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Disaggregating the SWOT Analysis of Marine Renewable Energies

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Energy transitions require strategic plans that minimize inefficiencies and maximize energy production in a sustainable way. This aspect is fundamental in the case of innovative technologies based on marine renewable energies. Marine renewable energies involve problems and advantages which imply a reconceptualization of marine space and its management. Through an holistic SWOT analysis the main strengths, weaknesses, opportunities and threats are highlighted in this paper, considering social, economic, legal, technological, and environmental dimensions. We disaggregate the SWOT analysis for marine renewable energy technologies in order to create an overview of pros and cons for every dimension and better identify specific hotspots and possible solutions in different fields.

Keywords: marine renewable energy, energy transition, marine space, sustainable development, policy making, energy planning, MAESTRALE project

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INTRODUCTION

Nowadays one of the main issues facing all Countries is climate change and its associated global warming. In Rogelj et al., 2016, the Paris Agreement was signed to keep global average temperature below 2°C (Paris Agreement, 2016).[1] To mitigate climate change, the decarbonisation pathway is an essential step toward reducing CO_2 concentration in the atmosphere. In this perspective, the European Union has set three main targets to be achieved by 2030, which imply a 40% reduction in greenhouse gas emissions compared to 1990 level, at least the 27% of clean energy production from renewable sources, and 27% of energy savings (https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy).[2] Such an ambitious plan necessarily requires a transition from fossil to renewable energies.

Alongside more traditional renewable energy sectors, such as photovoltaic or onshore wind, innovative solutions for exploiting renewable sources are emerging, namely Marine Renewable Energies (MREs). MREs are "a form of renewable energy deriving from the various natural processes that take place in the marine environment" (Abad Castelos, 2014). Technologies that convert kinetic and chemical potentials or thermal properties of seawater are involved in the MRE definition. Generally, these devices convert kinetic energy from tidal currents or wind-driven waves, or exploit the potential energy deriving from the rise and fall of sea levels due to tidal range, or the temperature and chemical potential gradients, respectively, between surface and deep water and salt concentration (Pisacane et al., 2018). These sources of energy are usually named ocean energies

[1]UNFCCC. Adoption of the Paris Agreement. Report No. FCCC/CP/2015/L.9/Rev.1

[2]European Commission.2030Energy Strategy.Available from https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy

and derive from waves, tides, marine and tidal currents power, thermal and salinity gradients. Together with the already mentioned ocean energy sources, MREs include offshore wind and algae cultivation. Several prototypes to exploit MREs already exist and show different technological features concerning the design, the functioning principle on the basis of the source exploited.

As Wright (2015) argues, MREs are laying the foundations for a new "industrial revolution" based on oceans, seas and their exploitation and industrialization. For this reason, the promotion and development of MREs have several implications and would require a re-conceptualization of marine spaces and a deeper investigation of the impacts in terms of social, economic and environmental sustainability (Wright, 2015). These evaluations are necessary to avoid social or economic conflicts, preserve and protect fragile natural ecosystems and ensure the sustainable development of this energy sector considering the three pillars of sustainability. With the aim of gaining awareness of the main advantages or disadvantages that MRE technologies could lead with their installations, a SWOT analysis (the acronym stands for "Strengths, Weaknesses, Opportunities, and Threats") has been produced using a transdisciplinary approach. Indeed, the SWOT analysis allows to identify the main factors that may hamper or contribute to the development of the MRE sector. The SWOT analysis has already been applied in the literature to establish problems to face or possible policies to implement in order to promote an energy transition. Terrados et al. (2007), applied the SWOT analysis to redesign the regional energy system in the province of Jaén, a region in southern Spanish, demonstrating that the SWOT analysis has been a successful tool for energy planning and for the elaboration of policies. Similarly, Markovska et al. (2009) applied SWOT as a baseline to diagnose the Macedonia energy system and lines of action for more sustainable development.

The scope of this study is to provide a schematic knowledge framework for the development of the MRE sector. The paper focuses on tidal, current, wave and offshore wind technologies which have in common a quite similar development pathway. The knowledge framework is established through the elaboration of a SWOT analysis on the potential implications of the development of MRE.

Through a disaggregation process, all factors that may influence exploitation of the MRE are divided into five main subcategories: social, economic, legal, technological, environmental, with the aim of acquiring a holistic perspective. The results are expected to address the implementation of guidelines for the development of the MRE in different marine regions and, focusing on possible gaps or obstacles, promote discussions within the political and scientific community, also involving entrepreneurs, citizens and other stakeholders.

The final output of the SWOT analysis will identify:

- The main impactful factors for the development of MREs;
- The factors that can be influenced by innovative and programming policies;
- The possible policies to implement.

As baseline for this study we have used information and knowledge collected by MAESTRALE, an InterregMed project mainly dedicated to investigate the potential development of the MRE sector in the Mediterranean area. MAESTRALE is based on a transdisciplinary approach and analyzes MREs from different perspectives.

MATERIALS AND METHODS

The SWOT analysis refers to a kind of analysis designed for strategic planning processes of small and medium-sized enterprises (Houben et al., 1999). However, some research experiences show that the SWOT analysis is also a powerful tool to analyze the national energy sector for sustainable energy development (Terrados et al., 2007; Markovska et al., 2009). The aim of the SWOT analysis is to allow decision makers to design the qualitative structure of a process or system, identifying changes that will strategically and consistently improve it by maximizing strengths, reducing weaknesses, exploiting available opportunities, and avoiding threats (Fertel et al., 2013). On one hand, strengths and weaknesses are factors which exert pressure within a system; on the other hand, opportunities and threats are determined by the external environment. As intrinsic factors, strengths and weaknesses are manageable; opportunities and threats are external and less manageable (Dyson, 2004; Phadermrod et al., 2016). In particular, strengths are resources or capacities that stakeholders involved in the field can use to progressively develop MREs; weaknesses are limitations which may hamper MRE diffusion. Opportunities and threats are favorable or unfavorable (contextual or external) situations to face (Karppi et al., 2001). In general, SWOT underlines strengths upon which to build a strategy or weaknesses to eliminate in order to achieve established goals; at the same time, it also points out opportunities to exploit or threats to mitigate (Karppi et al., 2001).

In this study, the SWOT analysis has been performed to understand the main internal and external forces which can hamper or encourage the deployment of MRE, with a special focus on Italy.

The analysis follows a framework divided into five main subcategories or dimensions in order to investigate social aspects, economic and funding tools, legal background, technological features, environmental and ecological dimension together with the energy potential. This disaggregation enables a wide overview of what MRE technology implementations imply under different viewpoints (dimensions).

The analysis is based on a literature review in the five different dimensions and also make use of the support tools developed in the MAESTRALE Project (MASTRALE Project Deliverable, 2018). Moreover, it takes into account the results from a questionnaire designed to measure the social acceptance of citizens and a participatory approach through meetings attended by key stakeholders and experts in the field of MRE in the Tuscany region.

RESULTS AND DISCUSSIONS

Tables 1–5 present a survey of the factors belonging to different SWOT compounds. In particular, information has

TABLE 1 | SWOT analysis of social factors.

Forces	Internal	External
Social	Strengths	Opportunities
	New job positions	Public support Development of an ecological citizenship
	Weaknesses	Threats
	Social and recreational activities overlapping Visual landscape impact Risk of noise	Uncertainty in social-political acceptance Uncertainty in community acceptance

TABLE 2 | SWOT analysis of economic and funding factors.

Forces	Internal	External
Economic and funding	Strengths	Opportunities
	Major energetic independence Major control of resources by communities To share the ownership of the renewable technological park Lower price volatility	European funding Interministerial Italian decree to incentive renewable energies through public funding
	Weaknesses	Threats
	High financial and investment costs Start-up risks Lack of competitiveness Possible overlap of economic activities	Early stage of the MRE market Lack of market acceptance

TABLE 3 | SWOT analysis of legal factors.

Forces	Internal	External
Legal	Strengths	Opportunities
	Institution of a national cluster for the Economy of the Sea	2017 Italian National Energy Strategy supports the transition toward a renewable energy system European Directives are useful to promote a legal framework
	Weaknesses	Threats
	Slow existent procedures to obtain permissions and authorizations	Italian law sees gaps in the regulation of MRE installations Overlapping competences between different political actors Delays in the implementation of European directives

TABLE 4 | SWOT analysis of technological factors.

Forces	Internal	External
Technological	Strengths	Opportunities
	Increasing number of Italian R&D studies in MRE technologies Already existent infrastructures onshore or nearshore	Knowledge transfer among Mediterranean research centers and universities
	Weaknesses	Threats
	Technological designs require more studies Resources estimation in Italy is incomplete	Unexpected and extreme phenomenon Risk of survivability High sea depth

TABLE 5 | SWOT analysis of environmental and MRE potential factors.

Forces	Internal	External
Environment and MRE potentials	Strengths	Opportunities
	Good geographic position Good energy potentials Stability in time and predictable potentials	Climate change mitigation Better air quality Increasing of biodiversity
	Weaknesses	Threats
	Scarce and not homogeneous resource potentials on national level	Risk of changing hydrodynamics Risk for life under water Risk for life above water (i.g birds) Risk of noise

been disaggregated into five sub-categories in order to highlight specific topics to be faced and discussed. The next paragraphs are devoted to present sectoral specificities.

In the next paragraphs, items highlighted in the tables are presented as crucial aspects to be faced when dealing with the implementation of any MRE plants in Italy.

Social Aspects

The creation of new job positions (strength) is a positive social consequence of MREs. Communities can locally grow and develop through new specialized works. This factor may increase the public support of politicians and citizens.

Internal problems concern social and recreational activities overlapping (weakness) i.e., the possible interference between different activities, such as fishery, beach tourism, sailing, diving, shipping. Nevertheless, limitations to these other activities can be opportunely managed. Moreover, the possibility to exploit MREs as touristic attractions or hubs for the regeneration of marine ecosystems remains an open issue.

The visual landscape impact (weakness) is a huge challenge to solve. Offshore wind farms, or huge overtopping technologies may dramatically change the shape of a territory increasing, at the same time, conflicts between communities and developers.

Simultaneously, the risk of noise (weakness) during the construction phase or the functioning of technologies may represent a critical obstacle.

The choice of the site is therefore crucial. For example in some cases feasibility of new installations is higher in industrial ports than in touristic harbors. Potential visual or acoustic pollution in natural areas or in places close to residential areas has to be taken into account.

Considering the possible threats, there are uncertainties regard the social acceptance of these technologies. The social acceptance of MRE technologies could be low when the installation process is real since possible problems or fears could arise. Three sub-dimensions, namely socio-political, market and community, can be identified (Wüstenhagen et al., 2007). In this paragraph only the socio-political and the community acceptance will be briefly considered. The market acceptance will be introduced in the following section.

At this date, uncertainty in social-political acceptance (threat) is a critical issue for MRE implementation. Wüstenhagen et al. (2007) describe the socio-political acceptance as a wide concept that involves stakeholders and policy makers at supra-local and national level. The socio-political acceptance could be estimated observing the presence of policies enhancing market and community acceptance, or encouraging the establishment of financial procurement systems or spatial planning systems that stimulate collaborative decision making (Wüstenhagen et al., 2007).

Italy is not yet pro-active in supporting the installation of MRE plants. For example, considering The Regional Environmental And Energy Plan (PAER) of Tuscany, it is evident that the energy strategy by 2020 does not consider as possible exploitable renewable sources the MREs, preferring, on the other hand, hydroelectric, geothermal, photovoltaic or onshore wind technologies (Regione Toscana., 2013). Similarly, the regional energy plans of Lazio and Liguria do not include MREs (Regione Liguria, 2014; Regione Lazio, 2017).

Uncertainty in community acceptance (threat) refers to a local dimension and local stakeholders with interests in a given area (Wüstenhagen et al., 2007). Estimating community acceptance may be difficult because it should not be assumed that citizens are ready to accept a technology in their territory. The siting decision may impact on community acceptance and the more a technology directly affects the community, the stronger the social opposition can be. This effect is commonly known as the NIMBY effect (not in my backyard). NIMBY refers to protectionist and oppositional attitudes adopted by community groups when unwelcomed project are developed in their neighborhood (Dear, 1992). It is affected by multiple variables such as for example, physical features, the proximity of a technology and the temporal dimension considered (Devine-Wright, 2005). Research on social acceptance of wind farms conducted by Warren et al. (2005) has shown that proximity to the installation site has a negative impact during the design phase of a technology, whereas the trend changes after construction when the technology is operational. The results of this study on onshore wind farms are probably also expected in the case of offshore wind farms. However, the first studies on the social acceptance of MREs, such as tidal and wave devices, show a positive social acceptance of these technologies (Devine-Wright, 2011; Heras-Saizarbitoria et al., 2013). This demonstrates that social acceptance cannot be taken for granted, but appropriate strategies and policies can contribute to turn social acceptance into a strength.

Although socio-political and community acceptance shows uncertainties, public support (opportunity) seems to be favorable. Public support depends on general factors that can influence the opinion of local communities, progressively improving the feasibility of interventions (e.g., social acceptance, technological and economic feasibility, etc.).

The literature shows a high level of public support for renewable energies in Europe and UK (Toke, 2005); in general, the social context is favorable to the development of MRE technologies. In order to gain preliminary information on the public support of Italian citizens, a questionnaire was produced to elicit perceptions from the civil society. The questionnaire was circulated on the Web through social media and face to face interviews. The results of this preliminary survey showed that the sample of respondents counts 353 units, of which 92% come from Tuscany, and 58% of them live near the sea (0–10 km). 77.8% of the respondents were in favor of the construction of MRE plants in their territory with a vote of more than 8 (on a scale from 1 to 10) and 92.6% with a vote higher than 6.

Moreover, the development of an ecological citizenship (opportunity) is another important consequence of the diffusion of MREs. Ecological citizenship is defined as a continuous social process through which individuals and groups commit themselves to broaden their rights through the recognition, representation and participation of ecological practices or reasoning (Islar and Busch, 2016). In this perspective, territories close to the sea can exploit MREs and start a process of energy transition on a local scale that implies the direct and proactive involvement of local communities. The emblematic case of Samsø is an excellent example of how renewable energies can encourage the development of an ecological citizenship based on shared responsibilities and good behavior (Islar and Busch, 2016). The inhabitants of Samsø have been actively and directly involved in the energy transition process and now share ownership of renewable energy facilities, thus enjoying economic benefits.

Economic and Funding Aspects

The advantages of the development of the MRE sector lie in a major energetic independence (strength). Territories close to the sea with high potential may increase the diffusion of indigenous and renewable sources obtaining a major energy independence (IRENA Report., 2014).

In addition, MREs guarantee a major control of resources by communities (strength) and the possibility for communities to share ownership of the renewable technological park (strength). Again, Samsø is an example of how a small island community can produce energy by increasing its independence and earning revenue (Islar and Busch, 2016).

Also a lower price volatility (strength) may be a possible advantageous output as these marine renewable sources are decoupled from geopolitical interests or crisis (Pireddu, 2015). This leads to greater price stability, which is more independent of exogenous shocks. Nevertheless, one comment needs to be made. Due to climate change, there may be an increase in extreme events and damage to technologies. In this way, price volatility would not decrease.

In the economic field, there are many weaknesses that require strategic management. High financial and investment costs (weakness) are the primary cause of these delays in the commercialization of MRE technologies (Magagna and Uihlein, 2015). Investors are usually reluctant to invest in the MRE sector as technological feasibility and survivability increase risks more than traditional renewables (Leete et al., 2013). This condition drives toward the "valley of death," defined as a critical financing gap where "available funding is not sufficient to scale up from prototype to full scale deployment" (Leete et al., 2013, p. 867). Thus, since private finance is still reluctant to invest in MREs, there is a need to produce public policies and incentives to support this technological push phase.

The previous factor is strictly related to start-up risks (weakness). Indeed, for example, investors may spend huge money resources in project or installation that risk to not be implemented or that will have lower revenues.

The lack of competitiveness (weakness) is another huge obstacle to overcome. The competitiveness between several technologies is measured by the Levelized Cost of Energy (LCOE). The LCOE is measured as a ratio between the total lifetime cost of an investment and the cumulated generated energy by this investment (Pawel, 2014). The total costs are discounted at equal points of time (Ebenhoch et al., 2015). From a study conducted by Astariz et al. (2015), it is possible to observe that the LCOEs of MREs, such as offshore wind (165 €/MWh), tidal (190 €/MWh) and wave energy (325 €/MWh) are much higher compared to more traditional resources(average 46 €/MWh) based on fossil fuels.

These conditions have led to two main conclusions: the deployment of MREs is still too expensive and their technological development is only possible through public funding and financial support.

Besides, possible overlaps of economic activities (weakness) may further increase the incompatibilities of MREs with other economic sectors. Seas and oceans have important economic functions linked to tourism and the maritime industry. The total value of goods and services produced by maritime activities in Italy is €43 million, equal to the 3.5% of the GDP and provide occupation for 835.000 employees (UNIONCAMERE., 2016). Looking at these numbers, it is easily understandable that MRE technologies could not be installed everywhere and that a structured maritime spatial planning should be promoted by decision-makers and authorities with the aim of reducing possible conflicts with local communities and, at the same time, increasing synergies between activities.

The main threats concern the energy market. The early stage of the MRE market (threat) needs special attentions. According to Magagna and Uihlein (2015), ocean technologies prototypes based on tide and wave sources are more developed than osmotic and thermal gradient converters which still are in a research and innovation phase. Considering wave and tidal devices, the latter is more advanced. Indeed, tidal technologies are in a phase of market push mechanisms (Magagna and Uihlein, 2015) that is due to the early commercial stage; the need of incentives or specific funding programs to have any chance is fundamental. Likely, a market pull condition, referring to an advance commercial phase involving private investors, will take some years to be achieved. Among all the technologies, the wind offshore seems to be the most mature one thanks to its heritage from onshore wind.

Besides, there is a lack of market acceptance (threat). The market acceptance refers to the market capacity of responding to a new technology supporting and favoring it (Wüstenhagen et al., 2007) through possible tools, such as incentives, subsidies or funding. As said, in Italy there are available funds for promoting renewable energies, but these tools are not restricted to MREs. The consequence is that money resources are spent in more competitive technologies.

Although the possible issues, the European Union provides European funding (opportunity) in order to reduce some of the weaknesses mentioned. EU is aware that MRE technologies can be developed only through the creation of a stable and advantageous economic environment. For this reason, EU provides financial support to increase capacity building and knowledge transfer in the MRE sector. For instance, at the moment some of the main funding come from Horizon 2020 (https://ec.europa.eu/programmes/horizon2020/), InterregMed (https://interreg-med.eu/) Programmes.

Also considering the national dimension it is visible a more availability of funding. An Interministerial Italian decree to incentive renewable energies through public funding (opportunity), (D.M. 23/06/2016),[3] was produced by the Italian Government and it increases the number of available funds for renewable energies. In total 5.8 billions of euro per year was released to invest in renewable energies, except for photovoltaic (http://www.sviluppoeconomico.gov.it/index.php/it/normativa/decreti-interministeriali/2036874-decreto-interministeriale-23-giugno-2016-incentivi-fonti-rinnovabili-diverse-dal-fotovoltaico).[4]

Legal Aspects

The national legal background within which MREs should be developed is slow in the elaboration of well-established laws that regulate the development of MRE technologies.

Certainty, the institution of a national cluster for the Economy of the Sea (strength) established by the Ministry of Education, Universities and Research through the Decree N. 1610/3 in August 2016 is a step forward. Within the competences of this technology cluster is included the need of promoting MREs. The decree contains the main guidelines to develop project within the cluster and the stakeholders working in the field of MREs can

[3]Ministero dell'Istruzione, dell'Università e della Ricerca. (2016). Decreto Direttoriale 3 agosto 2016 n. 1610. Avviso per lo sviluppo e potenziamento di nuovi 4 cluster tecnologici nazionali. Available from http://attiministeriali.miur.it/anno-2016/agosto/dd-03082016-(3).aspx

[4]Decreto interministeriale. (23 giugno 2016). Incentivi fonti rinnovabili diverse dal fotovoltaico. Available from http://www.sviluppoeconomico.gov.it/index.php/it/normativa/decreti-interministeriali/2036874-decreto-interministeriale-23-giugno-2016-incentivi-fonti-rinnovabili-diverse-dal-fotovoltaico

directly take part to initiative to promote the sector. The cluster is in a beginning phase, thus, it will require some more time to be incisive, however, it could have a key role for developing the right basis of MREs and it will be a good tool to create a network.

Slow existent procedures to obtain permissions and authorizations (weakness) to install MRE technologies do not encourage developers. It could happen that bureaucracy may obstacle these installations due to complex and several procedures. Moreover, there are not specific authorization for these devices as emerges from the screening of the Italian Jurisprudence documents and rules. Thus, the major legal risk is to face blocks which bring to discourage the developers and to abandon the project.

Besides, Italian law sees gaps in the regulation of MRE installations (threat). Since MRE technologies are innovative, a specific regulation for these devices does not exist. Some open issues regard the property rights in the maritime environment, the main procedures to follow for their installation and the bureaucratic applications. The State regulatory uncertainty is one of the most thorny barrier for the development of the ocean energy sector (Leary and Esteban, 2009).

The overlapping of competences between different political actors (threat) is dangerous on a procedural level as well. The territorial sub-divisions in Regions and Municipalities and the special Regional Autonomies, sometimes, increase overlapping of competences and juridical conflicts. For instance, due to Constitutional Law 3/2001[5] which modifies the Constitution's Title V, Regions gained a competence for regional energy policies and efficiency. The result is that there is not an homogeneous legal framework for the development of a MRE sector on a national level. This fragmentation may hamper the installations of technologies creating confusion and deadlocks.

In addition, delays in the implementation of European directives (threat) slow down the formation of legal stable conditions. For example, in 2014 the European Parliament adopted the Directive 2014/89/EU[6] on the establishment of a maritime spatial planning. Italy ratified this directive but its effective implementation is still on the way. However, the right management of areas and activities is fundamental to create synergies and harmony between MREs and other sectors. This is a threat since Italy could fall behind with respect to the European guidelines and criteria slowing down the development process which is already quite slow.

The 2017 Italian National Energy Strategy[7] supports the transition toward a renewable energy system (opportunity). It has clearly improved the objectives set in the 2013 edition. An effective transition to renewables and the abandonment of fossil fuels, except for natural gas, is a promising feature. Nevertheless, MRE technologies are not explicitly mentioned in the National Strategy, with the exception of (hypothetical) off-shore wind farms. This may be a symptom of political carelessness or lack of priority in the development of MREs; anyhow a specific role is assigned to innovation and experimentation of new solutions.

Contrary to the Italian measures, the European Directives are useful to promote a legal framework (opportunity) that will advances MREs and their installations in marine ecosystems. The document "Blue Growth Opportunities for marine and maritime sustainable growth" shows that one of the objectives of Blue Growth concerns the development of Blue Energy (as it is called the energy sector that exploits marine renewable energy), which has "the potential to improve the efficiency of the collection of European energy resources, minimize the land use needs of the energy sector and reduce greenhouse gas emissions in Europe" (COM(2012)494 final, p.7).[8] The development of a MRE scenario is a priority goal to be pursued and its importance is also reiterated in the Communication "Blue Energy—Action needed to deliver on the potential of ocean energy in European seas and oceans by 2020 and beyond" (COM(2014) 15 final) issued by the European Commission. The Communication promotes the development of MREs and, at the same time, encourages the implementation of new laws since "[...]ocean energy will benefit from a clear, stable and supportive policy framework to attract investment and develop to its potential" (COM(2014) 15 final). The basic directive for the development of MREs still is the Renewable Energy Directive (Directive 2009/28/EC[9]) which promotes the use of energy from renewable sources on the basis of the targets and criteria set out in the document. These directives directly encourage the development of MREs development. Other directives provide the main guidelines to be respected when MREs are installed in marine ecosystems. For instance, the Marine Strategy Directive (Directive 2008/56/EC[10]) directly affects the quality of sea and oceans by promoting the achievement of good environmental status in the marine environment, while, the aforementioned Maritime Spatial Planning Directive (Directive 2014/89/EU) organizes spaces and activities in order to manage in a sustainable way the activities which occur in marine areas, with the aim to avoid contrasts between the various competing interests. Alongside these legal documents, the Habitats Directives (Directive 92/43/EC[11]) and

[5]Servizio Studi Ufficio ricerche sulle questioni regionali e delle autonomie locali a cura di Marcelli, F. (2001). La legge costituzionale 18 ottobre 2001, n. 3. Available from http://piattaformacostituzione.camera.it/application/xmanager/projects/piattaformacostituzione/file/EventiCostituzione2007/files/Dossier_n.270.pdf

[6]Europa. (2014). Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. Official Journal of the European Union L 257/135.

[7]Ministero dello Sviluppo Economico. (2017). Italy's National Energy Strategy 2017. Available from http://www.sviluppoeconomico.gov.it/images/stories/documenti/BROCHURE_ENG_SEN.PDF

[8]Europa. (2012). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Blue Growth opportunities for marine and maritime sustainable growth. Brussels, 13.9.2012, COM(2012)494 final.

[9]Europa. (2009). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union L 140/16.

[10]Europa. (2008). Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European L 164/19.

[11]Europa. (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities No L 206/7.

its Natura 2000 network must not be forgotten as essential tools for the preservation of protected areas.

Technological Aspects

Italy is proactive in the development of the MRE sector as shown by the increasing number of Italian R&D studies in MREs technologies (strength). Several Universities, such as the Polytechnic University of Turin, The University of Florence, the University of Tuscia, the University of Naples Federico II, the Mediterranean University of Reggio Calabria and research centers, such as ENEA and CNR are working for developing and improving ocean energy (Sannino and Pisacane, 2017). At national level there is an active group of experts that supports research and innovation concerning these technologies.

Already existent infrastructures onshore or nearshore (strength), such as harbors, wharf and offshore platforms may embed MRE technologies, such as wave-to-energy plants. In the case of extensions of existing docks or breakwater systems, these solutions can be easily implemented through an additional investment with promising payback time.

However, technological designs require more studies (weakness) since technologies based on MREs have not discovered yet their full potential and resistance within the marine environment. The operational experience in marine technologies date back to the end of ′90 and it regards small-scale testing of marine technologies prototype (Mueller and Wallace, 2008). Thus, the operational experience is mainly based on simpler and small devices tested in controlled environmental condition. Simulating sea states and extreme events during the testing phase enables developers to better understand if devices can operate under water in hard conditions and if the design software is adapted to reach a good energetic performance.

Resources estimation in Italy is incomplete (weakness). There is a lack of studies on potentials and this does not allow a clear knowledge of MREs and technology implementation.

The main technological obstacles once that the devices are installed are due to the intrinsic features of marine ecosystems.

For example, unexpected and extreme phenomenon (threat), such as strong storms which could destroy the technology or some components and simultaneously increase the risk of investors.

Thus, the risk of survivability (threat) of technologies due to the environment in which they are installed is one important factor to consider. The survivability is defined as "the ability of a marine energy system to avoid damage, during sea states that are outside of intended operating conditions, that results in unplanned down time and the need for service" (Brown et al., 2010). Extreme wave, wind and current events may destroy or damage technological component of devices. Also, in ordinary condition the marine environment can induce corrosion and structural stresses (Mérigaud and Ringwood, 2016) which require maintenance operations.

Moreover, technologies may be influenced by the high sea depth (threat). In the Mediterranean depth puts some constraints, especially for the installation of off-shore wind turbines. In Sicily and Sardinia, sea depth is higher than 30 m within a few hundred meters from the coast. This hinders the installation of fixed wind towers and calls for innovative solutions, such as floating wind turbines (Van Haaren and Fthenakis, 2011; Rosenauer, 2014).

Neverthless, the knowledge transfer among Mediterranean research centers and universities (opportunity) is currently increasing in the field of MREs and this is an opportunity to fast the MRE process development and improve the adaptation of these innovative technologies to the environment. This process is encouraged also by the European Union programmes.

Environmental and MRE Potential Aspects

Good geographic position of Italy (strength) surrounded by seas with more than 8,000 km of shores and 458 small islands in its territory. This allows for identifying many opportunities for the development of MREs considering the extension of coasts, number of harbors and other maritime infrastructures.

Good energy potentials (strength), even though the average power is lower than that of oceans or the Northern Sea, there are some advantages, such as lower intensity of extreme events, higher frequency and continuity. Regarding offshore wind, the major source intensities are located close to the two main islands. For example in west Sardinia, the annual mean wind speed is about 5.4 and 4.9 m/s while, in Sicily, close to the Messina strait, the annual mean wind speed is about 5.7 m/s (European Centre for Medium-Range Weather Forecasts, 2015). Wave energy is directly related to wind. From studies conducted by Iuppa et al. (2015), higher potentials are located in the south-western coast of Sardinia (9.05 kW/m) and more moderate potentials close to Sicily (4,75 kW/m). The areas with the greatest potential in terms of marine tidal currents are close to the Venice Lagoon, to the Strait of Bonifacio in Sardinia, while the most promising site is the Strait of Messina in Sicily (Sannino and Artale, 2011).

Stability in time and predictable potentials (strength) characterize the MRE Italian situation. This aspect allows to develop and test technologies for a definite environment with features known.

Scarce and not homogeneous resource potentials on national level (weakness) are nevertheless observed in most of the Italian marine environment. In particular, marine currents are generally low. In the Tyrrhenian Sea the average speed is lower than 1.0 m/s whilst, observing the already existent prototypes and technologies, turbines usually need a stream speed of at least 1.5–2 m/s to operate efficiently.

Among threats and opportunities, the major aspect to consider concerns the possible negative or positive impacts of these technologies on the environment.

Risk of changing hydrodynamics (threat) is a possible negative impact of MRE devices, especially for plants with huge dimensions. These technologies in some way can calm the sea creating a slow "recirculation" process (Pelc and Fujita, 2002) limiting the transport of gases, nutrients and food to sedentary organisms (Shields et al., 2011).

Risks for life under water (threat) exist with some wave or tide technologies due to the possibility to inhibit or limit physiology, nutritional behaviors, migration habitudes, etc., of fishes or other living species due to the presence of devices and consequently cause their death (Pelc and Fujita, 2002).

Risk for life above water (threat) is mainly related to the interaction between offshore wind and birds. Offshore farms may hamper birds, and if they are installed along a migratory route the possible impacts increase (Sun et al., 2012).

Risk of noise (threat) is possible during the phase of construction and during the activity of the technologies. Some species may be particular sensitive to noise and suffer it avoiding the area (Gill, 2005).

Climate change mitigation (opportunity) is the general objective of promoting new initiatives and innovation in the MRE sector. The Ocean Energy Europe[12] estimated that 100 GW can be obtained by ocean energy industry (exploiting waves and tides) by the end of 2050. This would be enough to provide electricity for 76 million of European citizens. The contribution of every single installation in the Mediterranean area is difficult to estimate yet, but any pilot initiative or test is highly desirable.

A better air quality (opportunity). Fossil fuels may be progressively substituted by cleaner energy production systems, such as MRE technologies. Especially in islands, where most of the electricity is produced locally by thermoelectric plants fueled by heavy oil or diesel, air quality is often compromised and the exploitation of MREs can be a definitive solution.

Increasing of biodiversity (opportunity) emerges as a positive impact from literature. MRE technologies may work as artificial reefs favoring the concentration of nutrients and thus fish concentration (Pelc and Fujita, 2002). Moreover, the presence of technologies would likely forbid the navigation in their proximity and therefore create a sort of protected area for reproduction of species.

The SWOT analysis reveals the main advantages and disadvantages of technologies based on MREs. Among opportunities, general political and social enthusiasm has a good impact on the development of renewable energies, in general, and marine renewable energy technologies, in particular. Such a condition may be virtuous because political action could orient investments toward the development of renewable energy technologies generating people's consensus that, in turn, can further corroborate policy and management choices in that direction. The political and legal support toward renewable energies has a double dimension which derives from the European directives and the national energy strategy simultaneously. The growing interest in MREs is also demonstrated by the increase in public and private studies in MRE technologies and in the number of pilots and prototypes realized. Research and innovation studies are conducted with the aim of maximizing the opportunities created by MREs.

At the same time, the MRE sector shows important issues to solve for pursuing an efficient strategic plan.

As we already said, social acceptance should not be taken for granted. Especially in a pre-construction phase, citizens tend to be more skeptical about a plant and they show a major resistance. Heras-Saizarbitoria et al. (2013) proposed a review of articles in literature dealing with social acceptance. From their work it emerges that variables, such as perceived benefits, information, low visual impact, procedural justice and trust, and local community involvement have pivotal role in addressing citizens toward the acceptance of a technology. Thus, strategies may be thought from these starting point.

For instance, more reliable relations could be created by participatory and inclusive processes established *ad hoc* to allow citizens to express their opinion and acquire knowledge about technologies. In fact, knowledge may clarify and solve doubts and fears, stimulating positive debates. According to Disconzi (2011), information plays a crucial role in the acceptance of wave and tides technologies. By means of a questionnaire, Disconzi noted that the three most important strategies for wave technologies regard the importance of being informed about the utility of these technologies to reduce the GHG emissions, the importance of being informed by communication tool and the opinion of scientists. Other strategies can be pursued, in this sense because communication of the potential benefits for the community may generate a higher level of acceptance of citizens.

Legal, economic, funding and technological issues are mostly related with each other, and synergies between several actors involved are fundamental. Leete et al. (2013) investigated the main factors that investors consider fundamental when investment plans have to be decided. Investors clearly express the requirement to have a consistent and predictable regulatory support background and, at the same time, financial support mechanisms and confidence in the technology functioning. Indeed, a clear framework of rules to regulate technologies which exploit MRE is not mature yet. This instability creates uncertainties in the private finance and an unwillingness to invest in MRE projects. This aspect lead to delays in the technological development which is only supported by public funding. As mentioned before, the Ministerial Decree (D.M. 23/06/2016) for renewable energy establishes a huge amount of money to enhance the development of new technologies. However, it does not specifically direct money to the MRE sector. The result is that funds are mainly used for more competitive technologies. In short, MREs are in a critical stage now: on one hand, there is the need to develop the technologies in order to improve their efficiency and durability, decreasing at the same time the high initial costs; on the other hand, the high initial costs and the lack of funding inhibit technological innovation and drive investors toward more competitiveness alternatives. Nevertheless, it is demonstrated that investing in these technologies will improve the learning curve in MREs. Adopting a microeconomic point of view, the learning curve is used as an empirical method to understand what are "the effect of learning on technological change [. . .]" (Jamasb and Kohler, 2007, p. 2) and it measures the learning effect in terms of "reduction in the unit cost (or price) of a product as a function of experience gained from an increase in its cumulative capacity or output" (Jamasb and Kohler, 2007, p. 2). Thus, the learning curve can be considered as an experience curve that measures the ability to reduce costs by virtue of cumulative experiences in producing and deploying a unit of product (MacGillivray et al., 2014). This means that investing in R&D activities will entail a learning by doing process that creates the right basis to improve the learning rate of the technologies

[12] Ocean Energy Europe. Europe needs ocean energy. Available from https://www.oceanenergy-europe.eu/ocean-energy/

decreasing their costs and improving their technological features at the same time (Jamasb and Kohler, 2007; Esteban and Leary, 2012). Thus, funding are necessary to implement R&D activities and later shift MREs from a market push to a market pull phase.

A clear legal framework is a fundamental condition for MRE development. In Ireland in 2014, an Offshore Renewable Energy Development Plan (OREDP[13] was published. The OREDP is a sort of manual whose aim is to give guidelines to increase the development and the deployment of MREs. It encourages the collaboration and the share of information between several stakeholders trying to affect the governance, the maritime spatial planning and thus the test sites, the creation of economic support tools, the collaboration between companies, research centers and experts, and the environmental monitoring (https://www.dccae.gov.ie/documents/OREDP%20Interim%20Review%2020180514.pdf).

Creating political and legal necessary favorable pre-conditions for the MREs installations, the OREDP also introduces some preliminary market support schemes. The adoption of the OREDP can contribute in increasing the chance of investments in MRE sector, giving positive signals to investors and resolving potential issues.

Strengths, weaknesses, opportunities and threats are all linked with each other. If we consider all the investigated dimensions or sub-categories it may happen that what is considered as a strength in one dimension it is actually a weakness in another. Thus, it is important to properly manage the implementation of the MRE sector in order to reduce possible conflicts pursuing a path that better satisfies the general well-being according to the sustainability concept.

CONCLUSIONS

The article aim was to identify and study factors that can hamper or encourage MRE sector development, with a focus on the Italian context. The SWOT analysis has proved to be a good tool for investigating on MREs adopting an holistic approach. Indeed, factors involved in the development of MRE technologies have been divided into several dimensions in order to encompass all the possible social, economic, legal, technological and environmental aspects. However, the main limit of SWOT analysis concerns the arbitrariness. The selection or the exclusion of factors may depend on the perspective of the analyst. In order to avoid as much as possible this risk, a review in literature on MREs was done aiming at pointing out the main impactful factors across several dimensions. Another limit that SWOT analysis could experience concerns a possible loss of information or compensation processes when the information is aggregated. To alleviate this problem the disaggregation seems to be a possible solution since it allows to narrow the search to specific disciplines considering more detailed information.

The SWOT analysis reveals important outputs for the several dimension.

[13]Government of Ireland. Offshore Renewable Energy Development Plan (OREDP). Interim Review. May 2018. Available from (https://www.dccae.gov.ie/documents/OREDP%20Interim%20Review%2020180514.pdf)

- Considering the social aspects it emerges that major issues concern the social acceptance of technologies. However, good transparency, communications and participatory policies may contribute in creating cohesion between the several stakeholders involved. Generally, the public support toward renewable energies is high, and for this reason also MREs could be seen positively by citizens and decision makers. An important aspects to consider is the location of technologies in order to not interfere or disturb with the recreational activities or the seascape.
- In the economic and technological field, it is possible to affirm that economic challenges stem from the increase in investment costs due to risk factors that projects face and the lack of competitiveness of MREs compared to more conventional fossil sources or more traditional renewable energies, such as photovoltaic or wind onshore. Although in Italy several research centers are promoting MRE technologies by developing innovative prototypes, the lack of subsidies, incentives or sectorial policies increases uncertainties. This condition is caused both by the early stage of MRE market and by a lack of market acceptance of MREs. The advantages bring by MREs are several in the economic field. Local control of indigenous resources together with the chance of sharing the ownership of the marine technological park, can increase the energetic independence of communities reducing price volatility. Besides, thanks to European funding, MRE could have an initial economic support. However, with the aim of stimulating the growth of the MRE sector, policy makers should introduce more economic incentives or subsidies or funding to the market. In particular, they should be explicitly oriented toward MREs to avoid investments focusing on more competitive technologies.
- A weak legal framework without clear and defined rules and laws for the deployment of MREs discourages investors. In particular, the slowness of existent procedures for obtaining permits and authorizations create delays and losses. This situation is even worsened by overlapping responsibilities between different political actors. Nevertheless, the European Union is trying the give cohesive guidelines to all Member States in order to facilitate the legal development of MREs. Also on a national dimension, in recent years, more efforts have been done to implementing renewable sources in general, and more specifically, the last year, a cluster for the Economy of the Sea was designed and now is taking shape. Reducing the legal uncertainties through sectorial laws on MREs, or simplifying the bureaucracy procedures, could be a first starting point to increase the optimism of MRE investors.
- From a technological point of view, the MRE sector seems to be promising as several research and design studies are carried out by many private and public actors and a good knowledge transferring is occurring at the Mediterranean level. However, more technological design studies and better mapping of resource potentials should be implemented. The major technological threats stem from the risk of survival due to extreme environmental phenomena, or from the environmental characteristics of marine ecosystems, such

as the high seas, which could prohibit the installation of technologies.

- Considering the environmental aspects, Italy shows good and stable energetic potentials in specific areas close to Sardinia and Sicily. For example, the annual average wind speeds close to Sicily and Sardinia are considered exploitable. Similarly, tidal currents in the Strait of Messina or in the Strait of Bonifacio have been found strong enough to be deployed. The possible environmental impacts regard risks for life below or under water and risk of altering the marine ecosystem. However, with a maritime spatial planning strategy and thanks to environmental evaluations, these possible impacts could be reduced by identifying areas which present low risk impacts. On the other hand, the opportunities which derive from the technologies may give a huge contribution in the mitigation of global warming, reducing the CO_2 emissions, and improving the marine environment quality.

Technologies based on MREs are promising and require a good planning. Economic, legal and technological factors are particularly relevant for the MREs sector. Since these three dimensions are connected, it is important to design a comprehensive path to act simultaneously on weaknesses and threats.

AUTHOR CONTRIBUTIONS

GG performed the SWOT analysis and wrote the draft paper. MG, FP, NM, and GS supervised the social, economic, and environmental chapters and co-authored the paper. MM and FV supervised the legal part and co-authored the paper.

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