Mechanical Testing and Diagnosis
ISSN 2247 – 9635, 2021 (XI), Volume 1, pp. 11-19

AN EVALUATION OF THE POTENTIAL IMPACT OF EXTRACTING MARINE RENEWABLE ENERGY IN THE COASTAL ENVIRONMENT OF THE BLACK SEA

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ABSTRACT

Energy production based on fossil fuels is the main reason for global warming. Many countries have begun switching fossil fuels with renewable energies, reducing the effects of climate change. A tremendous potential in future energy needs plays the Marine Renewable Energies (MRE). The MRE industry should take into consideration the potential environmental effects and if it poses any risks to marine animals, surrounding habitats or ecosystem processes. This research provides some insights regarding the MRE development and points out the potential environmental effects of implementing them and finally, draws some lines regarding the ecological effects of the MRE extraction from the Black Sea.

Keywords: Marine renewable energy, potential risks, marine environment, mitigation, Black Sea.

1. INTRODUCTION

In order to mitigate the climate change induced by human activities, the energy production source should shift from fossil fuels to a complex energy portfolio, based on renewables.

As an alternative, a possible solution for reducing global warming may come from the natural resources use. The Marine Renewable Energies (MRE) industry can play an important role in climate change mitigation by reducing greenhouse gas emissions, providing a clean and renewable source of energy, and redirecting the energy industry towards achieving a sustainable future. Although MRE embraces climate change mitigation, there are concerns that MRE installations and systems could affect the marine environment [1].

In the present paper, five marine environmental potential risks for the MRE industry are discussed:

1. animal colliding with turbines or entanglement with underwater structures,
2. effects of electromagnetic fields (EMF),
3. effects of underwater noise from MRE devices on marine animals,
4. changes in benthic and pelagic habitats,
5. changes of the movement of water and sediments [2].

This paperwork methodology is organized into three parts: the first section has sought to identify the most common types of marine renewable energy; the second is destinated for the description of the environmental impact of the MRE systems and installations, and in the final part, to apply a synthetic analysis of the Black Sea Basin regarding the potential environmental risks associated to the extraction of marine renewable energy.

2. MATERIALS AND METHODS

The study on the potential ecological implications of MRE industry should begin by understanding the hydrodynamic nature of the energy resource and, then, by highlighting the feasible ecological consequences of using them.

2.1. Marine Renewable Energy

The sea is a fluid rich in energy flows that can be exploited. The most common MRE sources are: wind energy, wave energy, tidal energy. Harnessing all these energies is possible and it has already started in different locations around the world, at different stages of development. A summary of each source and their main uses are presented in the following sections.

2.1.1. Wind Energy

The wind is much stronger and more constant at sea than on land. Offshore wind power captures the kinetic energy of sea winds using large diameter horizontal-axis rotors. As it can be seen in Fig. 1, the offshore wind farms can be distinguished depending on their anchoring systems, as:

- gravity based foundations – through their own weight or dense materials the offshore wind turbines are attached to the bottom of the sea. The seabed requires special preparation for this type of anchoring system; they are used in shallow waters,
- single pile foundation (monopile foundation) – the wind turbines are attached to the sea by a steel pile driven 10 m to 20 m into the seabed. The seabed does not require any preparation but, where bedrock is encountered, a suitable hole must be drilled for each monopile. The monopiles are much lighter and more resistant and can be installed in water depths of up to 30 meters,
- tripod foundations and jacket foundations are made up of three steel piles – the wind turbine has an anchoring system formed by four legs connected by a trellis. Tripods and jackets are used in deeper water (25 – 50 m), but not less than 6 m,
- floating wind turbines – these types of turbines are floating platforms that are anchored to the sea-bed. These devices can be installed in very deep water (50 meters or more) [3, 4].

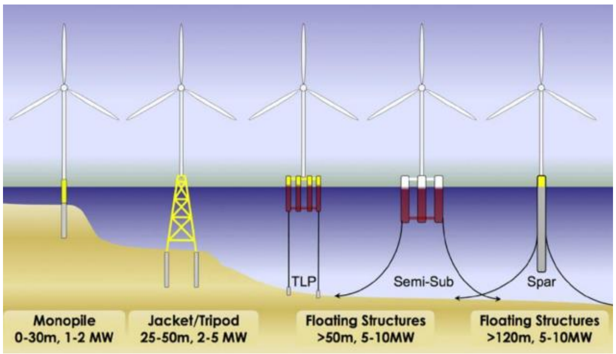


Fig. 1. Types of wind farms, depending on their anchoring system [6]

2.1.2. Wave Energy

Wave power utilizes the kinetic energy of wind-driven surface waves [3].

There are three fundamental wave energy devices used for converting wave power into electric power.

a) Wave Profile Devices

Wave profile devices float on or near the sea surface and move in response to the shape of the wave. The submersible devices move up and down under the influence of the variations in underwater pressure as a wave moves by. The WPD turns the oscillating height of the ocean's surface into mechanical energy [5].

The waves energy is absorbed using 4 types of motion: vertical (heave), horizontal - in the direction of wave travel (surge), angular - about a central axis parallel to the wave crests (pitch), angular - about a vertical axis (yaw), or a combination of all four, the energy being generated by reacting these different movements against some kind of fixed resistance called a reaction point. In Fig. 2, three types of wave profile devices are presented [5]. The first one uses a heavy ballast plate suspended below the floating buoy. It is tethered to the ocean floor to prevent floating away. In this way, the point absorber operates offshore in deeper waters. The difference between the first and second WPD is that the freely heaving buoy reacts against a fixed reaction point (a fixed dead-weight on the ocean floor). The point absorber (bottom-mounted) is operated in shallower nearshore locations. The third WPD swings perpendicularly towards the waves, being tethered to the ocean floor by an anchor. It floats on the water surface (linear absorber) and as the waves pass along its length, they cause its cylindrical body to sag downwards into the troughs of the waves and arch upwards when the crest of the waves is passing [5].

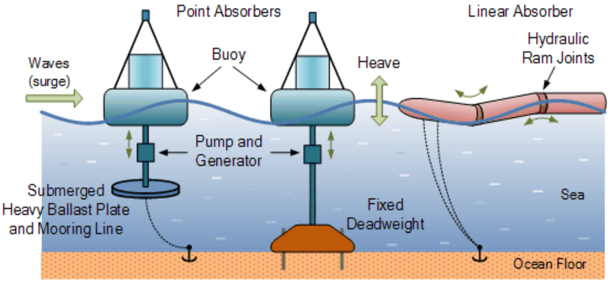
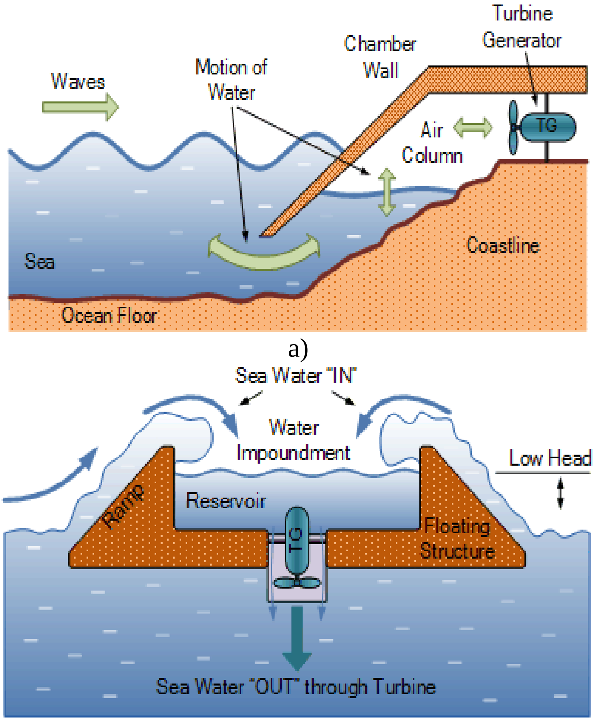


Fig. 2. Types of WPD

b) Oscillating Water Columns

The Oscillating Water Columns (OWC) are devices positioned onto or near rocks or cliffs which are next to a deep-sea bottom. The OWC consist of a partly submerged hollow chamber fixed directly at the shoreline which converts wave energy into air pressure. [5]

The OWC structure is built perpendicular to the wave (Fig. 3a). The structure can be either a natural cave (or a chamber made by man) with a blowhole or a duct with a wind turbine generator situated above the water's surface. The chamber is open to the sea below the waterline and part of the ocean surface is trapped inside. The waves are constantly ebbing and flowing which allows the water trapped inside the chamber to oscillate in the vertical up-down direction [5].



a)

b)

Fig. 3 – a) OWC, b) OWPD [43]

The advantage of the OWC is that the turbine can be easily removed for maintenance or repair. The disadvantage is that the output is dependent on the level of wave energy, which varies day by day, according to the season [5].

c) Wave Capture Devices

A Wave Capture Device (Overtopping Wave Power Device**)** is an energy device used from shoreline to nearshore (Fig. 3b). It converts the movements of waves and tides into potential energy. The OWPD captures and impounds the seawater into a reservoir above the sea, creating a low head situation. The seawater then, is drained out through a reaction turbine (Kaplan Turbine) located at the bottom of the wave capture device, generating electricity [5].

2.1.3. Tidal Energy Systems

Tidal energy is another form of marine renewable energy. As the Earth, the Moon and the Sun rotate around each other in space, the gravitational movement of the moon and the sun causes millions of gallons of water to flow around the Earth's oceans, creating periodic shifts in these moving bodies of water, called tides [5].

Tidal energy benefits from the advantage of predictability and regularity of tides. The movement of the tidal water is greater when the tides influences are larger, resulting in more potential energy that can be harvested. Furthermore, the sea water can flow in both directions in a tidal energy system, resulting in power production in either direction of the rotor blades [5].

a) Tidal Barrage

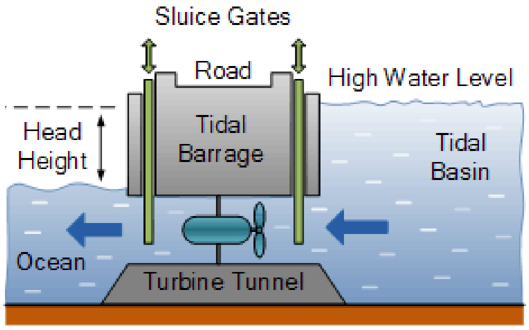
A tidal barrage is a tidal energy device that involves the construction of a low dam wall (barrage) across the entrance of a tidal basin or inlet creating a tidal reservoir (Fig. 4a). The numerous underwater tunnels cut into the barrage width allow sea water to flow through in a controllable way using "sluice gates". The water turbine generators fixed within the tunnels, spin as the water rushes past them generating tidal electricity [5].

This type of tidal energy system uses the difference in the vertical height between the incoming high tides and the outgoing low tides to produce electricity. As the tide ebbs and flows, sea water can flow through a one-way underwater tunnel system in or out of the reservoir, causing the rotation of the water turbine generators producing tidal energy on both incoming and outgoing tides [5].

b) Tidal Stream

A tidal stream is a turbine that converts the mechanical energy produced by the speed of marine currents into electrical energy (Fig. 4b).

Because the water has a much slower flow rate and is much denser than air, tidal stream turbines have higher tip speed rates and much smaller diameters as compared to the equivalent wind turbine. It generates tidal power on both the flow and ebb. As they are submerged under the surface of the water, they can create hazards to navigation and shipping [5].



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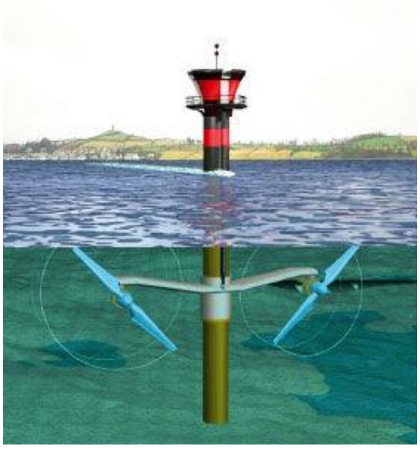

b)

Fig. 4 – a) Tidal barrage, b) Tidal stream [5]

2.2. Environmental Risks Associated with the Extraction of MRE

MRE development is hampered by a lack of rigorous evidence regarding the long-term ecological side-effects of marine power plants and device farms. MRE devices affect biodiversity, food availability, local flow hydrodynamics, blockage, wakes, mixing, turbulence, sediment transport, seabed morphology, littoral drift, scour, turbidity and water quality. There are concerns that marine mammals, birds and fish could collide with the dynamic parts of MRE industry. Renewable energy device foundations and support structures could act as artificial reefs improving biodiversity, although there are negative aspects like attracting invasive species. Species abundance may be improved by biofouling, but on the other hand, it leads to higher sedimentation rates and eutrophication [7, 8].

In the next paragraphs, five stressors between MRE devices and the marine environment (receptors) are discussed (Fig. 5).

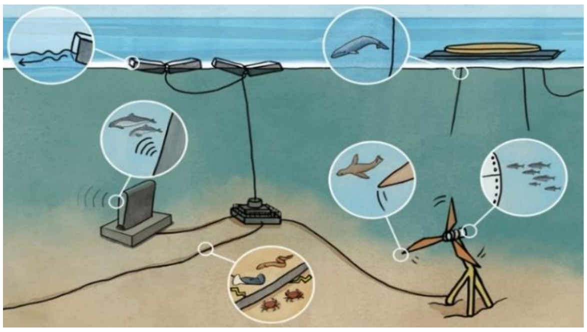

Fig. 5. Interactions between stressors and receptors associated with marine renewable energy devices [1]

2.2.1. Animal Colliding with Turbines or Entanglement with Underwater Structures

The primary concerns about the MRE devices installed on the sea are the avian or marine animals to collide with the blades or to entangle with the underwater structures, resulting in injuries or even death.

The collision hazards presented by MRE industry are divided into two main categories: firstly, the collision of avian beings (birds and bats) with dynamic parts of MREI above the water (blades), and secondly, collision or entanglement of underwater beings (mammals, fish, vertebrates) with submerged structures of turbines.

a) Avian animals colliding with turbines

The main environmental issue associated with wind farms is birds colliding with dynamic parts of installations. Migration and commuting are disturbed by wind farms because the flight altitude for most migratory birds is generally lower offshore than inland [9].

The rotors are an obstacle in the bird's flight, especially when they are located in high traffic areas (between islands). Although, the blade rotation is emitting sounds that result in a flight reaction and so the collision risks are reduced (or possibly eliminate), day or night or even in conditions of turbidity [4].

The studies show that birds could pass between the blades, driven by the flow of water. Seabirds possess the agility and sensory perception and they are aware of the turbine blades' movement. In other words, they can predict the rotation and speed of the blades and avoid colliding with them. The sensitivity of birds to a collision depends on their hunting methods. It is believed that birds diving from the surface have relatively controlled diving trajectories and thus have a good ability to avoid obstacles. In contrast, species directly performing their dive from their flying height have a weaker capacity to avoid obstacles and get injured more easily [4].

On the other hand, few studies/observations are known about the potential risks associated with bats colliding with MRE structures [9].

b) Marine animals colliding with turbines or entangling with the underwater structures

Speaking about the probability of entanglement, the underwater turbines do not represent a significant risk, whereas the wave and tidal energy collectors may pose it. The fixed submerged structures of the devices face little collision risk, while cables, power lines, chains and free-moving components on the surface or in the water column present a high risk of entanglement or entrapment for some marine animals. The key elements of an encounter are the cable configuration and the depth where it is located and the animal's size and behavior [10, 11, 12, 13].

The marine mammals' studies show a general focus on injury and mortality caused by entanglement with fishing gear (e.g., nets of slacklines) or submarine telecommunications cables, each with a loose end or loop that could ensnare an animal. No loose ends are found in the MRE mooring lines and the cables are sufficiently taut that no looping can occur. The marine animal's entanglement has not been considered a significant concern issue within permitting processes for small numbers of MRE devices. These risks are poorly understood, largely because of the lack of empirical data and focused studies [12, 13].

2.2.2. Effects of Electromagnetic Fields (EMF)

To transfer power between devices, transformers and mainland submarine electrical cables are needed. These cables produce electromagnetic fields, which are thought to potentially affect a wide variety of electro or magneto-sensitive marine organisms (bony fishes, marine mammals, sea turtles and elasmobranchs) by interrupting their navigation, orientation and/or hunting [2, 4, 11].

The EMF effects depend on cable type, current power and type, and burial depth. Generally, the export cables are buried on the seabed, but the inter-device cables may be suspended in the water column. The electrical field can be shielded and to evaluate the EMF emissions measurements of the magnetic and induced electrical fields emitted from cables and energized devices are used [1].

EMF studies were made to show if there are any physiological or developmental changes in certain species. Additional EMF has been hypothesized that may alter the animals' ability to respond and detect the natural field, especially those who use electroreception as a fundamental sensory mode to detect the very low-frequency bioelectric fields emitted by prey to locate mates and for orientation (lampreys, sharks, sturgeons, rays, the whole taxonomic class of Agnathans, Chondrichthyes, Chondrostei) and those who the magnetic field of the Earth for orientation and migration (crustaceans, fish, marine mammals, elasmobranchs, herptiles and cetaceans) [14, 15, 16].

On the other way, several experiments and studies have been made to show if there are any changes and delays in crustaceans and fish physiology. The studies made to determine if the EMF emissions might prevent animals from reaching their preferred habitats or feeding grounds (barrier effect) found no evidence to support this hypothesis in European eels, in two commercial species of crab in the United States, or in several species of elasmobranchs or American lobster [16, 17, 18, 19].

A better research on EMF emissions from MRE cables is needed, to better understand the likely, based on the configuration and electricity loads of specific cables, to identify potential effects. In 2009, Langhamer et al. noted that with better cable technology, EFM only affects the immediate environment near the cable to the extent that the earth's magnetic field is generally predominant within only a few decimeters of the cable. The association of this technology and the burial of cables in the ground leads to the elimination of problems due to EFM [15, 20].

2.2.3. Effects of Underwater Noise from MRE Devices on Marine Animals

The oceans possess an important diversity of sounds. From a biological perspective, the acoustics are vitally important in communication, reproduction, orientation and the perception of prey and predators.

The impact of underwater noise and vibrations emitted from MRE devices may affect marine life by causing changes in behavior, masking critical biological systems used for underwater communication and navigation. Risks to marine animals from anthropogenic sounds, including the operation of MRE devices, vary with the amplitude, frequency, and directionality of the noise source, as well as propagation losses, prevailing ambient noise, animals' hearing thresholds, and possible behavioral responses [21].

Underwater noise propagates according to local bathymetry, temperature and salinity. Depending on the location, season and local climate conditions, the sound can be spread in the ocean over large distances and focus at different depths, separated by several tens to several hundreds of kilometers from the source of its sound. The sound is usually spread in all directions from the source, the areas influenced by the noise are given in terms of distances from the source, thus indicating a radius rather than a straight line [4, 22].

Marine mammals and fish are potentially at risk of sub-lethal exposure to underwater noise arising from MRE devices in different phases: construction (impulsive noise from piling operations), operation (continuous noise associated with operational wind turbines) and vessel activity (continuous noise from engines and propellers) and from decommissioning activities (cutting and drilling to remove/cut off subsea structures). As sound propagates through seawater it loses energy, which happens more quickly at high frequencies but can still be detected tens of kilometers away [22, 23, 24].

The piles driving is without a doubt the most intense noise generating the highest sound pressure levels most damaging to fauna. These activities can generate very high sound pressure levels for a relatively wide frequency range (202 Hz - >20 Hz). Levels of noise impact associated with the pile driving depend on the length and diameter of the pile (it depends on the type of foundation: ~4 m monopile, tripod = 3 m, jacket = 1.5 m) and the energy impact [25, 26].

Pile driving can cause behavioral changes in seals, dolphins (Tursiops truncatus, Globicephala, Delphinus delphis) and harbor porpoises (Phocoena phocoena) found at more than 20 km. Seals are capable of detecting wind turbines at distances of 360 - 10,000 meters. It has been demonstrated that seals react to simulations of noise from wind turbines of 2 MW without showing signs of fear [22, 25, 27, 28].

The fish's sensitivity is based on differences in their anatomy. Some are highly sensitive, such as Clupeids (herrings) and Gadoids (cods). Most other species detect sound through particle motion [29, 30].

The effects of sound on invertebrates are still a controversial subject. Invertebrates represent a wide range of animal groups and generalizations about the effects suffered must be done with caution. Possible reactions are likely to vary widely and little information is available regarding the potential effects on different stages in their life cycle [4].

One of the major challenges to understand the potential effects of underwater noise from MRE devices remains the ability to differentiate between MRE device noise and ambient noisescapes in the ocean. To date, there is no evidence that operational noise from MRE devices harms marine animals physically or behaviorally [31].

2.2.4. Changes in Benthic and Pelagic Habitats

The presence of new structures in marine ecosystems may alter or eliminate the surrounding habitat, affecting the behavior of marine organisms. Just as wrecks provide shelter to marine beings, the man-made structures placed on the sea become artificial reefs, which are often used to enhance fisheries, for habitat rehabilitation, for coastal protection. The ecological footprint of a single MRE device may not be significant, but several devices may act as interconnected artificial reefs, resulting in an ecosystem spread, and affecting the functioning and structure of local and regional food webs [2, 32].

MRE devices include buoys, rotors or other moving structures (ocean current and tidal), cabling systems, hard-fixed structures (such as monopoles or jackets), rock scour protection, anchors, electrical cables, or pressurized pipes which become supports where organisms fix themselves. The process is named "fouling" (or bio-fouling) and it is a natural phenomenon where a wide range of organisms (bacteria, algae, barnacles, sponges etc.) come and colonize underwater installations [4].

The anchor cables and buoyant structures oscillation provide a better oxygenation and/or better contact with the nutrients in suspension and get covered with living epiphyte organisms and become microhabitats, attractive to young alevins and organisms. In this way these underwater structures may also become an interesting habitat for mobile species (including commercial species), crustaceans and molluscs, and also invasive species [4].

Turbine bases can provide fish refuge. A typical offshore wind turbine can support up to four metric tons of shellfish. The lower trophic levels species colonization is followed by larger invertebrates, such as small fish, crabs and lobsters, thereby attracting larger predatory fish. Such alteration of the local biodiversity status may have a positive ecosystem influence (biodiversity, tourism and fisheries effects). Studies have concluded that offshore wind farms can be at least as effective as marine protected areas in terms of creating refuges for marine mammals and fish [14].

During MRE device installation, areas of benthic habitat may be lost completely under the foundation or degraded (causing sediment plumes and smothering), displacing organisms permanently or temporarily. There may also be impacts associated with lighting and vibration, such as cable trenching remote-operated vehicles and foundation installation [1, 4].

Studies show that the foundations of wave energy converters can act as secondary artificial reefs, with structures becoming rapidly colonized by both epibenthic assemblages and fishes. The implementation of MREI should be very thorough not affecting the sensitive zones or of interest such as spawning grounds, resting areas, feeding, strategic routes or regions with rich biodiversity [11, 24].

2.2.5. Changes in the Movement of Water and Sediments

The physical presence of structures can disrupt coastal dynamic processes in the fields near to and far from MRE installations and change the landscape. The recovery of energy from waves and currents involves intercepting the kinetic energy, which, in other circumstances, would be dispersed elsewhere in the marine environment. The interruption of the natural dynamics of marine energy will affect other physical processes (sedimentation, currents) and ecological (dispersal of food resources, larval recruitment, reproduction of species etc.), as well as human activities that are influenced by the functional dynamics of environment or dependents. The consequences of such disturbance can have a direct impact on many environmental receptors: flora and fauna, navigation channels, coastal terrain, coastal defenses etc. [4, 33].

A decrease in energy (height & force) of the waves and a change in currents (direction & force) will be felt at or near the coast, where, under natural circumstances, a large part of the energy is dispersed. A reduction in waves, especially those from a specific direction (downstream from a device) could lead to a change in the littoral drift and, therefore, materials and ultimately, the morphology of the beaches, bathymetry of shallow waters and substrates [4].

Complex forces acting on the organism are more created during the waves breaking on the shore than those in a tidal current. During the course of a wave, water accelerates in different directions creating an unsteady flow. Any organism in an unsteady flow will be subjected to acceleration forces in addition to drag. When water accelerates near an organism that is gravity subjected, the force acting on the organism is proportional to the mass of the water displaced by the organism. As water accelerates near a sessile organism, the mass displaced will contribute to the total force experienced by the organism. Therefore, the acceleration force on a sessile organism is a function of the organism’s volume, inertia, gravity and the acceleration of the water. Any ecological changes related to far-field alteration of flow will ultimately depend on the sensitivity of benthic species and habitats to the alteration of energy in the environment and may, in effect, only alter species distribution with little or no overall effect on the ecosystem [34].

3. THE IMPACT OF ENERGY EXTRACTION ON THE BLACK SEA ENVIRONMENT

In 2009, EU leaders set a target that by 2020, 20% of EU energy consumption will come from renewable energy sources. In 2018, the target was set that by 2030, 32% of EU energy consumption will come from renewables. There are currently debates on the future policy framework for the period after 2030. The share of electricity from renewable sources continues to grow (Fig. 6) and a major aspect in this development represent the marine renewable energy.

3.1. Marine Renewable Energy in Black Sea Basin

The Black Sea is tideless, but there are studies to prove that it has potential in the MRE domain due to its wind and wave. In their research studies, Rusu and Onea concluded that, in the western part of the Black Sea, wind farms can be implemented. The wave energy technology is expected to rise and the local renewable energy portfolio could be diversified with hybrid energetic marine projects [35, 36, 37, 38].

Harvesting the energy from the Black Sea basin should take into consideration many aspects (technology costs, transport infrastructure network costs, suitable port installations and specialized vessels, authorization and licensing procedures, lack of subsidies, possible objections by the general public, technical problems, such as connecting to the grid etc.) that are not always easy to achieve in a space that has historically been marked, not only by the absence of mutual trust, but also by rivalries between neighboring states and even open conflicts [39].

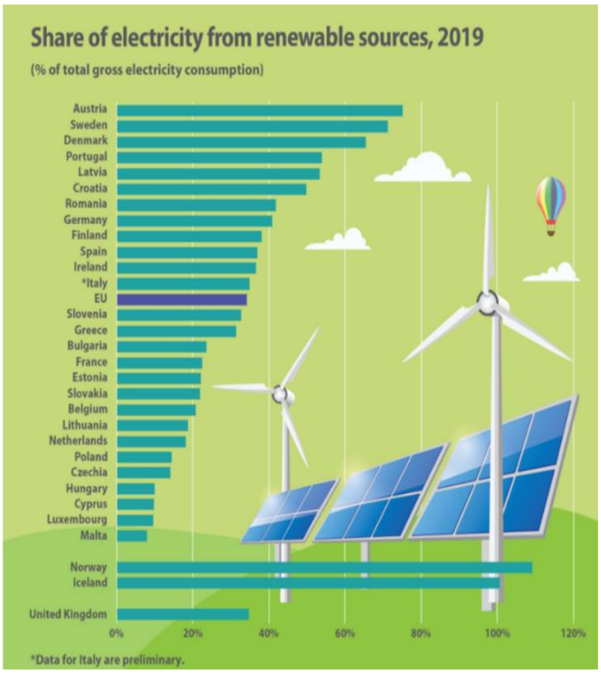

Fig. 6. The share of electricity from renewable sources in 2019 [40]

3.2. The Black Sea Fauna and Flora

The Black Sea region is extremely rich in wildlife species due to its climate and sheer variety of coastal habitats and wetlands. In their migration route (Via Pontica Flyway) to or from their wintering or breeding grounds, millions of birds rest or spend the winter in the Danube Delta or in one of the other wetlands along the coast. In total, no less than 12 globally threatened bird species live in the EU Black Sea Region (the Dalmatian pelican, red breasted goose, lesser white-fronted goose, ferruginous duck, pallid harrier, pygmy cormorant and the slender-billed curlew) [41].

The wetlands are also home to a large number of fish, invertebrates and amphibians. Almost a third of the fish species listed in the Habitats Directive are found in the Black Sea Region. The Danube Delta alone is said to have up to 70 different species, including such rarities as the starry sturgeon and the Pontic shad [41].

Altogether 79 animal species and six plant species listed in the Habitats Directive exist in the region, as well as over a third of the bird species listed in the Birds Directive. Amongst them, there are 12 species of bats, which roost in the numerous rock cliffs, caves and forests [41].

Some of the plant species listed in the Habitats Directive are characteristic of the region, such as the cinquefoil, the orchid and the floating water plantain [41].

In the Black Sea region, several species are stated endangered: the European Eel, the Mediterranean Monk, the Russian Sturgeon. On the other hand, there are some mammals present around the Black Sea, which became endemic to this sea: the Black Sea bottlenose dolphin, the dolphin Delphinus, the Black Sea harbor porpoise, the otter and the European mink [41, 42].

3.3. The Black Sea Environment Degradation

The environmental status of the Black Sea has been the subject of major environmental concerns since the early 1990s, leading to the Black Sea Convention, signed in 1992. As a virtually enclosed inland sea, the ecosystem is suffering from substantial environmental degradation. The numerous human activities, such as industrialization, urbanization, overfishing or transport have led to serious problems of pollution, loss of biodiversity, extinction of species and eutrophication etc. [39].

The sea's main environmental problem is eutrophication, caused by the excess of nutrients flowing via rivers or directly from coastal areas into the sea. Eutrophication is widespread in the Black Sea, but its effects are more pronounced on some areas, such as in the North West region, in the vicinity of the Danube Delta. [10, 41].

The Black Sea's fish stock has declined drastically in recent decades (from 800 000 t/y for all species in 1984, to 250 000 t/y in 1991), causing considerable economic losses to the fishing industry in the region. The drop in fish stock is a result of overfishing, pollution, eutrophication and of habitat loss [43, 44].

Another concerning issue is the increasing introduction of alien species, either intentionally for aqua-culture, or accidentally in ballast waters and on ship hulls. The best example of alien species presumed to be introduced via ballast waters is the Mnemiopsis jellyfish [43, 44].

Accidental pollution is also noted as a significant problem affecting the Black Sea, particularly oil spills, which causes considerable damage in the vicinity of ports and industrialized areas. Waste dumping remains a problem and discharges from both residential and industrial sites result in contamination by heavy metals, oil and derivatives, persistent organic compounds or radionucleides [43, 44].

The current situation of environmental degradation affecting the Black Sea makes it a ~~an ideal~~ space for investing in climate-friendly technologies since they help to reduce emissions and avoid the risk of accidents with serious consequences [39].

4. CONCLUSIONS

The present analysis has sought to reveal the major environmental risks associated with energy harvest from the movement of air, water, temperature and salinity gradients in the water, as well as to provide perspective on those risks in the Black Sea Basin, describing a path forward to decrease uncertainty and bringing clarity in the support of siting and permitting MRE projects in this area.

The present work provided a short description of the potential ecological hazards of the MRE development, based on a literature review. Each energy source was presented and five stressors between MRE devices and the marine environment were highlighted. In the final chapter, the MRE development and its risks to the Black Sea environment were pointed out.

The following stages of research will request a deeper analysis to be provided, with summing up a wider spectrum of the impact of renewable energy extraction on the Black Sea marine environment.

In conclusion, the renewable industry is a dynamic environment defined by multiple opportunities, especially in the case of waves and offshore wind. Therefore, it is important to have access to a solid database regarding the impact of renewable energy extraction on the marine environment in order to evaluate in detail the energy profile of a specific site, and also to predict the performances of the MRE industry.

ACKNOWLEDGEMENTS

This work was carried out in the framework of the research project DREAM (Dynamics of the REsources and technological Advance in harvesting Marine renewable energy), supported by the Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding – UEFISCDI, grant number PN-III-P4-ID-PCE-2020-0008.

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