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Evaluation of Floating Renewable Energy Potential for Sustainable Energy in Türkiye

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Highlights:

- Importance of floating structures
- Importance of floating energy systems
- Solar, wind and wave energy potential of Turkish coasts

ABSTRACT:

Energy is an increasing necessity due to the change in needs and the development of the industry with the rapid growth of the world's population. Today, the energy supply usually meet from non-renewable (fossil-based) sources. This situation causes adverse effects globally and a decrease in the fossil resources that future generations need. Sustainable, efficient, and clean energy will only be possible using renewable resources. Installation of renewable energy systems requires large areas, but suitable terrestrial for onshore are not always available. Therefore, in our country, it is necessary to increase floating renewable energy power plants. In the study, the offshore installation potential of solar, wind, and wave renewable energy required for sustainable energy production in Türkiye was examined. A qualitative evaluation was conducted for solar, wind, and wave energy generation. It has been concluded that coastal areas and stagnant water surfaces of Türkiye are suitable for the installation of floating energy systems. This study aims to emphasize the necessity of floating renewable energy systems for Türkiye. It also provides essential contributions to the studies to be carried out on floating energy systems in Türkiye.

Keywords:

- Sustainable energy
- Renewable energy
- Floating structure
- Floating energy systems
- Türkiye

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INTRODUCTION

Energy is a need that we need in every aspect of our daily life that contributes to the development of societies and has a vital quality in-country policy. With the rapid growth of the world's population, urban expansion, the change of needs, and the progress of industry, the requirement for energy demand is increasing. Especially the developments in technology cause an increase in energy demand.

However, today people use fossil resources such as coal, oil, and natural gas more intensively. This situation causes environmental problems due to global warming and its effects. Environmental destruction to prevent human beings have been turning to renewable energy sources in the last 20 years (Anonymous, 2019). The sustainability of living life requires a sustainable energy supply. For this reason, renewable energy should be used instead of fossil resource use, which cannot be self-renewable.

According to the United Nations world population projection estimates, it has been mentioned that the world population increased from 2.5 billion to 7.3 billion between 1950 and 2015, and this figure is expected to increase to 8.3 billion by 2030 (IEA, 2014). This situation in population growth means that energy consumption will increase again. According to the 2020 World Energy Report, China, USA, and Europe are the leading countries that are mainly at the forefront of world energy consumption (BP, 2020).

The research conducted by the International Energy Agency (IEA) in the first quarter of 2020 indicates that the severe restriction of global economic activity and mobility has resulted in a 3.8% reduction in global energy demand compared to the first quarter of 2019. Again, in the research conducted by the International Energy Agency, it was stated that although the efforts to prevent the virus since 2020 have reduced the energy demand, if successful, this decrease will be limited to 4% (IEA, 2019). Because of this, there is essentially no reduction in energy demand. The increase in population, human needs, and industrial uses constantly bring the need for energy to the fore. Therefore, to meet the increasing energy demand, investments in energy production should also increase in parallel, and renewable resource uses should be supported.

However, in the World Energy Outlook 2019 Report by the International Energy Agency, fossil fuel use rates are estimated to be 80% in 2010, 81% in 2018, will be 77% in 2030, and 74% in 2040 (IEA, 2019). According to the ratios, the use of fossil resources is decreasing, and the use of renewable resources is starting to increase. However, energy production from renewable sources is insufficient, and fossil fuel reserves are rapidly decreasing in the face of global energy demand. The limited resources and the presence of many polluting features in terms of the environment also oblige countries to develop new strategies and policies to increase renewable energy production potential.

The adverse effects of fossil resources, especially from an environmental point of view, climate change experienced as a result of global warming, increased pressure on their living habitats, and the influence on human health due to the increase in various diseases are essential reasons to be taken into consideration. Renewable resources are necessary for the continuity of human health and living life. Renewable resources are of great importance both for making energy sustainability possible and for the supply of sustainable energy. In this regard, our country and other countries attach importance to renewable energy to reduce external dependence due to fossil-based resource consumption and to establish a livable world future. The more use of renewable resources in our lives is due to this.

Currently, there also is an integration of renewable energy systems, which are generally widely developing in terrestrial areas, into floating structures offshore. In particular, the observation that water surfaces allow for large-area uses and the potential of these areas for energy sources such as solar, wind, wave, and thermal provides an alternative energy supply for coastal regions.

Increasing renewable energy systems provides sustainability in protecting our future and an efficient and sufficient energy dimension in today's conditions. Therefore, this study emphasizes the importance of using renewable energy sources instead of fossil resource uses. In addition, especially for our country, which is a peninsula, points to coastal areas can also be used besides the renewable energy systems that develop in terrestrial lands.

The regions where we live do not have the same characteristics. Some coastal cities may not be suitable for installing renewable energy technologies in terrestrial areas. For this reason, it is advantageous to add floating energy systems to the energy supply for coastal cities. In addition, large water surfaces such as dam lakes provide favorable environments for floating solar panels. At the same time, meeting the energy needs with floating systems in offshore floating structure designs, which are the projects of the future, makes floating renewable energy technology necessary.

In this study, Türkiye's floating renewable energy potential evaluate for sustainable energy supply. In the initial section of the study, for sustainable energy production, the sustainability, floating energy concepts, floating structures, and floating energy systems concepts explain. In addition, it provides examples of studies conducted globally and in Türkiye on floating renewable energy systems. The second part of the study examines Türkiye's floating renewable energy potential for developing floating renewable energy systems in Türkiye.

Our country generally encounters terrestrial renewable energy power plant installations. For this reason, coastal areas with high energy potential should be evaluated regarding floating power plant installation. This study reveals the energy potential of Türkiye's coasts for floating renewable energy power plant installations, which are not many examples in our country.

Sustainability, Sustainable Energy, Floating Structure, Floating Energy Systems and Examples

sustainability

The concept of sustainability was first mentioned in article 27 titled “Sustainable Development” of the report published under the title “Our Common Future” of the United Nations in 1987 as “Humanity can make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987). According to this description, the concept of Sustainable Development was accepted as "Sustainability" and explained with the definition of "development that meets today's needs without compromising the ability to meet the needs of future generations" (Republic of Türkiye Ministry of Foreign Affairs, 2021). However, the concept of sustainable development in this description primarily emphasizes economic progress and development. For this reason, it would be more accurate to express it as "Sustainable Development" in Turkish to emphasize environmental importance. Sustainable development/development can also be briefly defined as “being able to meet the needs of future generations while meeting today's needs and expectations” (Cesur et al., 2018).

In the continuation of the Bruntland report, it is stated that the limitation of the concept of development means the ability to reduce the pressures of technological and social activities on environmental resources and absorb the adverse effects of humans on the biosphere rather than absolute limitation. At the same time, it was stated that by reducing poverty, everyone's basic needs could be met, and a better life could be provided; otherwise, the world would always be open to ecological and other disasters (United Nations, 1987).

The concept of sustainability is often seen as the intersection of three parameters. These parameters include economic, social, and environmental qualities (Hauke et al., 2016).

In addition, ecology, technology and energy should be included. With the new parameters, it is possible to explain the definition of sustainability as "An understanding in which the values of natural resources are used by preserving and management decisions are taken at the point benefit from this of future generations, that development is achieved in every sense." with the work of Cesur et al. (2018) (Figure 1). In particular, the presence of energy in every part of our lives requires its supply dimension to be sustainable and innovative.

Figure 1. Sustainability parameters and energy, technology, and ecology inputs

Sustainable Energy

It is possible to define sustainable energy as the ability to produce energy that can be used over and over again without creating the danger of extinction, taking into account the needs of future generations while meeting the needs of today's generations (Anonymous, 2019). The depletion of energy sources widely used today and cannot be self-renewable restricts a sustainable energy supply for future generations. Considering the reason for the prevention of environmental damage, the widespread use of renewable resources is an essential reason for a sustainable energy supply.

Continuing open or secret conflicts between countries on the sharing of energy and energy resources today, the sustainability of energy, the security of energy supply, and accessibility to energy sources threaten many nations (Üçgül & Elibüyük, 2016). In this case, those with energy conversion technologies will continue to maintain their existence (Üçgül, 2010).

However, the United Nations General Assembly declared 2012 the International Year of Sustainable Energy for all and mentioned three critical goals that must be achieved globally by 2030 (IEA, 2014).

- To ensure universal access to modern energy services,
- To double the rate of global improvement in energy efficiency,
- To double the share of renewable energy in global energy systems

The importance of renewable energy sources in sustainable energy management globally is emphasized in these targets. At the same time, it is possible to say that the sustainable energy concept is closely related to renewable energy technologies.

Why Should Develop Floating Structures and Floating Energy Systems

Seas cover approximately 70% of the Earth's surface, and it is estimated that about 50% of the world's population by 2030 will live within 100 km of the coast (Bates et al., 2008). According to the IPCC's SR1.5 report, the change in temperature rise will increase to approximately 1.0°C today and up to 1.5°C between 2030-2052. This situation shows that coastal cities will be affected by rising waters

due to climate change. For this main reason, countries and local communities create living spaces with water. Various floating architectural designs are developing due to the increase in sea level threatening coastal areas and the decrease in coastal regions of some countries.

It is possible to define floating architecture as structures with varying functions, sizes, material usage, use of renewable technologies, and fixed or mobile properties, which vary depending on public or private uses (Moon, 2014; Cesur & Campian, 2020). Especially today, there are many examples of these structures, such as floating houses, bridges, airports, stadiums, solar gardens, various concept hotel projects, marina areas, fish pond facilities, mosques, pasture-grassland, greenhouses, schools, cemeteries, pools, ice rink, floating islands, city projects. While some floating structures have the feature of movement, they usually consist of fixed systems with a specific location to provide infrastructure services (Cesur & Campian, 2020).

It is seen that there is also increase in floating structure projects where developments for every purpose are seen. As mentioned below, many factors explain the reasons for developing floating structures and floating energy systems (Table 1).

Table 1. The reasons for the development of floating structures and floating energy systems

1	Coastal countries, whose land surfaces are limited, gain space by land reclamation method (by filling or drying), creating much cost for the country's economies (Watanabe et al., 2008; El-Shihy & Ezquiaga, 2019). However, after the construction of floating structures, the assembly can be done on the site, which significantly reduces the cost, and any coastal form does not have to be changed.
2	With land reclamation, the coastline is changing, and ecosystems are damaged. Floating structures and energy systems do not require any changes on the coast.
3	Floating energy systems do not change situations such as sea waves, tides, and bottom currents and turn them into energy (Watanabe et al., 2008; El-Shihy & Ezquiaga, 2019).
4	Floating structures and energy systems do not affect the underwater reservoir and ecosystems. It also has less environmental impact than fossil sources (Ferrer Gisbert et al., 2013; Kızılova, 2019).
5	According to the user density, floating structures are functional and can be built easily and quickly (Kızılova, 2019). If desired, the modules can be added to each other to provide wide space usage or removed and moved to different places. (Watanabe et al., 2008; El-Shihy & Ezquiaga, 2019). Especially floating solar PV (Photovoltaic) systems are easy to install (Dünya Bankası Grubu, 2019).
6	Since the floating structure and energy systems are unstable, they are not affected by the rise and withdrawal of water (Watanabe et al., 2008; El-Shihy & Ezquiaga, 2019).
7	It can be used as a port, pier and dock for small boats and ships (Cesur et al., 2018). It provides the necessary environment, especially in the fish farm.
8	Floating structures provide new areas for green space and recreational activities (Cesur et al., 2018).
9	Floating structures and energy systems can use new and sustainable material technologies.
10	Due to the intensive population growth, the opening of green areas, and agricultural land to construction, and with the reduction of these areas, disasters that may occur globally are prevented.
11	Thanks to its energy autonomy (Kızılova, 2019), besides solar and wind energy in energy supply, it provides self-sufficient energy production by using marine resources.
12	Site preparation is not required for floating energy systems (Dünya Bankası Grubu, 2019). In addition, there is less evaporation in the water reservoir (Ferrer Gisbert et al., 2013; Bulut et al., 2018; Dünya Bankası Grubu, 2019).

For such reasons, floating structures that contribute to the protection and keeping of the seas clean should be disseminated. In addition to the increasing need for energy, the fact that the seashore and water surfaces of HES ponds are also suitable for installing floating solar gardens highlights the need for floating energy systems.

Floating Energy Systems and Examples

While providing energy in floating structure projects, it is essential not to damage the environment, aquatic ecosystems and living life. In offshore structures that are not connected to the coast, it is necessary to take advantage of high waste disposal for recycling by using self-sufficient energy systems. In addition, supporting coastal cities with floating energy systems will contribute significantly to the

urban's energy network. It will also provide sustainability to the country and the urban, both economically and ecologically. For many such reasons, developing renewable energy systems on floating platforms is necessary. In this respect, first of all, if we need to look at the concept of floating energy;

It is possible to define a floating energy platform (Narasimalu, 2020). By making specific sizing of energy systems such as photovoltaic systems, tidal turbines, wind turbines, and wave energy in tune with the determination of the energy source at a site and integrating them structurally into a giant floating structure, as well as electrically integrating them through an intelligent hybrid AC-DC nano-grid technology and by being strengthened with complementary machine learning-based energy forecasting principles and load programming techniques to ensure the overall floating hybrid renewable energy system as a clean energy supply system that provides reliability in terms of certainty and reliability in power production for basic needs such as general electricity, water, air conditioning, etc.

Energy supply with fossil fuels affects our future negatively, and this situation contributes to renewable energy production. The fact that the world's water areas are more than terrestrial areas and the existence of different renewable resource potential increases the use of floating renewable energy. Thanks to the hybrid energy systems that can be designed on floating construction platforms, innovative floating energy technologies are developing.

On Earth, the energy potential that can be obtained from the ocean (sea) is 32 Pwsh / year, but a small amount of it is harvested (Islam and Hasanuzzaman, 2019). The capacity of the total ocean-based resources also (Narasimalu, 2020; Wikipedia, 2021);

- The amount of thermal energy gradient is 10 000 TWh,
- Wave energy amount is 8 000-80 000 TWh,
- Tidal energy of more than 300 TWh,
- The amount of sea current is more than 800 TWh,
- Osmotic power (Saline gradient) 2000 TWh,
- Offshore wind amount is more than 192 000 TWh.

In this respect, using energy resources such as solar, wind, wave, tide, thermal, and salinity gradient provides a sustainable, efficient, and clean energy supply.

Studies on floating energy systems are increasing worldwide and our country, and the technologies used are progressing. Sample studies on the subject are given below (Table 2).

Table 2. World and Türkiye floating energy system studies

Energy Type	Examples
Wind	Güzel (2012), Turhanlar (2018), Uraltaş & Yumurtacı (2021), Tortumluoğlu & Doğan (2021)
Solar	Bulut et al. (2018), Solomin et al. (2021)
Wave	Ding et al. (2015), Subekti (2020), Ocean Power Technologies (2022)
Hybrid	Michaelis & Michaelis (2008), Qu et al., (2022)

Uraltaş & Yumurtacı (2021) have determined that the energy needs of the Adalar District of İstanbul can be met by 93.3% with a wind farm to be installed on the sea and land. Again, in the study Turhanlar (2018) determined the appropriate turbine for the region by determining the offshore wind farm potential in Bozcaada. Güzel (2012) examined offshore wind energy production in and around Bozcaada and Gökçeada. Tortumluoğlu and Doğan (2021) determined suitable areas for offshore wind turbines in Gökçeada, Bozcaada, Çanakkale, and Ayvacık regions by using the WAsP package program in their study.

Solomin et al. (2021) researched “FPV + hydro systems, FPV + pumped hydro, FPV + wave energy converter, FPV + solar tree, FPV + tracking, FPV + conventional power, FPV + hydrogen” hybrid

floating solar energy for renewable energy studies. Bulut et al. (2018), in the study, about projects of floating hydro solar power plants in operation around the world and examining the technologies used in the project hydro solar was revealed the technology development.

Subekti (2020) conducts the design of wave hybrid power plants by combining wave energy with wind energy. The Power Buoy wave energy converter can operate at a depth of more than 20 meters and produces 8.4kW of energy (Ocean Power Technologies, 2022). In the study of Ding et al. (2015), a wave converter proposal was developed for wind and wave hybrid energy Spar-Torus in three ways as "Tri-floater and a point absorber; Tri-floater and two OWC; Tri-floater and three oscillating surge converters.

Qu et al. (2022) designed a hybrid floating system using a floating wind turbine, PV and wave energy converters. It has been designed from the grid system to increase the buoyancy of the floating foundation. The Energy Island Design project was designed by Michaelis & Michaelis (2008). This project, it is aimed to produce 2000 MW of power with a total of 8 hexagonal modules, each of which can produce 250 MW, by using hybrid solar, wind, undercurrent, and ocean thermal energy together.

Floating Renewable Energy Türkiye Potential

Renewable energy is an energy source in which natural resources are used in energy production, can be self-renewable, is unending, has continuity and perpetuity, reduces the external dependence of countries with domestic resource uses, and minimizes damage to the environment. It is possible to separate renewable energy sources as solar, wind, biomass, geothermal energy, hydrogen energy, and water-based sources (hydraulic, wave, tidal, ocean, and current energy) (Üçgül & Elibüyük, 2016). In recent years, countries have been turning to renewable energy production thanks to rapidly developing technology and green energy policies.

In the International Energy Agency SDG7: Data and Projections (2020) report, the growth of modern renewables outpacing the rate of increase in energy consumption, it is stated that the share of renewable energy in total energy consumption reached 11% in 2018, and this share is expected to grow to over 15% by 2030, but it is well below the target of 23% in 2030 specified in the Sustainable Development Scenario (IEA, 2020a). In the Renewables Information: Overview (2020) report, it is expressed that since 1990, renewable energy sources have grown by an average of 2.0% annually, slightly more than the total energy supply (1.8%). These increase rates are 36.5% in solar energy; 23.0% in wind energy; 11.5% in biogas; 10.9% in thermal solar energy; 9.7% in liquid biofuels; % 4.9 in municipal waste; 3.6% in geothermal; 2.4% in hydro; 2.3% in wave and tide; 0.9% in solid biofuel (Figure 2) (IEA, 2020b).

Türkiye, on the other hand, obtained more than 90% of the energy consumed in 2000 from fossil fuels; at the end of 2018, this rate decreased to 86%. The share of renewable energy in the total energy produced also increased from 0.1% to 5.6% (KPMG, 2020). Electricity production in 2018 was derived 37.3% from coal, 29.8% from natural gas, 19.8% from hydraulic energy, 6.6% from wind, 2.6% from solar, 2.5% from geothermal energy, and 1.4% from other sources (Republic of Türkiye Ministry of Energy and Natural Resources, (2021). Considering Türkiye's total installed power network of 91.3 GW in 2019, it is seen that hydro energy source from renewable sources has 28.6% and wind and solar energy has 14.9%. (Figure 3) (KPMG, 2020).

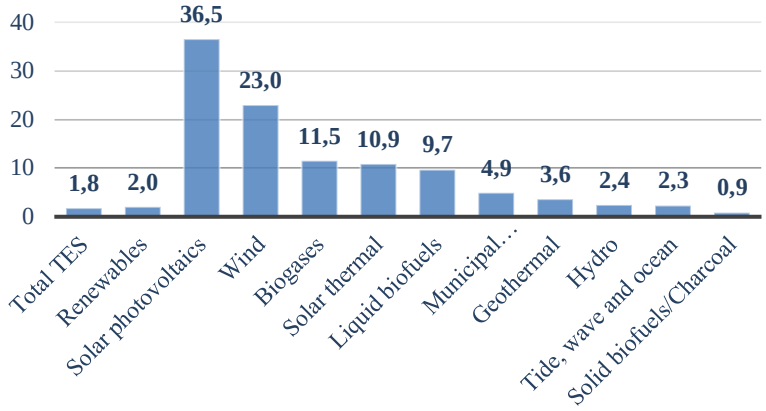

Figure 2. Average annual growth rates of world renewable energy supply, 1990-2018 (IEA, 2020b)

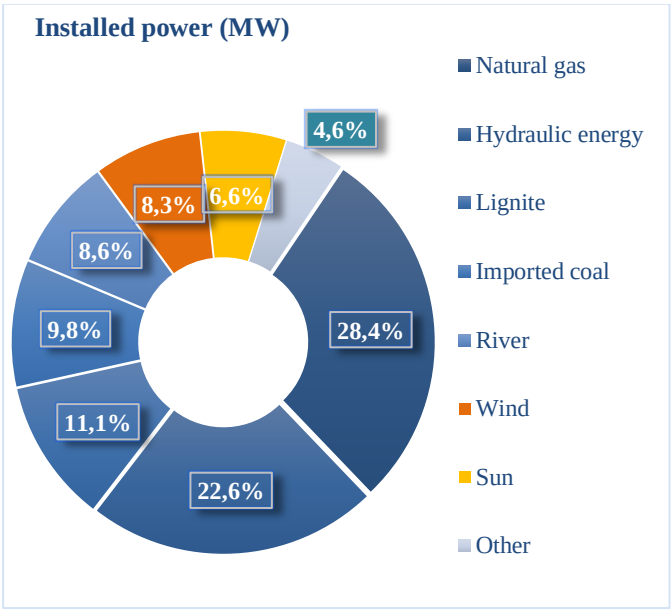

Figure 3. The total installed power network of 91.3 GW was owned by Türkiye in 2019 (KPMG, 2020)

Considering the installed power network of Türkiye, it seems that fossil resources come to the fore. However, Türkiye's renewable energy resource potential is high and advantageous in this respect. The Republic of Türkiye Ministry of Energy and Natural Resources 2019-2023 Strategic Plan (Table 3) has set 7 aims and 31 targets, and here, Aim 1. To ensure Türkiye's sustainable energy supply security. Target 1.1 to ensure that the ratio of installed electricity based on domestic and renewable energy sources to total installed power is increased from 59% to 65%. (Republic of Türkiye Ministry of Energy and Natural Resources, 2021).

According to the table, it is seen that the installed power in Türkiye's renewable energy sources (solar and wind) lag behind domestic sources. In particular, it is observed that floating wind, solar, wave and current systems are not evaluated offshore. However, the fact that Türkiye is surrounded by seas on three sides brings the energy potential to the forefront in the offshore as well as in terrestrial areas. For this reason, the potential of the Turkish seas should also be taken into account while creating the Strategy plan.

Table 3. 2019-2023 Strategic Plan, Aim 1. Ensuring Türkiye's sustainable energy supply security (Republic of Türkiye Ministry of Energy and Natural Resources, 2021)

Aim(A1)		To ensure Türkiye's sustainable energy supply security								
Target (T1.1)		It is to ensure that the ratio of installed electricity based on domestic and renewable energy sources to total installed power is increased from 59% to 65%								
Performance Indicators		**Effect on Goal (%)**	**Plan Period Initial Value**	**2019**	**2020**	**2021**	**2022**	**2023**	**Tracking Frequency**	**Reporting Frequency**
P.I 1.1.1	Electricity installed power (MW) based on solar energy (cumulative)	%25	5.063	5.750	7.000	7.750	8.500	10.000	Every 6 months	Every 6 months
P.I 1.1.2	Electricity installed power (MW) based on wind energy (cumulative)	%25	7.005	7.633	8.883	9.633	10.633	11.883	Every 6 months	Every 6 months
P.I 1.1.3	Electricity installed power (MW) based on hydroelectric energy (cumulative)	%15	28.291	29.748	31.148	31.688	31.688	32.037	Every 6 months	Every 6 months
P.I 1.1.4	Electricity installed power (MW) based on geothermal energy and biomass (including biogas) energy) (cumulative)	%10	2.094	2.678	2.717	2.772	2.828	2.884	Every 6 months	Every 6 months
P.I 1.1.5	Electricity installed power (MW) based on domestic coal (cumulative)	%25	10.204	10.664	10.664	10.664	11.464	14.664	Every 6 months	Every 6 months
Responsible Unit		Republic of Türkiye Ministry of Energy and Natural Resources								

Türkiye Solar Energy Potential

According to the data of the Türkiye Solar Energy Potential Atlas (GEPA), the annual total sun time is 2.737 hours, and the annual total incoming solar energy is 1.527 kWh/m². The total solar energy of the coastal regions is respectively Mediterranean 1.390, Aegean 1.304, Marmara 1.168, and the Black Sea 1.120 (kWh/m^2-year) (Figure 4) (Özgür, 2018; Turkish State Meteorological Service, 2020a).

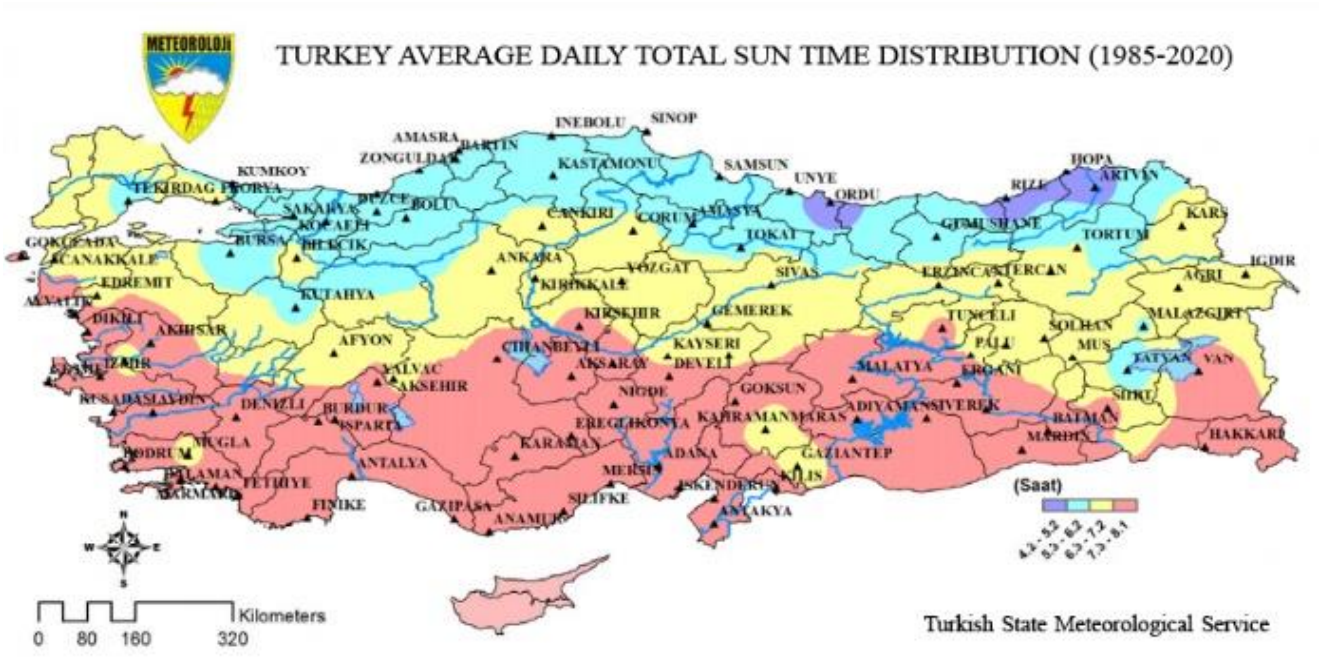

Figure 4. Türkiye sun atlas (a) (Turkish State Meteorological Service, 2020a)

Between 1970 and 2020, the average seawater temperature of the Mediterranean Sea was 21.4°C, the Aegean Sea 18.6 °C, the Marmara Sea 15.6 °C, the Black Sea 15.3 °C (Figure 5) (Turkish State Meteorological Service, 2020b).

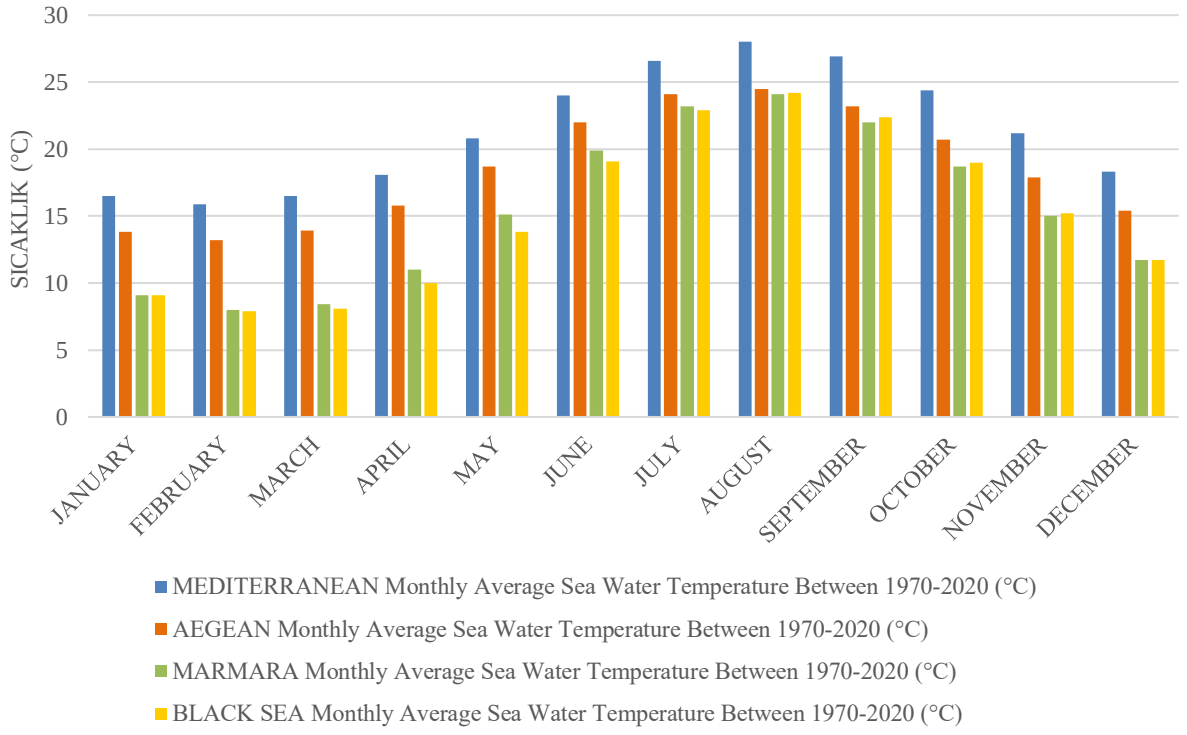

Figure 5. Mediterranean, Aegean, Marmara, Black Sea Monthly Average Sea Water Temperature Between 1970-2020 (°C) (b) (Turkish State Meteorological Service, 2020b)

When looked at, Türkiye's sun time is high, and its solar energy production potential is high. Evaluating offshore and inland waters such as dam ponds and freshwaters will contribute to renewable energy production. In addition, floating solar energy systems have advantages such as reducing the

evaporation of water, preventing PV installations on fertile land, and increasing the energy efficiency of PV Systems with the cooling effect of water (Bulut et al., 2018).

Türkiye Wind Energy Potential

According to the Energy Sector Management Assistance Program (2019), Türkiye's Aegean Sea northwest regions that offshore wind speeds up to 9 m/s; the most extensive area has technical offshore wind potential of 6 GW fixed and 19 GW floating (ESMAP, 2019; Solarbaba, 2022). It has good characteristics in the Marmara Sea and the Black Sea with a wind speed of 7-8 m/s. There are also many opportunities on the West Coast and in the Southeast. Areas with a total water depth of fewer than 50 m have a technical potential of 12 GW and a further 57 GW up to a depth of 1000 m (Figure 6) (ESMAP, 2019; Solarbaba, 2022). Thanks to these characteristics of the Turkish coast, it is seen that it has the opportunity to produce offshore wind energy.

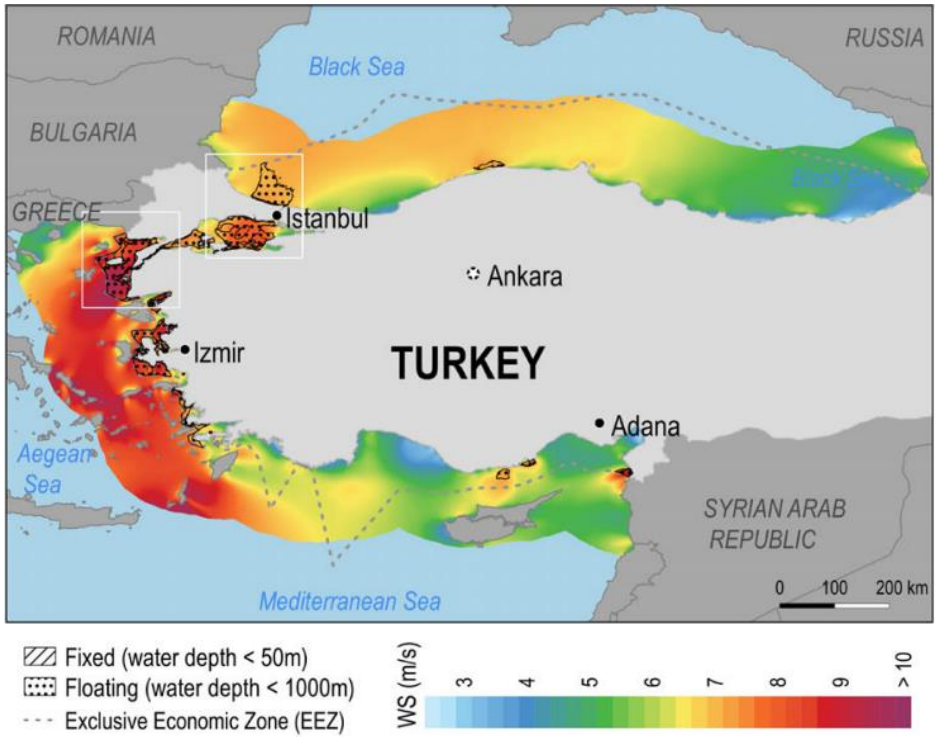

Figure 6. The technical potential for offshore wind within 200 km of Türkiye (ESMAP, 2019)

Özkol examines the mechanical behavior of floating-type wind turbines installed in the deep seas in the TUBITAK 1001 project. Özbahçeci stated that of the approximately 70 gigawatts of offshore wind energy potential in Türkiye, about 57 gigawatts of it can be obtained by floating in the deep sea, and 12 gigawatts of it can be gained with a fixed wind turbine (Anonymous, 2022).

Considering the wind period of Türkiye's seas, the potential for offshore wind energy is high. At the same time, it has advantages such as higher wind intensity at sea, more excellent wind continuity, no need for expropriation on the sea, no land losses with the wind energy system, and cheaper sea transportation than land (Temiz Enerji, 2021).

Türkiye Wave Energy Potential

Offshore wave characteristics are waves occurred by wind and vary depending on the bottom topography and changing water depths. In Türkiye, the average wavelength height is most seen on the Southwestern coast and is up to 2 m. (Figure 6) (Metin, 2021).

According to the measurements made in the Mediterranean, the wave energy power varies between 8.4-15.5 kW/m throughout the year, and it is estimated that one-fifth of Türkiye's coasts has a potential

of 18.5 billion kWh by taking advantage of this potential (Kadıoğlu & Tellioğlu 1996; Demirci, 2021). Especially the wind potential on the Aegean Sea and the Mediterranean provides an average annual wave power of 4-17 kW/m. The coasts corresponding to Dalaman-Finike are shown as the most suitable place between İzmir and Antalya (Oral, 2021; Demirci, 2021).

According to Demirci (2021), wave intensities of Turkish coasts;

- Black Sea-1.96-4.22 kWh/m, Aegean Sea-2.86-8.75 kWh/m, Mediterranean-2.59-8.26 kWh/m, it is given as İzmir-Antalya-3.91-12.05 kWh/m (Oral, 2021; Demirci, 2021).

It is stated that in waters with a wave power of 4-17 kW/m annually, a total of approximately at least 10 TWh/year energy can be obtained (Sağlam et al., 2010), which constitutes about 12.5% of Türkiye's hydroelectric energy potential (Figure 7) (Demirci, 2021).

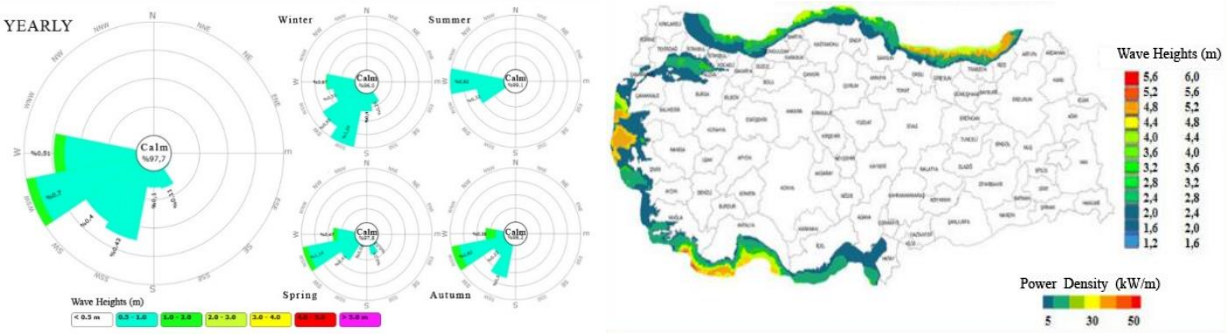

Figure 7. Türkiye climatic wave rose graph (Metin, 2021), Türkiye wave height map (Demirci, 2021)

According to the location and climatic characteristics of Türkiye, it is possible to say that the coastal and inland waters are high in terms of renewable energy potential.

CONCLUSION

Since energy is a need in all areas of life, it is necessary to ensure its continuity in its supply. A sustainable future can only be achieved by meeting the needs without disturbing the natural balance and without harming their living lives. Because of this, while meeting their energy needs, human beings should make optimal use of resources by considering future generations and respecting nature. At this point, the importance of renewable energy sources emerges and is considered necessary to provide a sustainable future. Renewable energy has a significant role in sustainable energy production.

Countries meet most of their energy needs from non-renewable sources. This causes rapid depletion of resources, global climate change, destruction of natural areas, and the impact on living lives. The negativities experienced and the fact that our future is under threat lead countries to develop sustainable energy policies. The inexhaustible and clean energy supply of renewable resources makes it common in terrestrial areas worldwide and in our country. Also, Türkiye activates renewable resource dynamics to reduce external dependence on energy and ensure economic and sustainable growth.

Today, possible that due to the various needs of floating structures in every field to develop in energy production and provide alternative resource potential. Also, *The emergence of living spaces (floating cities) on water surfaces and the difficulty of supplying energy from the coast for these areas, * The fact that 70% of the Earth is covered with water surfaces and most of them can benefit from renewable resources with different potentials, can be evaluated seas, and some large freshwater (such as dam lake) from this point of view, * Floating energy systems are developing rapidly due to reasons such as the suitability of marine coastlines in terms of renewable resource uses such as solar, wind, wave, tidal, undercurrents, salinity.

The rapid progress of renewable resources in Türkiye takes place in terrestrial areas. However, floating systems need to be developed in our country, which is surrounded by sea on three sides and is

suitable for renewable energy systems. For this reason, our coastal waters and inland waters under favourable conditions should be evaluated for sustainable energy production.

In the study, Türkiye's floating renewable energy system potential for sustainable energy production was evaluated. In particular, studies on solar, wind and wave energy production, which we find commonly in world examples, were studied. Türkiye's ocean thermal energy potential is insufficient because it does not have a coast to offshore. In addition, the tides are not large enough to produce energy. Therefore, thermal energy and tidal energy were not evaluated. The conclusions reached are that Türkiye's floating energy potential is high and studies on this need to be increased.

In this way, our country's coastal waters will be used more actively in energy supply, and clean and sustainable energy production can be increased. It should not be forgotten that the importance of renewable energy sources is critical to ensure a sustainable future, and countries should be able to make this progress at sea scales as well as terrestrial developments.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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