, legal, technological, economic and social contexts. Of key importance are issues such as environmental sustainability, technological innovation, social acceptance, as well as possible conflicts with sensitive marine ecosystems.

The main deliverable of Maestrale is the establishment of the Blue Energy Labs (BELs), taking place in each participating region. BELs aim to involve local enterprises, public authorities, knowledge institutions and citizens in an effort to support future blue energy policies and plan concrete strategies for blue growth. The identification of a set of pilot projects in each participating country is envisages as a mean for awareness raising and social acceptance in order to increase the feasibility of future Blue Energy initiatives. Forty BELs will be organized (4 by each partner institution), in order to promote Blue Growth taking into account, the Blue Energy potential in the region the availability of technological infrastructure, the legislation as well as funding and investment opportunities.

1. INTRODUCTION

Energy demand increases year by year. The current primary energy mix is made up from more than 80% of fossil fuels (IEA, 2015). In addition, the energy sector is responsible for a significant percentage of CO_2 emissions globally (IEA, 2015). As a result, the energy sector must turn to new energy sources and more efficient technologies in order to be able to fill the energy demand with clean energy, such as onshore renewable energy sources and ocean energy. The ocean is regarded as a vast source of renewable and clean energy that exceeds our present and projected future energy needs many times (Takahashi and Trenka, 1996) and is expected to play a crucial role in the future energy system (Magagna and Uihlein, 2015). It thus has the potential to help reduce CO_2 emissions and alleviate the global climate change threat, but it is also critically important that the development of new ocean energy technologies does not harm the marine environment (Pelc and Fujita, 2002).

Blue energy (BE) is not strictly defined in the literature. Initially, this term was used to describe only the energy produced by exploiting salinity differences between fresh and salty water (Ross and Krijgsman, 2004; Kuleszo et al., 2010), while in others this term describes the energy coming from any form of offshore marine renewable source (Soma and Haggett, 2015; Lillebø et al., 2017). According to Ellabban et al. (2014) ocean energy is the energy coming from waves, tidal currents, ocean currents, salinity gradient, and ocean thermal energy conversion (or temperature gradient energy).

EU is currently at the forefront of ocean energy development (Magagna and Uihlein, 2015) but still blue energy is currently a nascent industry. Even though the highest potential for the development of ocean energy is in the Atlantic seaboard, it is accepted that there exists potential also in the Mediterranean and the Baltic basins. Magagna and Uihlein (2015) presented a critical review of the status of ocean energy technologies. They concluded that tidal and wave energy represent the two most advanced and promising types of ocean energy technologies in converting ocean energy into renewable low-carbon electricity and noted that tidal energy technologies are expected to become commercially viable before wave energy.

Maestrale is a three-year project (1.11.2016-31.10.2019), funded within the framework of the Priority Axis n. 1 of Interreg MED 2014-2020 Programme and co-financed by the European Regional Development Fund. The project consortium includes 10 partners from 8 countries from the Mediterranean (MED) region. The leading partner is the University of Siena (UNISI), Italy. The rest of the consortium is comprised by: International Renewable Energy Agency (IRENA, Croatia), Aristotle University of Thessaloniki (UATH, Greece), the Oceanography Centre of the University of Cyprus (OC-UCY, Cyprus), INFORMEST from Italy, the University of Algarve (UAlg, Portugal), Gorizia Local Energy Agency (GOLEA, Slovenia), Malta Intelligent Energy Management Agency (MIEMA, Malta), the European Centre for Business and Innovation (CEEI) and the Marine Maritime Cluster of Andalucia (CMMA) from Spain.

The three main objectives of Maestrale are: (i) Knowledge transfer between the partners and professionals who already have experience in the sector outside the MED area; (ii) Creation of regional and transnational networks (Blue Energy Labs) of key stakeholders such as policy makers, public authorities, research institutions, entrepreneurs and citizens, in order to promote and establish Blue Energy projects; and (iii) Elaboration of two or more pilot projects in each regional area with the highest feasibility conditions for the region.

In the frame of the Maestrale project, Blue Energy is considered in a broader sense and includes: (i) wave energy (offshore and onshore), which can be embedded on manmade structures, such as ports and wave-breakers, or on floating buoys; (ii) offshore wind energy by means of floating or fixed-foundation turbines; (iii) marine biomass, which includes sea weed farms or micro-algae absorbing seawater nutrients and CO_2; (iv) salinity gradient energy, i.e. energy extracted by exploiting the difference of salt concentration between fresh and salty water; (v) ocean thermal energy, where the temperature difference between air and ocean is exploited for cooling or heating buildings; and (vi) marine current energy, using floating, seabed moored and kite-like turbines.

2. ENERGY POTENTIAL IN THE MEDITERREANEAN

To achieve the first objective of the project, partners needed to cooperate to detect maritime renewable energy potentials in participating countries of the MED region with regards to their physical, legal, technological, economic and social contexts. To analyse the potential of all BE forms, the project partners were requested to investigate and report the energy potential of each BE form and highlight the most promising in their study areas. The findings of each partner for their region are summarized in this section. Figure 1 indicates the locations (solid circles) or regions (hollow circles) of BE forms highligted by each partner.

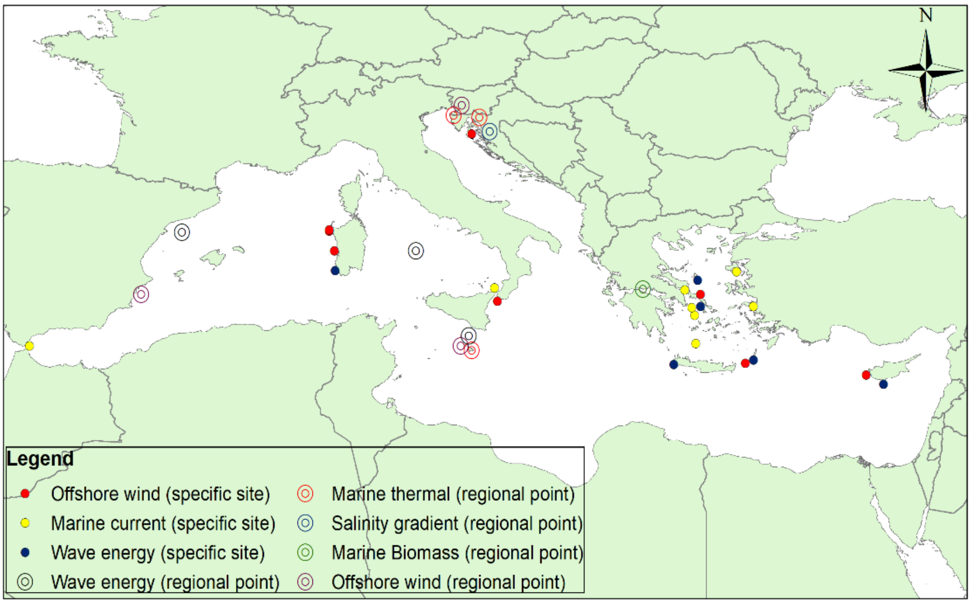

Figure 1: Locations of highlighted BE forms as reported from the partners. Solid circles represent specific locations, while hollow circles represent general regions.

2.1. Italy

Two partners (UNISI and INFORMEST) have submitted independent potential energy reports, the findings of which are merged here. The highlighted BE forms are offshore wind energy, wave energy and marine currents. For offshore wind energy, two high-potential locations were identified at Alghero and Oristano near Sardinia and in Messina Straits near Sicily with annual mean wind speeds of 4.9, 5.4 and 5.7 m/s, respectively (Soukissian et al., 2017). One important drawback in this case, is bathymetry, which can exceed a depth of 30 m in just a few hundred meters distance off the coast. However, this issue may be addressed with new emerging floating technologies. The mean wave energy identified for the region is 9.4 kW/m at the south-west coast of Sardinia and 4.75 kW/m near Sicily (Soukissian et al., 2017) and at the Tyrrhenian Sea (Luppa et al., 2015). In addition, marine current exploitation is feasible at very specific locations. In general, the marine current velocity is low, apart from Messina Straits where it ranges from 1.8 m/s to 3 m/s during spring tides (Soukissian et al., 2017).

Table 1: Highlighted BE forms in the seven participating countries in the MED region

BE forms	**Croatia**	**Cyprus**	**Greece**	**Italy**	**Malta**	**Slovenia**	**Spain**
Offshore Wind	High potential at Cres, Krk and Senj	High potential at South coast of the island	High potential at Steno Kafirea and Kasos.	High potential in Oristano, Alghero and Messina Straits	Proposed the use of floating turbines due to steep bathymetry	Modest expectations for exploitability	Most promising BE form. Floating turbines for medium level wind speeds
Marine Thermal	Most promising BE form in the region (already in use)	Highlighted in 1st regional BEL. (already used by a hotel)			Heating the buildings	Most promising BE form (already in use)	
Wave		Highest potential at the West coast	High potential at Skyros, Andros, Tinos, Karpathos and western Crete	High potential in Tyrrhenian Sea and S-W of Sardinia	High potential for offshore wave technologies		Hybrid technologies usage for greater exploitability
Marine Current			High potential at Evoia, Kea, Samos, Kithnos and Mytilene	High potential at Messina Straits			
Marine Biomass		Highlighted as promising in the in 1st regional BEL	High potential but further research is required				
Salinity Gradient	High salinity gradient due to river inputs (not mature technology)						

2.2. Croatia

The analysis of IRENA for Croatia showed that the BE forms with the greatest potential are offshore wind, salinity gradient and thermal energy. The most promising areas for offshore wind energy are near Cres and Krk islands and near Senj (Figure 1). According to the feasibility scenarios of Hundleby and Freeman (2017), under certain assumptions, an offshore wind energy park is feasible if the mean wind speeds are 7.5-8 m/s. These scenarios and assumptions lower the feasibility potential of offshore wind energy in Croatia. It has been reported that salinity-gradient energy exploitation is favoured by the high vertical differences in salinity observed due to river runoffs in North Adriatic Sea (Russo and Artegiani, 1996). The main drawback for this BE form is the technology, which is still developing and has not reached a commercialization level yet. The BE form with the most highlighted potential is thermal energy. This BE form is used directly for heating and cooling using marine heating pumps. Heat is extracted for heating the buildings and is stored during the cooling phase of buildings. The temperature differences between air temperature and seawater make this BE form the most promising and viable in the region.

2.3. Greece

The BE potential analysis carried out by AUTH concluded that the most promising BE forms are offshore marine currents, wave energy, wind energy, and marine biomass. Marine current energy is generally low in the MED region. This potential is remarkably high and can be exploited only in certain areas. Such areas in Greece, are located near Evoia, Kea, Samos, Kithnos, and Mytilene (ORECCA, 2011), where the minimum spring tide marine current is near 1.75 m/s, a magnitude that allows the exploitation of marine current energy. Wave energy potential ranges between 5-10kW/m near Skyros, Andros and Tinos in the central Aegean Sea, near Karpathos and western Crete, where wave energy harvesting may be feasible. Regarding offshore wind energy, the areas with the highest potential are found in the Aegean Sea at Steno Kafirea, with a mean annual wind speed of 7.5 m/s and with available wind potential energy of 546 W/m^2. Another favourable location is Kasos, in the Karpathian Sea, with a mean annual wind speed of 8 m/s and with available wind potential energy of 570 W/m^2. Finally, the potential of marine biomass is highlighted, but for its exploitation, further research advances and better understanding of its commercialization impacts are still required.

2.4. Spain

Two separate potential analyses have been carried out by the two partners (CMMA and CEEI) in Spain. Offshore wind energy and wave energy are highlighted as the most promising BE forms. The two analyses suggest that the most promising BE form is offshore wind energy. It was also pointed out that the only viable solution for commercialization of offshore wind energy is floating wind turbines due to the deep bathymetry of the MED region. The W2Power floating wind turbine was proposed as a possible solution, since it can operate well at the wind speed ranges encountered in the MED region and has been tested extensively. For wave energy, a hybrid solution of wave extraction technology is suggested, in order to increase the feasibility of wave energy extraction projects due to relatively low wave energy potential at the region. Such technology is the Butterfly converter from Rotary Wave. Finally, tidal energy is also highlighted for the area near the Straits of Gibraltar, where current velocities reach up to 2 m/s. The issue with this BE form is that existing technologies cannot harvest energy at these current speeds and new technologies are not yet mature enough.

2.5. Slovenia

The coastline of Slovenia is only 46 km, which limits the possible site allocation of any potential offshore renewable technology. Nevertheless, according to the report of GOLEA, the most important BE forms are offshore wind and marine thermal energy. The offshore wind energy does not allow very high expectations, since mean annual wind speeds can reach up to 5 m/s. An important feature is micro-siting which can favour higher wind speed at specific locations. The most promising BE form, however, is marine thermal energy. This energy form is not used to produce electricity but is rather used for energy efficiency. In fact, the existing capacity of the region is 1.4 MW with an annual heat extraction of 2300 MWh. The mean annual sea temperature is 17.6 ^{o}C ranging from 9 degrees in February to 26 degrees Celsius in July and August (Figure 2). These temperatures are much lower or higher compared to the air temperature, hence they are suitable for heating or cooling.

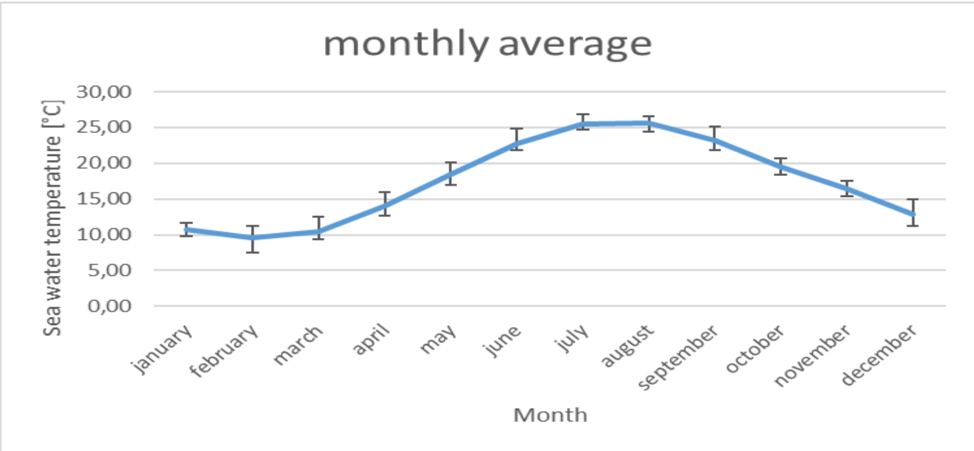

Figure 2: Interannually monthly average of sea water temperature, at 3m depth, in Slovenia (2008-2017)

2.6. Malta

According to the BE potential analysis report of MIEMA, the most promising BE forms for Malta are wave energy, offshore wind energy and marine thermal energy. According to the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) the wave potential of the region reaches up to 7 kW/m at 25 km off the coast of Malta and becomes lower closer to the coast. In addition, offshore wind speed reaches 6 to 7 m/s in areas located 25 to 50 meters from the coastline (ORECCA, 2011). Once again, floating-turbine technologies are mentioned since the steep bathymetry of the region does not allow the use of fixed-foundation wind turbines. Finally, as in Croatia and Slovenia, the marine thermal energy is proposed for use as energy storage and source when needed. This can be a feasible scenario for energy savings due to the sea/air temperature differences both in the summer and in the winter.

2.7. Cyprus

The results of the BE potential analysis for Cyprus showed that the most promising BE forms are offshore wind and wave energy. For the offshore wind energy, it was found that the areas with higher potential are areas north and south of the island, where the highest wind speed velocities can be found (Figure 3). Low-potential areas are near the east and west coasts of the island, where the lowest maximum mean wind speeds are reported. The highest wind speed values are found at the Eratosthenis seamount area (that is far from the coast) and near Akrotiri Bay, reaching up to 5.8 m/s during winter. The interannual maximum mean wind speed in these regions can reach 8 m/s during February. Regarding the wind energy potential, the Levantine Basin winds follow a seasonal pattern. During the winter months of December, January and February we see an average wind speed of 5.5 m/s in North and South Levantine, a trend which starts to decrease with the onset of March. During the summer months there are some high offshore wind speeds in some locations (Akrotiri Bay, near Eratosthenes and near Livera during June). Overall, the annual offshore wind speed average is 4.5 m/s. In Figure 3, the February mean wind speed field over the period 2010-2017 is shown as a typical winter example. The monthly averages for the same period at three (3) nearshore locations with relatively high potential shown in Figure 3 are tabulated in Table 2. In all cases minimum values appear during October, while maximum ones are observed in January.

According to Soukissian et al. (2017), an acceptable wind speed threshold of 4.5 m/s at 10 m height is required for an area to be suitable to accommodate a wind park. As a result, Cyprus is at the lower limit with mean annual wind speeds ranging between 4 m/s and 6 m/s. These wind speeds may allow the creation of a sustainable offshore wind farm but far from the coast. The sustainability of such offshore wind parks might be increased with emerging technologies. Such technologies could be hybrid solutions, harvesting two different energy forms (e.g. wind and wave).

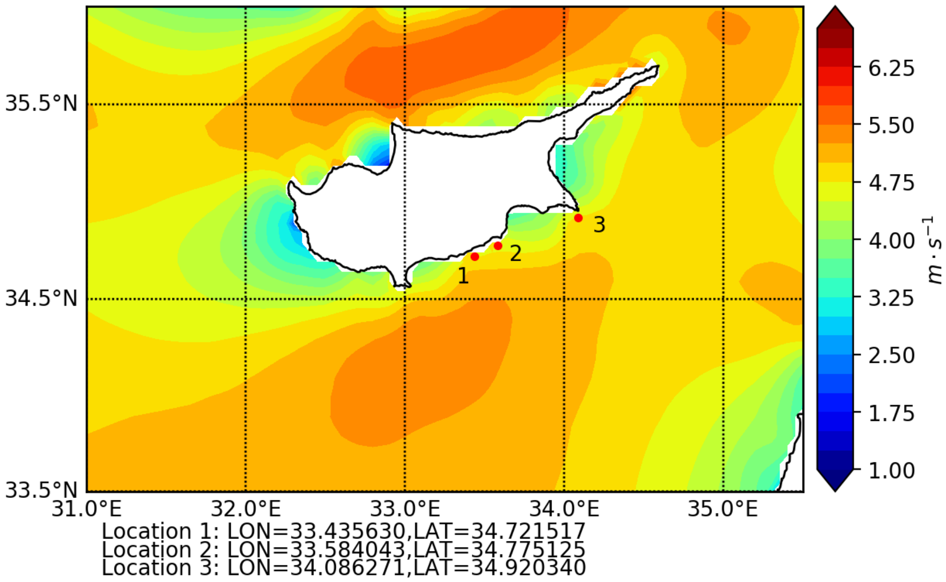

Figure 3: Interannual mean wind speed during February 2010-2017 (m s^{-1}) and three selected locations near the coast.

Table 1: Monthly mean wind speeds (m/s) during 2010-2017 over the three selected locations indicated in Figure 3.

MONTH	Location 1	Location 2	Location 3
January	4.661	4.682	4.857
February	4.581	4.545	4.688
March	4.305	4.214	4.457
April	3.774	3.681	3.717
May	3.683	3.544	3.427
June	4.002	3.799	3.684
July	3.921	3.828	3.906
August	3.576	3.468	3.496
September	3.266	3.126	2.920
October	2.766	2.750	2.838
November	3.637	3.634	3.860
December	4.484	4.531	4.745
Overall	**3.888**	**3.817**	**3.883**

Regarding wave energy, the areas with the highest potential are the west and southwest coasts of Cyprus, where the highest wave energy values, of 3 kW/m, are encountered (Zodiatis et al., 2014). Another location which is far from coast, however, is Eratosthenis area where the mean values reach up to 4 kW/m. The maximum mean wave-energy values that occur in these regions can exceed 12 kW/m during February (Figure 4). Apart from the west and southwest coasts of the island, other coastal regions do not have high enough maximum mean wave energy (Figure 4) in order to be considered as potential locations for the exploitation of wave energy. Furthermore, the wave energy values for the west and south-west coasts are not very promising, but once again the feasibility can be increased with the emergence of hybrid technologies. As for the marine current energy, this is not considered exploitable, since mean current velocities are near 0.1 m/s (Figure 5), while the threshold set by Soukissian et al. (2017) ranges from 1.5 to 2 m/s.

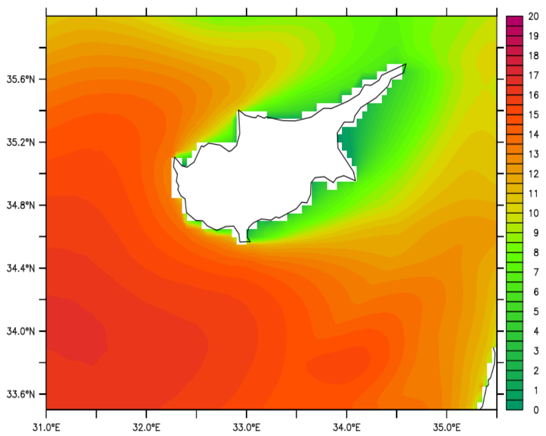

Figure 4:Interannual maximum mean wave potential energy (kW/m) for February (2010-2017)

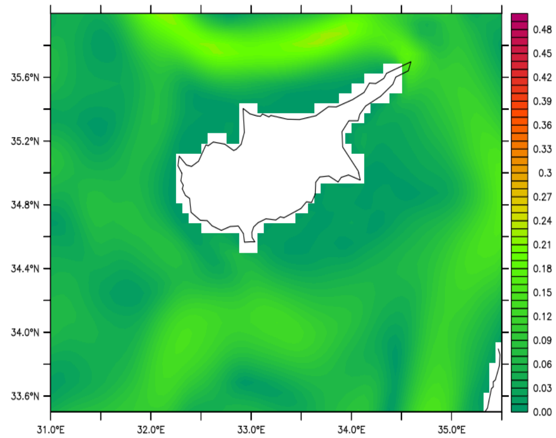

Figure 5: Interannual maximum mean surface currents (m/s) in February (1987-2016).

Finally, two BE forms not included in the report but highlighted during the 1st regional Blue Energy Lab held in May 2018 are marine thermal energy and marine biomass. Marine thermal energy is already exploited at the facilities of a large hotel in Limassol for cooling and heating purposes. Regarding marine biomass, a recently completed research project (Med-algae) showed that the use of micro-algae as a biofuel is a quite promising technology.

2.8. External impacts on energy potential

Other factors that impact the development of BE projects have been identified by the partners of the Maestrale project. Such factors include increased bureaucracy in obtaining the required licences and permits, lack or insufficient national legislation for offshore renewables-constructions as well as public and local acceptance. Many of the partners reported that while renewable energy is widely accepted on a national level, Blue Energy projects must fulfil certain criteria on a local scale, such as low visual impact and minimum interaction with other important activities (tourism, fishing, etc.).

Physical constraints that may negatively affect BE potential in the MED region have also been identified by the project partners. Such a constrain is the steep bathymetry, which characterizes most of the MED region, representing a major economical barrier as it increases the BE exploitation cost. To overlap this barrier, most of the partners recommend the use of floating rather than fixed-foundation BE technologies. A great advantage of floating structures is that they give the flexibility of avoiding high interest areas while at the same time remaining at areas with high energy potential.

3. BLUE ENERGY LABS

One of the main objectives of the Maestrale project is the establishment of, a permanent collaboration network called Regional Blue Energy Lab (BEL) in each participating region. BEL’s will aim to gather together Quadruple Helix actors (i.e, public administration, businesses, research and education institutions, and the civil society) of the Blue Energy sector, for fostering cooperation for business development, through training and capacity building actions. Each regional BEL is expected to engage local actors through events, workshops and focus groups in order to promote both knowledge as well as technological transfer. A training course is also envisaged focusing on topics such as Blue Energy technologies, funding opportunities, regulations as well as procedures to prepare business plans for the implementation of future BE projects.

During 2018 and up to the summer of 2019, forty (40) meetings of the BELs, i.e. 4 in each participating region (Italy and Spain include two regions while the rest of the participating countries are considered as one region), are foreseen. Each Regional BEL will aim to develop two (2) different pilot Blue Energy projects, based on different technologies specified through the BE potential analysis performed by each partner. The choice of the two pilot projects will derive from the outputs of the Blue Energy Labs. As of the end of May 2018, BELs have been so far organized by IFORMEST (15.2.2018, Monfalcone, in Friuli Venezia Giulia region) and University of Siena (3.5.2018, Grosetto) in Italy, by Malta Intelligent Energy Management Agency in Malta (5.4.2018, Valletta), by University of Algarve in Portugal (15.03.2018, NERA, Loulé, Portugal), by IRENA in Croatia (3 BELs organized in August/September 2017, Roving, Croatia), and by the Oceanography Center, University of Cyprus and the Cyprus Employers & Industrialist Federation in Cyprus (15.5.2018, Nicosia).

The aim of the first BEL in Cyprus was to encourage discussion and share perspectives on the promotion of Blue Energy in Cyprus, with invited guests from both the public and private sector. The Maestrale project, the BE potential analysis for Cyprus, and past initiatives for promoting BE in Cyprus were presented and discussed. The participants discussed the opportunities for using BE technologies in the area as well as the need to establish a common framework for maritime spatial planning, the need to define the legal framework and permitting procedures in the maritime space of Cyprus. During the meeting a PESTLE analysis took place to investigate the political, economic, social, technological, legal and environmental aspects of the promotion of BE in our island. The participants stated the importance of cooperation and knowledge sharing between the different entities in order to solve important issues such as the permitting procedure and the maritime spatial planning, the technological innovation and maturity as well as the possible environmental effects. The importance of such meetings was stated as essential for preparing the national plan for the maritime spatial planning.

4. CONCLUSIONS

The main objective of the Maestrale project is to create initiatives in the MED region for the development of offshore renewable energy. To this end, the project partners have analysed and identified the potential of each BE form, in their region. All BE forms are highlighted throughout the MED region, but these vary from region to region due to the unique regional geomorphological characteristics. In addition to the energy potential, any prospective BE projects must also take into account socio-economic factors, such as national legislation and impact on the local society, which may affect the project development. The Maestrale project will attempt to promote BE by bringing together Quadruple Helix actors to create a permanent network of cooperation through the establishment of regional BELs. The aim of this cooperation is to identify any barriers which may affect the development of any potential BE projects. Furthermore, BEL's aim to promote different technologies, raise awareness in public, provide training to local enterprises and eventually lead to at least two feasible BE projects in each region.

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