A SWOT Analysis of the Marine Energy Sector at the European Level

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Abstract: The present work aims to present the main potential sources of marine renewable energy: offshore wind and ocean energy (wave, tide, marine currents, temperature gradients, salinity gradients) and their social and environmental impact to make an analysis of the degree of capitalization of these alternative energy sources. The main objective of the proposed research is to identify the most relevant strengths, weaknesses, opportunities and threats (SWOT) in order to outline an overview of the use of the renewable marine energy resources at the European level that is to identify the possibilities of increasing the quota of exploiting the potential of the marine energy sector.

Keywords: SWOT analysis; ocean energy technologies; renewable sources; offshore wind; marine energy sector

JEL Classification: P48

Nomenclature

SWOT- strengths, weaknesses, opportunities and threats;

OTEC (Ocean thermal energy conversion) - method that use the temperature difference between cooler deep and warmer shallow or surface seawaters;

IEA- International Energy Agency;

LCOE- Levelized cost of energy;

RED (reversed electro dialysis) - practical method based on osmosis with membranes use for the salinity gradient power;

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PRO (pressure retarded osmosis) - practical method based on osmosis with membranes use for the salinity gradient power;

RUE- Renewable Energy Sources in the EU;

EMEC-European Marine Energy Centre;

kW (kilowatt)-10^3

MW (megawatt)-10^6

GW (gigawatt)-10^9

TW (terawatt)-10^{12}

PW (petawatt)-10^{15}

Introduction

The world population growth, expansion of the global economy, improving the living standards and dependence on the technology in developing countries, can an increase of the energy demand, even in the conditions of increasing progresses regarding the economic efficiency.

Nowadays, more than a billion people do not have access to electricity, but they expect that in 2040 their number will be reduced to about 500 million.

According to the International Energy Agency (IEA) scenario, an increase of 30% in global energy demand by 2040 means an increase in all the modern fuels, but also a significant change in the structure of the primary energy consumption. (Renewable Energy Market Analysis Latin America, 2017)

While the global oil reserves can support a current level of consumption by 2040 and the natural gas resources can support this level by 2070, the demand for the energy can be satisfied by using the renewable energy resources. (Onea et al., 2015)

Major concerns on the threat of the global climate change and other environmental effects caused by the use of the fossil fuels have increased the interest in the use of the renewable energy resources and have drawn attention to the huge marine energy stocks. These resources have an important energy potential and are locally and nationally available. (Gasparotti & Rusu, 2012)

The use of the renewable energy sources provides economic and energy security benefits, and it also ensures the energy independence of the countries by limiting the import of energy resources and creating at the same time the environmental benefits, by reducing the emissions of greenhouse gases, that cause the global warming effect, and thus contributing to the reduction of the environmental pollution. (Rusu et al., 2014)

Renewable energy includes: solar power, wind power, hydropower, ocean energy/sea, biomass energy, geothermal energy. These types of energy alternatives are affordable, reliable, sustainable and modern as well. (Rusu, 2016)

Within a worldwide context aimed at creating a sustainable development, the use of these renewable energy resources is one of the main objectives of the global energy policy.

The United Nations Organization strives for ensuring the access to the energy for all the planet's inhabitants, while promoting at the same time the sustainable energy resources, focusing on the renewable energies.

The United Nations Development Program and Project RIO+20 support "the sustainable, low carbon, climate resilient pathways". (Kolios & Read, 2013)

At the EU level, the energy policy for the next period until 2020 has as targets the sustainability, competitiveness and security in the energy supply. In December 2008, the European Parliament adopted the "Energy-Climate Change" regulation package, which sets the targets for reducing the greenhouse gas emissions by at least 20% compared to 1990, increasing the share of the renewable energy sources by 20% of total EU energy consumption and a 20% reduction in the energy consumption based on the energetic efficiency improvement.

The 2030 targets are more ambitious (Figure 1): reduction of the greenhouse gas by 40%, increasing the share of the renewable energies by 27% and increasing the energy efficiency by 30%. (Soede, 2017)

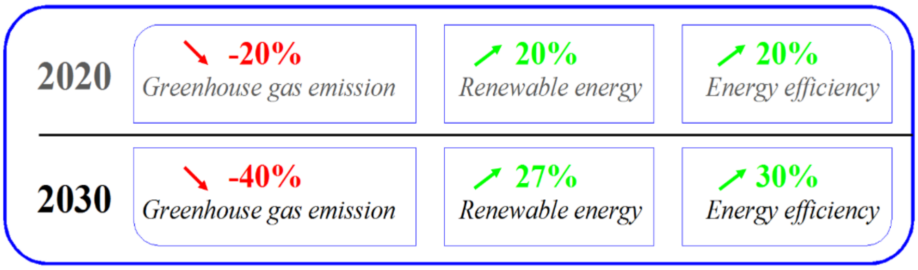

Figure 1. The EU objectives for the renewable energy area (processed from Soede, 2017)

In order to achieve these targets, mandatory national targets were been set for each Member State, as well as cooperation mechanisms in this field.

Europe is a leader in the renewable energy. In order to maintain its position, it must support the development of a new generation of renewable technologies and it must integrate the energy obtained in the energy system in an efficient and cost-effective way.

The aim of this paper is to present the main potential sources of renewable marine energy: offshore wind energy and ocean energy (wave energy, tidal energy, marine current energy, temperature gradients energy, salinity gradient energy) and their social and environmental impacts, in order to achieve a SWOT analysis, to highlight the factors with positive/negative influence on the exploitation of these alternative sources of energy.

2. Renewable Marine Energy (Blue Energy)

The seas and oceans are a huge potential of the renewable energy resources. The analysis of this energy potential suggests that usable marine energy far exceeds the global energy requirements. Renewable marine energy includes the offshore wind and ocean energy. (Ivan et al., 2012)

The latter is largely derived from the power of waves, tides and currents, and less from thermal and saline gradients in some locations.

The marine energy potential does not have a uniform oceanographically distribution. It is available in the most coastal countries.

The use of the ocean energy is in an efficient stadium. The costs of ocean energy are still very high, and that is a barrier to its implementation. There are also social and economic barriers, infrastructural and the environmental obstacles. (Onea & Rusu, 2014)

Transforming the ocean energy into electricity could play an important role in meeting the rising energy demand, diversifying energy supply, increasing energy security and protecting the environment, but also in boosting the economic growth in the coastal regions. (Raileanu et al., 2015a)

Europe is the leader in the ocean energy market. This is the place where the most technology developers work. The EU also has the major ocean power testing centres. The EU has strong mechanisms supporting the development of the ocean power technologies from the initial phase of prototypes to commercialization (Figure 2).

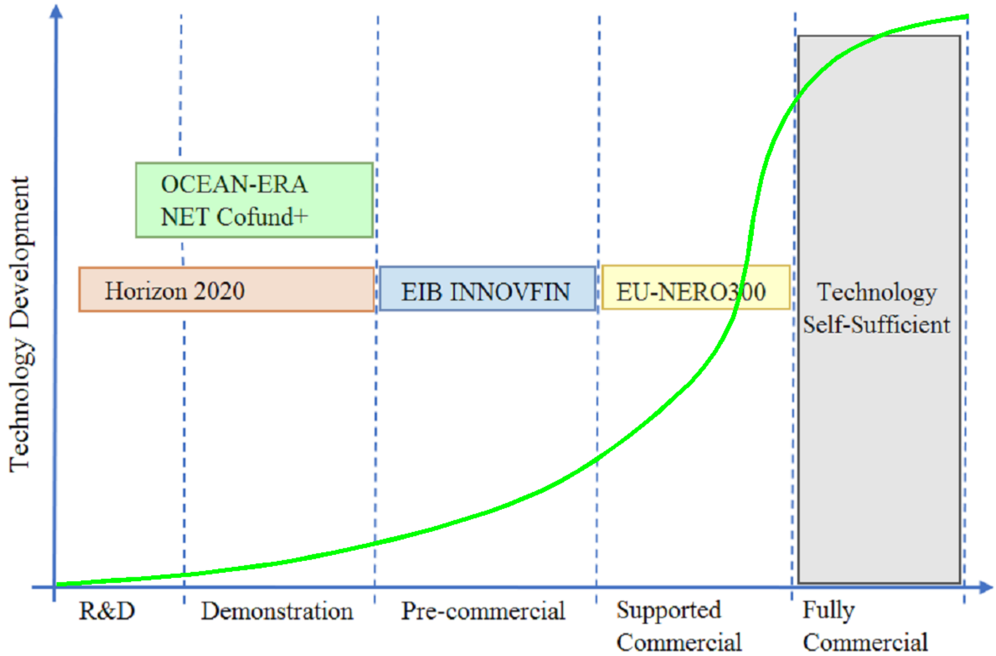

Figure 2. The development of the ocean energy supported by EU mechanisms (processed from Soede, 2017)

The Horizon 2020 Project has funded more than EUR 60 million for the Wave and Tidal energy research and development projects in only two years.

The NER-300, EIB-Innov-Fin tools contribute to supporting the deployment of the demonstration projects.

The ocean-going projects that benefited from funding from the different organizations (Horizon 2020, NER-300, EIB-Innov-Fin), which are expected to be operational in 2020, are 71 MW tidal energy and 37 MW wave energy.

Currently, in the EU have been announced projects of over 600 MW of tidal power and 65 Mw of wave energy, with operations expected to begin by 2020. (Magagna et al., 2016)

The Atlantic coast has the biggest potential for developing the ocean energy in the EU. It is followed by the Mediterranean Sea and the Baltic Sea basin. (European Commission, 2015)

Estimations that have been made reveal the fact that by 2050, the ocean energy could meet 10% of the EU’s electricity demand. (World Energy Council|World Energy Resources, 2016) Its total estimated value by the Caroon Trust (UK) will be of about € 575 billion between 2010 and 2050.

Along with Europe, the US has an important place in this area, but other countries such as South Korea, Ireland, the Netherlands, China are now “challenging their dominance”. (World Energy Council|World Energy Resources, 2016)

2.1. The Offshore Wind Energy

The offshore wind energy is obtained by using the current winds above the seas and oceans.

Wind is the air movement in report to the surface of the earth. The movement of the air mass is due to the unequal distribution of the atmospheric pressure in space that occurs as a result of the unequal warming of the earth’s surface. In wind installations, the wind transfers its energy to the propeller blades acting on a turbine, and thus it transforms the kinetic energy into the mechanical energy, which in turn is transformed into energy by an electric generator powered by the turbine. (Anton et al., 2017)

Compared to the land-based winds, the offshore winds are stronger and last longer. These characteristics vary from one region to another and vary seasonally or annually.

The power developed by the wind turbine is proportional to the third wind speed. It also depends on the air density where the turbine is located, which in its turn depends on the altitude, temperature, humidity, and the coordinates of the geographical area (latitude and longitude). Consequently, “the offshore wind energy will vary from one region to another”. (Wilhelmsson, 2010)

The wind energy potential is distributed across three types of sites. (Onea & Rusu, 2016)

Deep water sites (water depths up to 30 m) represent the largest part of the offshore wind capacity in the world. It is increasingly using the existing technology for the onshore wind installations, which makes it more economically viable. Installations, typically resting on the sea floor, rely on monopolies and gravity-base substructures to hold the turbine and blade aloft.

Transition depths (water depths between 30 and 60 m) use the installations that can rest on the sea floor, but could be developed more efficiently using the floating platforms instead of the rigid, grounded structures. The projects for transition depth can use the turbines of the kind used in the terrestrial projects, but they can also use the offshore turbines and blades capable of capturing more energy and resisting in the marine environment.

Depths (water depths greater than 60 m) are the largest offshore wind energy potential (approximately 60% of the estimated potential). These sites can be developed by using platforms rooted to the bottom of the sea or using floating platforms. (IEA, 2011) (Griset, 2010)

The first wind energy project was developed in 1991 in Denmark, in shallow waters (about 4 m depth) using 11 turbines, with a capacity of 5MW. In 2009, Denmark had the largest offshore wind power project with 91 turbines and a capacity of 209 MW. In the United Kingdom there is an offshore wind farm installed with a capacity of 1041 MW. In 2009, the turbines with a capacity of 584 Mw were installed in Europe, and beginning with September 2010, approximately 42 offshore wind projects have been installed, mainly in low-water (less than 30 m) areas with installed capacity of 2377 Mw. (IEA, 2011) (Griset, 2010)

During 2012, the offshore wind capacity of the EU increased by 33%, so at the end of the year there were 56 offshore wind farms located in 10 European countries with a capacity of 5 GW. These farms covered 0.5% of the total EU electricity consumption. Also in the EU, in 2014, 277 offshore wind turbines with a total capacity of 1Gw were installed. By 2020, new offshore wind turbines will be installed so that the installed capacity reaches 43 Gw, representing 3% of the total EU electricity consumption. (European Commission, 2015)

Offshore wind energy capacity in shallow waters is increasing in the northern seas of Europe. (Rusu & Onea, 2016)

Starting January 2017, 12631 MW were connected to the network.

The EU is a global leader, with about 90% of the projects recently completed in the world, with UK, Germany, and Denmark being on the top. Along with the improvement of the technologies, the deep water sites develop. In June 2009, the world's first floating wind turbine was installed in a demonstration project using a 2.3 MW Siemens turbine. The costs per energy unit were high, but it was estimated that in the future, "mature trading costs for floating implementations will be competitive with other offshore wind energy projects". (Griset, 2010)

It has been estimated that 80% of the EU's wind resources are in the deep waters, where fixed turbines cannot be used. This is the case for the waters off the coast of Iberia or the Mediterranean Sea, where the offshore wind power would be possible using the floating turbines." A wind float project of 2 MW is already installed in Portugal and another with three 8 MW turbines is in an advanced stage of implementation". (Wilhelmsson, 2010)

It is estimated that until now, the offshore wind energy is only 2% of the total global wind capacity. (World Energy Council|World Energy Resources 2016)

Social and environmental impacts

The analyses made in this field have shown that further studies on the environmental and social impacts of the offshore wind turbines are still needed.

However, it has been observed that for the wind farms that are not visible from the shore, the visual impact and the sound pollution are minor, and for those located away from the shore, in deeper waters, these are very small, which is why there are no reasons for their non-acceptance by the public. The noise generated by the wind turbines is mainly due to the interaction of the blades with the atmospheric disturbances. The noise is continuous and it registers frequencies greater than 100 Hz. It can be reduced through the technical measures. (World Energy Council|World Energy Resources 2016)

One of the few environmental inconveniences of the offshore and terrestrial wind installations is the potential to kill birds. But the careful location of the wind turbines, so as to avoid important corridors of the migratory birds, can significantly reduce this danger. With a careful location, it can also avoid the dangers of the migration or local fish. (World Energy Council|World Energy Resources 2016)

Taking these things into account, the offshore wind can be considered as one of the most environmental friendly marine energy sources.

2.2. Wave Energy

Waves are generated by the action of the winds, which transfer their energy to the superficial water layers. (Gasparotti & Rusu, 2016)

The dimensions (wavelength, height and wave propagation direction) are determined by the size of the water surface on which the wind acts, the duration and the speed of the wind, and the direction of the wind. (Niculescu & Rusu, 2017)

The waves contain kinetic energy and potential energy that can be used to drive turbines or other power take-off systems to generate the electricity. The world's available wave potential is about 2 TW, of which 320 GW in the EU.

From this overall potential, only about 10-12% could be used in the form of electricity, as a result of some factors, including the socioeconomic factors, hard ocean environment, energy conversion losses and costs. (Renewable Energy Market Analysis Latin America, 2017)

The biggest wind energy potential is the region with the strongest winds. These are the regions with temperate latitudes of 40º and 60º north and south latitude. (Onea & Rusu, 2016)

Among the wealthiest nations in terms of the potential for the wave energy is the United Kingdom, north of Scotland, where more than 50 TWh could be obtained by exploiting the wave energy. (Pelc & Fujita, 2002)

The wave power is based on the wavelengths and wave heights, as well as on the sea water density. (Irina Spana’s Wave Energy Valuation)

On the west coast of the Europe, the average of the wave power is 50 kW per each meter of the shoreline length and can reach, in storm conditions, up to 1000 kW/m.

For the ocean, the average of the specific wave power is 10 ... 100 kW/m, depending on the area.

The exploitation of the wave energy consists in capturing their energy and converting it into electricity.

The equipment used for this purpose can work by capturing the energy at the surface of the water or capturing the energy at a low water depth based on the pressure fluctuations. Wave energy converters may be floating or submerged beneath the surface of the water, but may also be located on the shore or bottom of the sea in low water. The electricity obtained is transported to the shore by the submersible cables (renewable energy systems).

There are more than 1,000 patent proposals for the wave energy capturing the technologies, out of which only a few have proven to be commercially viable (Renewable energy from the ocean).

In 1990, Ocean Power Technologies (USA) and Pelamis (United Kingdom) entered the market and they have provided significant financial resources for the development of the wave energy capturing devices. In 2003, the European Marine Energy Center (EMEC) was set up to provide opportunities for testing the wave’s energy devices.

Concerning the wave energy projects, during the 1990s, the European governments have supported the innovation in this area with a EUR 2 million investment under the Joule 2 program, which have led to the demonstration projects.

By the mid and late 2000s, the number of the demonstration projects has increased, but a significant number of them have subsequently cancelled due to the worsening of the financial environment.

Demonstrative projects take place in Great Britain, Denmark, and Spain. There are also some projects in the UK in a pre-commercial stage.

In 2004, Pelamis became the first company in the world that generated wired electricity from a wave energy converter (WEC), and in 2008 it delivered a wave energy recovery network using three Pelamis devices with a total nominal power of 2.25 MW. Unfortunately, it was soon decommissioned due to a malfunctioning. (World Energy Council|World Energy Resources 2016)

The development of the wave energy technologies has slowed down in the recent years due to the technological shortcomings, which have reduced the investors' confidence in the wave energy technology. According to the Ocean Energy Forum, the emphasis should be on testing of the existing prototypes, improving their performance and the service reliability.

Although most of the tested prototypes are being considered as advanced technologies, which survived under the ocean conditions, they generated a limited amount of the energy.

Between 2012 and 2013 a number of the equipment manufacturers left the market, and by the end of 2016 the situation was not very different from 2014, with a small number of projects being presented during this time.

The majority of them consist of WEC devices (wave energy devices) of low capacity (with a rated power below 50 kW) and only a small number with a higher capacity. (240-300 kW) (Magagna, 2016)

In 2016, Sweden began the construction of a large commercial brand for the wave energy at Sotenas, with 42 devices and a 1.05 MW capacity. (World Energy Council|World Energy Resources 2016)

A number of 21 projects are installed in the water or are expected to become operational in the near future, of which 15 projects are in the EU. Current plants have a capacity of less than 1 MW, but are expected to reach 10 MW on the long term.

Fig. 3 shows the wave energy capture capacity in Europe, in operation or under construction. (OES, 2016)

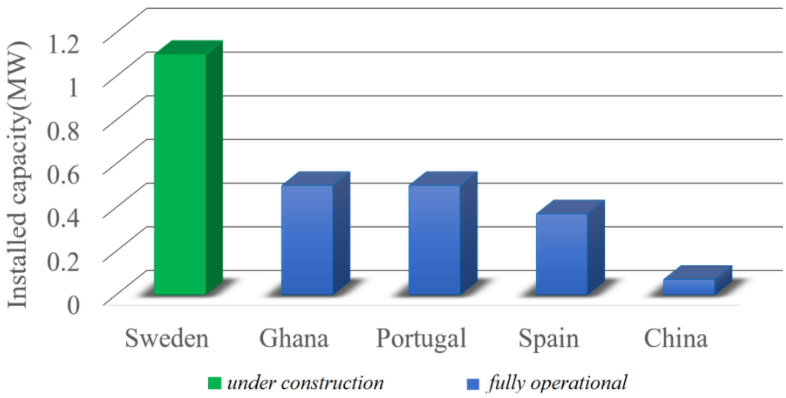

Figure 3. Europe-wave energy installed capacity in operation or under construction (processed from OES, 2016)

At the EU level, AWS Ocean Energy has proposed a two-phase project in the northern Scotland, the first phase with 4 devices (10 MW) and the second with 76 devices (190 MW).

In Portugal, the SWEU project with a capacity of 56 MW is in the early planning stage and it will have 16 Wave Surge oscillating converters of 350 kW (World Energy Resources) 2016.

Figure 4 shows the installed wave power in the future. (OES, 2016)

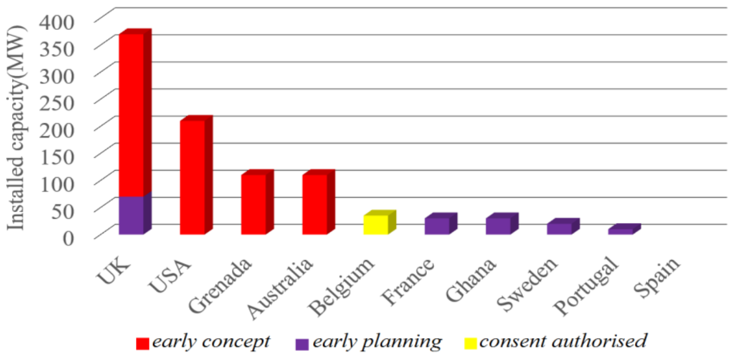

Figure 4. Wave energy installed capacity in development in Europe (processed from OES, 2016)

Oscillating water column, water accumulator installations and waves-powered floating installations (Bejan et al., 2015) are used to capture the wave energy.

The most advanced types of devices are those with oscillating water column (OWC). They are the best performing both as an operating and power factor. Even so, the power factor of OWCs is low, of 25%, while for other types of devices the registered percentage is 10% vs. 30% to 40% as needed for the technology to be economically viable.

The current LCOE (levelized cost of energy) regarding the wavelength cost of energy varies between 60 cEUR/kWh and 110 cEUR/Kwh for an average resource.

The EU targets for this LCOE are of 20 cEUR/kWh in 2020, 15 cEUR/kWh in 2030 and 10 cEUR/kWh in 2035. Achieving these goals is possible through the technological progress. (Magagna, 2016)

Impact on the environment

Studies on the environmental impact of the wave energy capturing devices have highlighted both positive and negative effects.

In the case of low-capacity installations, a positive effect is the increase of the biodiversity in the area due to the fact that various species of mussels, shells and algae are fixed on the components of the plant without affecting its performance. (Pelc & Fujita, 2002)

Concrete foundations at the bottom of the sea act as artificial reefs, and can be attractive to marine organisms. However, this could move marine organisms away from their natural habitats, which would increase their vulnerability. (Pelc & Fujita, 2002)

Regarding the noise issued by these installations, although there are few signals, it has been thought that the noise produced during the installation and operation of the wave energy capture devices affects the species using the biological systems for the orientation (that is the case of some species of fish, dolphins, whales, seals).

With regard to the effect of the electromagnetic field produced by underwater electrical cables on migratory marine organisms using the Earth's magnetic field to orientate, the studies are underway. (Pelc & Fujita, 2002)

Large-scale installations work as shock absorbers to calm the sea, and the result may be the slowing down in the mixing process of the superior layers of the sea, that could have a negative impact on the marine life and fishing, reducing their productivity.

The derived changes on the waves and currents can affect many fish species that partly depend on currents for the larval transport, so as that changing the water currents between breeding and feeding places could be damaging to fish.

Wave damping can reduce the shore corrosion.

Wave energy capture devices have a very low effect on the large waves.

Small capacity installation has a minimal impact on the environment. (Pelc & Fujita, 2002)

2.3. Tidal Energy

Tides are the lifting and vertical fall of the marine water and it is driven by the gravitational forces of the Moon and the Sun. This water movement is accompanied by the entry (high tide) and horizontal flow (low tide) of the water flowing into bays, estuaries and straits, a stream known as tidal current or tidal flow. (World Energy Council|World Energy Resources, 2016)

There are two ways in which the tidal energy can be exploited: by exploiting the kinetic energy of the tidal currents and by exploiting the potential energy resulting from the water level differences as a result of its vertical displacement at different levels and its tidal amplitude.

For the efficient use of the tidal energy, some natural conditions are required: a natural basin (usually an estuary), that communicates with the ocean through a very narrow opening and the tidal height is at least 8 m. (Soede, 2017)

The amplitude of the tide is the difference in sea level between high tide and low tide.

On most of the coastal sites, large tides and small tides occur twice a day (semi-diurnal tides), but in some places they occur once a day (daytime tide), while in other areas they occur as a combination.

Areas with high tidal amplitudes are the Severn Estuary of the UK (15 m tidal amplitude) and the Baie du Mont Saint Michel in France (13.5 m tidal amplitude), while in the Mediterranean Sea the tidal range is less than 1 m.

The global tidal resource is estimated at 1200 TW/year (OES, 2016), but only some of this energy is likely to be exploited because of the geographical, technical and environmental constraints.

The suitable locations for tidal energy use are those where tidal currents have speeds of 2-2.5 m/s.

Major tidal flows occur along the coasts of all continents, making it a global resource.

The availability of the tidal energy is, however, specific to the site. At an European level, 106 locations with high potential of the tidal currents totalling 48 TWh/year were identified. This potential is concentrated around the British Isles and English Channel. (World Energy Council|World Energy Resources, 2016) It is estimated that Britain's tidal energy potential represents about 50% of the Europe's tidal energy resources.

Tidal currents are reliable and predictable and have a great potential to drive turbines and generate electricity.

Technologies based on the tidal amplitude exploit the level differences in an estuary or in a dammed bay.

For the high energy use, modern tidal dams include fences and tidal turbines. Tidal fences consist of turbines stretching entirely across a channel where the tidal flow sets up relatively fast currents. Tidal turbines, also installed in the channels with tidal currents, resemble underwater wind turbines. The fences and turbines can be located where the sea flows create currents at speeds of 2-3 m/s. At lower speeds, the exploitation of the high energy is uneconomical, and at the higher speeds it can damage the turbines. (Pelc & Fujita, 2002)

The first large-scale power plant in the world to harness the tidal power was La Rance power plant (240 kW), which became operational in 1966 in Brittany, France and is still operating. Further major projects have been developed.

During the years 2000, the major developers have made successful demonstration projects. As a result, a large number of original equipment manufacturers have entered the tidal streams market.

Globally, there is an installed capacity of about 4.3 MW, with the largest installations being located in the South Korea and Northern Ireland at Strangford.

Other projects with a capacity of 10.5 MW are in operation, mostly in Scotland, where there is the world's largest tide network. Scotland holds about 25% of Europe's tidal energy resources. (Figure 5) (OES, 2016)

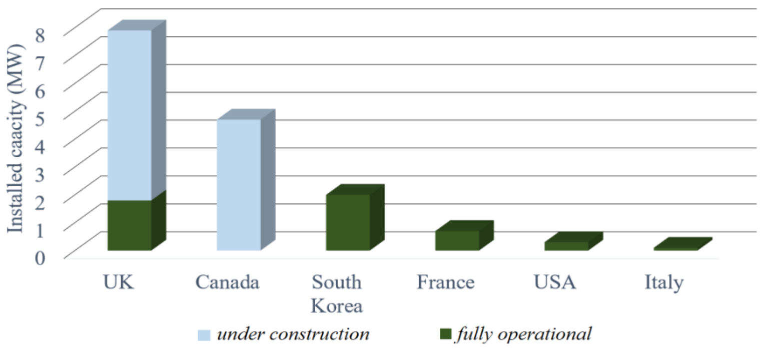

Figure 5. Installed capacity in operation or under construction for tidal stream

(OES, 2016)

In 2015, 400 MW power plant was installed in the Wales. The most important milestone in the commercialization of the high-energy technology is the Meygen project that has become operational since 2016, with four turbines with a nominal power of 1.5 MW, followed by the installation of the world's first sea energy series in the Shetland Islands.

A significant number of pre-commercial demonstration projects are under way. Among them there is a project in France with two turbines of 0.5 MW. There are ongoing projects, one in the Netherlands of 200 kW, another in France of 10 MW with completion in 2017 and another two with the term in 2018, one of 5, 6 MW and another of 14 MW. (Renewable Energy Market Analysis Latin America, 2017)

LCOE (levelized cost of energy) for the first tidal flow power plants (10 MW) varies between 24 and 47 cEUR/kWh. The EU objective is that in 2025 the price for tidal energy will reach 15 cEUR/ kWh and in 2030 at 10 cEUR/Kwh.

Technology innovation will make this goal achievable. (Magagna, 2016)

Impact on the environment

The exploitation of tidal energy involves some risks.

There is, however, a limited number of data and information on the medium and long-term effects of the tidal devices on the marine organisms.

Tidal installations can affect the water flow in the estuaries, its hydrology and salinity, with negative effects on the organisms in this environment, given that the estuaries are protective areas for many marine organisms and a unique habitat that is irreplaceable for the organisms living in estuaries.

Tidal fences can have a negative impact on the environment because they block the channels by hindering the migration of the fish and wildlife from these channels.

Tidal turbines do not block the estuaries or mouths of the estuaries; they do not interrupt the fish movement, or modify the water hydrology.

In order to protect fish and facilitate the transport of the nutrients and sediments, the location and construction of the tidal installations must be done so that important migration channels remain open. (Pelc & Fujita, 2002)

2.4. The Energy of the Marine Currents

The exploitation of the marine currents is based on the valorisation of their energy, which reaches very high values. Currents are formed due to the movement of the waters at the planetary level.

The exploitation of the marine currents energy can, in principle, be done in two ways: by technologies similar to those used to convert the tidal stream energy by submerging the turbine in stream/reflux or using the special arrangements (semi mobile dams, adductions), that control an "artificial" current of water to the turbo-generator. (World Energy Council|World Energy Resources, 2016)

The location of the turbines must be such that they do not affect the routes of the vessels and do not disturb the underwater fauna and flora.

The first commercial ocean-power capture facility is located on the shores of Scotland, at the confluence of the Atlantic Ocean and the North Sea, with four underwater turbines with an installed power of 6 MW. It is planned to have its installed capacity of 398 MW by installing another 269 turbines.

The global potential of ocean currents is estimated at about 5000 GW, with about 70 GW potential in the United States. (World Energy Council|World Energy Resources, 2016)

2.5. Temperature Gradient Energy (OTEC)

Ocean Thermal Energy Conversion (OTEC) uses the temperature gradient between ocean surface water and deep water in a heating cycle to produce the electrical energy.

Approximately 15% of the solar energy falling on the ocean surface is retained as thermal energy in the upper layers of the ocean. It decreases exponentially with the depth of water.

In order for the OTEC to function efficiently, a temperature difference of approximately 200^0 C is required. At a constant surface temperature of the 250^0 C ocean superficial layers, it is necessary that the cold water, having a temperature of about 50^0 C, is extracted from depths of 800-1000 m. The most suitable for this technology are the equatorial and tropical waters with sufficient depth, where the temperature gradient is at least 200 C throughout the year. (Griset, 2010)

The estimated global energy potential of the OTEC is 30-90 PWh, which is a much higher potential than other ocean energy. However, the amount of the energy that could be captured practically and economically is limited by the economic and technical constraints. It is appreciated that the energy efficiency of the OTEC in practice is 2-3%. At the same time, as the OTEC farms can operate continuously, they could reach capacity factors of up to 90%. (Magagna et al., 2016)

OTEC technology has made significant progress in the recent years. A number of pre-commercial demonstration projects are under way. These include a power plant of 200 kW completed in Korea in 2014 and a closed cycle OTEC of 100 kW in Hawaii, as well as an och-nava power plant of 100kW in Japan and a Kriso plant of 1MW from Korea. A project with a plant of 10 MW will be put into operation by 2019 in Martinique. The project is funded from the NER 300 program for a total of € 72 million.

Among the largest pre-commercial demonstration projects is a plant of 1 MW launched in 2016. It will be located in the Pacific Ocean and will be completed by 2020. In the Netherlands, an OTEC demonstration installation of 500 kW will be delivered to the Caribbean Curacao. (World Energy Council|World Energy Resources, 2016)

However, the large projects have not materialized yet.

Although, the OTEC is making technological progress, this technology presents limited resources to make an important contribution to the European energy system.

2.6. Salinity Gradient Energy (Osmotic)

Electricity generation based on the salinity gradient exploits the available energy resulting from differences in salt concentration between the seawater and freshwater.

In principle, in this technology seawater and freshwater are routed into different rooms, separated by a semi-permeable membrane. This membrane allows the passage of only water molecules. Because of the difference in osmotic pressure, there is a tendency to equalize the water concentration on both sides of the semi-permeable membrane, which makes the water molecules in the fresh water penetrate into salty water. The volume of the latter increases and consequently its hydrostatic pressure increases. The resulting pressure is used to drive a turbine.

There are two practical methods for this technology: reversed electro dialysis (RED) and pressure retarded osmosis (PRO).

This energy generation technology can be used in countries where large freshwater rivers flow into the sea. In this situation is the Netherlands and Norway. (Renewable Energy Market Analysis Latin America, 2017)

The total energy potential of the salinity plant was estimated at 657 GW, equivalent to 5177 TWh of energy consumed.

Salt gradient technology is in an early stage, although, in 2016 progressed a lot. This technology is in the research and development phase. Research and development activities take place in the Netherlands and Korea and aim to improve membrane performance and reduce associated costs. Currently, there is a demonstration plant of 50 KW operating in the Netherlands. It is estimated that demonstration installations up to 50 MW will be installed after 2020. (World Energy Council|World Energy Resources, 2016)

3. SWOT Analysis

For Europe to remain the world's No. 1 in the renewable energy field, efficiently and cost-effectively integrate renewable energy in the energy system and also to develop new generations of the renewable technologies. In this respect, a number of research and innovation objectives for more renewable technologies have been set up at European level with the effect of reducing costs and improving performance, as well as for their widespread expansion worldwide.

As the seas and oceans are clean sources of energy, capitalizing on this potential in a sustainable way is a key element of the EU's maritime policy. For this reason, this marine energy sector is an opportunity for the EU, contributing to the economic growth and job creation in the coastal areas, as well as to increasing the security of the energy supply and boosting the competitiveness through the technological innovation.

To explore the horizons of these marine energy technologies to exploit the potential of the seas and oceans, with important implications for the EU's economic and environmental benefits, a number of key actions are needed to make this energy a reality.

In order to outline an overview of the use of the renewable energy sources at the European level, and to identify the possibilities for increasing the share of the marine energy potential, a SWOT analysis has been made and it is presented in Table 1.

Table 1. SWOT analysis of the marine energy sector at European level

STRENGHTS	WEEKNESSES
- speeding up the development and deployment of the low carbon energy technologies; - reducing the greenhouse gases emissions and other pollutants; - economic and environmental benefits for the EU; - reducing the European Union's dependence on the fossil fuels for electricity generation; - developing the integrated offshore electrical networks; - technologies for the exploitation of the wave energy and tidal energy are relatively more developed than other technologies; - the ocean thermal energy conversion technology has a high potential; - ocean power is an asset in the EU's energy portfolio; - ocean power contributes to completing the energy stock derived from other renewable; energy sources, ensuring a constant global supply of electricity; -ocean-energy operating devices have a reduced visual impact, being accepted by the public; - fast growth rate of the offshore wind capacity; - electricity generated by offshore plants accounts for 0.5% of the total EU electricity consumption; - providing non-polluting electricity at the competitive prices in relation to the fossil fuel industry; - most of the ocean energy equipment is located onshore and they do not use valuable and significant land areas; -the European supply chain is in an advanced development stage; -a sustained progress of the tidal power converters development; - a high maturity level recorded by the tidal technologies;	- electric power generated by the ocean power does not have yet a significant impact over the global electric power generation in EU; - ocean energy is an early stage of the development regarding the exploitation technologies; - the early stage of developing the technologies exploiting ocean-energy; - high capital and operational cost for the marine energy technology development; - the current low development of the ocean energy technologies; - reduced the capacity and reliability of the ocean energy systems; - moving from the prototype demonstration to selling it on the market is difficult for the emerging technologies; - the complexity of obtaining the authorizations and approval procedures with effect in delaying the projects and increasing the costs; - the lack of the stable financial support; - low usage rates of the energetic technologies in the ocean; - the technologies based on the salinity gradient and temperature differences are the least mature from a technical point of view; - low probability that the salinity gradient technology will become competitive in the foreseeable future due to the limited involvement of the major stakeholders in the industry; - the cost and complexity of the offshore operations are very high; - delays in the development of the technologies; - a limited number of ongoing projects in the field of the ocean energy; - the slow rate of development of the wave energy sector; - wave energy testing devices, are considered to be prototypes with limited power generation;

- small sized equipment for the tidal power generation and the floating systems are reliable and cost-effective as well; - generation of a significant amount of the energy due to maturity of the tidal power technologies; - increasing the capacity of the energy absorption; - involving the European industry in developing the ocean power technology; - ocean energy is an important field for the regional collaboration.	- current wave power installations have a power of less than 1MW; - low progresses recorded in the development of the viable wave energy technologies; - the salinity gradient technologies are in the research and development stage; - week consolidation of the supply chain for wave energy, especially compared to tidal energy;
OPPORTUNITIES	THREATS
- the EU encouragement to increase the share of the electricity produced from the renewable sources; - an opportunity to generate growth and create jobs; - the chance of boosting the competitiveness through the technological innovation - collaborative opportunities in terms of the research and development and cross-border cooperation; - strengthening energy security in the EU; - export opportunities for both technology and knowledge in this area; - growing commercial interest for the ocean-power sector; - increasing the investments in the ocean-power sector; - the existence at EU level of the provisions to facilitate the development of the renewable energy sources; - funds provided by the EU in order to finance the actions for the ocean-energy technologies; -creation of the ERA-Net of the European Research Area for Ocean Energy; - European Research and Innovation Program to stimulate the industrialization of the ocean energy sector; - integration of the ocean energy into the national projects regarding the marine spatial planning;	- hard climatic conditions; - socio-economic and environment infrastructure barriers; - global social and economic uncertainties with negative impact on the investment; - inadequate political-judicial constraints and administrative obstacles that impede the implementation of the projects; - uncertainties regarding the correct application of the environmental legislation; - the significant reduction in funding and income support for the energy generated by other renewable energy sources, - diminishing the investor confidence; - fragmentation in the sector; - a small market for the ocean energy technology; - a market trend that points to the fact that the ocean energy technologies are less competitive compared to the costs and to other generation methods of the renewable energy; - the existence of risks associated with demonstrative exploitations that hinder the progress of tidal energy technology; - the lack of the mechanisms for financing the implementation of the demonstration stages for the tidal energy networks; - obstacles that prevent the development of the wave energy; -limited availability in terms of the power generation from the wave energy devices;

- joint the ocean energy programs contributing to capitalizing the benefits of the pan-European cooperation in the research and development; -the possibility of developing solutions to be put into practice in a forum for the ocean energy; - building public-private partnerships as a means of stimulating the private investment - setting up a sound energy policy framework for the renewable energy; -stimulating the competitiveness through the technological innovation; - the opportunity to reduce construction costs regarding the ocean energy generation due to the demonstrative projects and technological progresses; - political resolutions to be taken at the European level, initiatives that foster the stability for the developers of the ocean technologies in terms of the market commercialization; - setting the priorities for the research and development of the tidal power through the funding programs.	-uncertainties caused by the undiscovered wave energy technologies, in terms of the electricity generation; -market barriers and infrastructure in the implementation of the marine technologies in the medium and long term.

The analysis method is validated by a series of studies conducted in the field of energy and environment. (Helms & Nixon, 2010; Terrados et al., 2007, Jaber et al., 2015; Chen et al., 2014) The SWOT analysis on the exploitation of renewable marine energy sources aims to increase the visibility of existing information in this area and to boost their use as alternative sources of energy. The SWOT Strategic Analysis Tool combines strengths and weaknesses with existing and potential opportunities and threats on order to spot the potential of the marine energy sector in helping to design a development strategy.

The SWOT analysis can be used to investigate and assess the current state of Renewable Energy Sources in the EU (RUE), providing a good basis for formulating policy recommendations on the increased use of these resources. This analysis allows exploration of the conditions in the marine energy sector for a correct understanding of the current situation, which would serve as a basis for proposing objectives and strategies.

The figure below (Figure 6) briefly presents the main strengths, weaknesses, opportunities and threats that have been addressed by research based on existing studies.

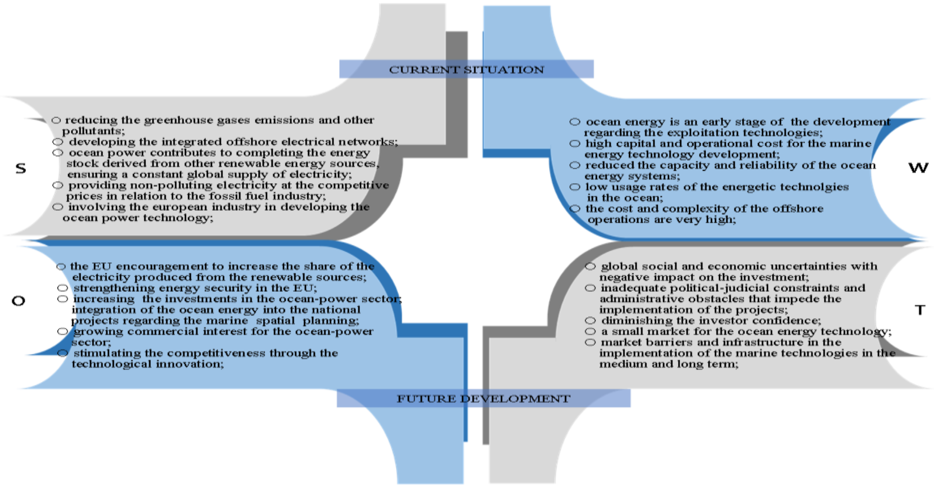

Figure 6. SWOT analysis

Finally, Figure 7 shows the existing barriers to the development of ocean energy technologies.

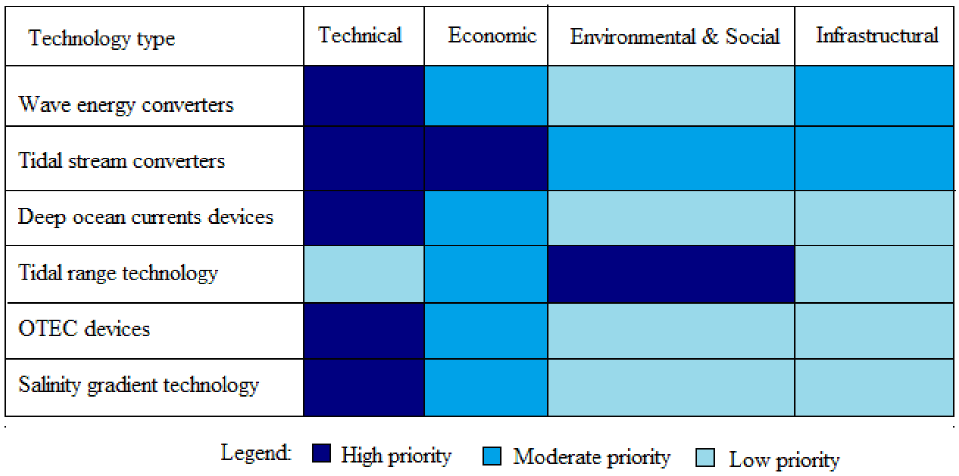

Figure 7. Barriers of the ocean energy technologies (processed from Ocean Energy Technology Readiness, Patents, Deployment Status and Outlook, 2014)

Conclusions

Marine energy is an inexhaustible source of the renewable energy. The main forms of the marine energy are offshore wind and ocean energy (wave, tide, marine currents, and temperature and salinity gradients.

Offshore wind, wave and tidal energy currently have the most mature technologies.

Capitalizing the economic potential of the seas and oceans is an essential element of the EU’s maritime policy.

With approximately 50% of the tidal energy and about 60% of the waves energy developers, as well as the majority of the ocean energy infrastructure (ocean energy testing centres) owned by the European Union, it is at the forefront of the technological development.

By development of the first tidal energy demonstration farms, Europe has reinforced its commitment for developing the ocean energy technology, setting out the ambitious targets for the ocean energy industry.

The European Commission has set targets for cutting the costs for the energy technologies in the ocean, contributing significantly to the future of the European Energy System. (European Commission, 2015)

The SWOT analysis achieved shows that an increase in the level of the capitalization of the marine energy sector potential depends on the following factors:

- the existence of a stable policy framework at the European level, which supports the development of the technology from the prototypes through the commercialisation;

- research projects and different financial instruments at European, national and regional levels that could boost the development of the marine energy sector;

- the existence of some targets that reduce the costs of the key technologies and improve the reliability and performance of the systems, to achieve a commercially supported cost, energy-efficient;

- implementing some actions on the development and integration of the innovative technologies and promoting the exchange of the best practices;

- European energy planning and strengthening of the policies to develop the renewable marine energy sources;

- an unified approach that encourages the transfer of the experience to help the ocean energy sector to overcome the technical, financial and environmental barriers that hamper the large-scale absorption of the ocean energy in the EU;

- the existence of some initiatives to improve the performance of the ocean energy technologies in the innovation, supply and value chain;

- the existence of some instruments to monitor the evolution of the Europe's technology, industry and markets in the field of the marine energy;

- measures on supporting the testing centers of these technologies, for accelerating the learning process and practical experience;

- promoting the international collaboration, technology transfer, and demonstration of the ocean energy technologies through collaborative research;

- including the development of the ocean energy in the maritime national plans.

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