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Determining the Hybrid Energy Potential of Türkiye's Blue Homeland in the Aegean Sea

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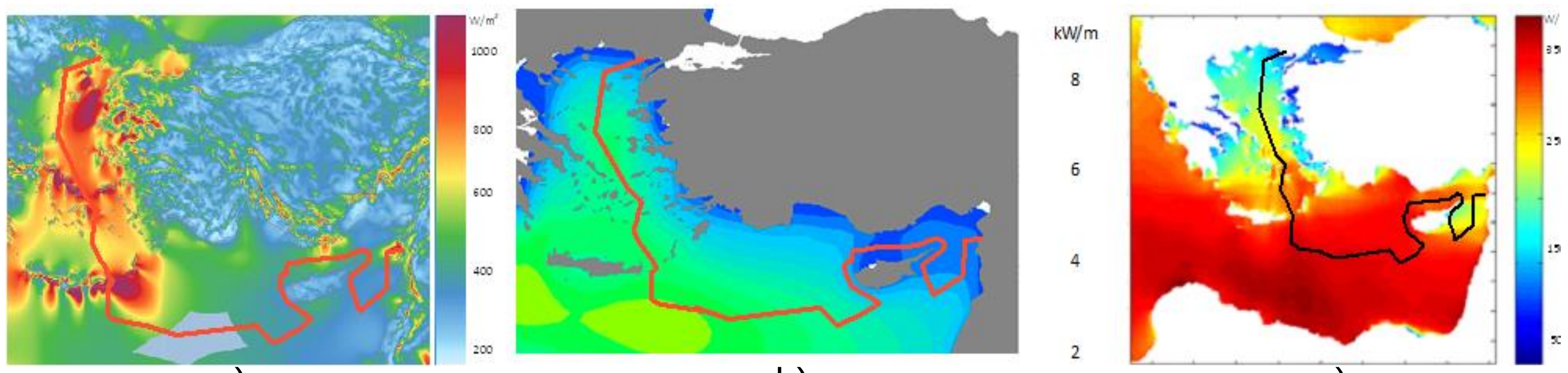
I. Abstract

The study aims to determine Turkey's offshore hybrid energy potential and green hydrogen production. For this purpose, the Aegean Sea within the Blue Homeland was analyzed. In addition to Renewable Energy Potentials (REP), geopolitical importance, energy transmission lines, transportation routes, military and security areas, hydrocarbon potentials were also taken into consideration in determining the sample locations in this zone. REP of the identified locations were determined. It was then planned to produce green hydrogen from renewable energy potential. In this case, techno-economic analysis of the system was carried out, taking into account the transmission of the produced hydrogen to the mainland in different forms and with different transportation methods.

II. System Description and Procedure

Within the Blue Homeland Continental Shelf Zone, 4 Zones with a square area of 3x3 km were identified. The rotor blades are directly effective in the conversion of wind energy into mechanical energy. The difference in kinetic energy when the wind touches and leaves the blades is equal to the amount of wind energy converted into kinetic energy. In the light of this information, it shows that Türkiye's RESs are developing and open to further development. In addition, wind energy, solar energy and wave energy potential maps of the Eastern Mediterranean and Aegean Sea are given in Figure 1.



a) b) c)

Figure 1. Blue Homeland energy potential a) Wind energy map b) Wave energy map c) Solar energy map

The amount of energy that can be obtained from a wind turbine is given in Equation 1.

$$E_e = \frac{q\,A}{2} v^3\, t \quad (1)$$

The coordinates and wind energy data for these Zones are given in Table 1.

Table 1. Coordinates and wind energy data for the Zones

Zone	Latitude	Longitude	Average wind speed (m/sn)	Power density (W/m2)
Zone 1	35.12103	26.60889	10.3	1123
Zone 2	37.53368	26.40838	9.51	910
Zone 3	39.82541	25.94696	9.53	914
Zone 4	40.18228	25.68191	9.25	939

The amount of energy to be obtained annually from a solar module is estimated using Equation 2.

$$E_e = A_{tp} \,.\, A_v \,.\, \eta_f \,.\, P_R \,.\, GHI \quad (2)$$

Solar energy data for the coordinates determined within the Blue Homeland Continental Shelf zone are given in Table 2.

Table 2. Solar energy data for Zones

Zone	DNI (kWh/m²)	GHI (kWh/m²)	DIF (kWh/m²)	GTI (kWh/m²)	Temperature (C)
Zone 1	1882.1	1904.8	642.2	2108.5	19.4
Zone 2	1941.8	1827.6	618.0	2052.4	18.4
Zone 3	1774.6	1707.7	615.1	1931.6	16.8
Zone 4	1681.3	1660.6	620.7	1873.5	16.6

In general, wave energy source is defined as the average wave power per unit of crest length. The wave energy source expression is given in Equation 3.

$$E_w = \frac{\rho g^2}{64\pi} \sum_{i=1}^{N} \sum_{j=1}^{M} H_s^2\, T_E\, f_{ij} \quad (3)$$

Wave energy data for the coordinates determined within the Blue Homeland Continental Shelf zone are given in Table 3.

Table 3. Wave energy data for the Zones

Zone	Depth (m)	Average Wave Height (m)	Period (sn)	J (kW/m)	E (MWh/m)
Zone 1	919	1.11	4.7	8.9	77.964
Zone 2	52	1.12	4.6	9.3	81.468
Zone 3	26	1.05	4.6	8.95	78.402
Zone 4	150	1.03	4.5	8.9	77.964

The wind farms to be created by installing Generic 3.45 MW wind turbines proposed to be established in the zone will generate 11.629 GWh of energy annually. With the 1000 kWp solar panels proposed to be installed in the zone, a total of 5.704 GWh of energy will be generated annually. With the 150 MW wave power plant to be established in the zone, 2.346 GWh of energy will be produced. Thus, the total amount of energy to be produced in 4 Zones will be 19.679 GWh of energy.

III. Hydrogen Production

Dinçer stated that the hydrogen era has begun (Dincer 2020). Hydrogen production has therefore emerged as an important engineering application. Although hydrogen is the most abundant and cleanest energy source, it is not readily available in nature as a chemical substance because it is mostly bound to other molecules. Therefore, it needs to be produced before it can be used. There are various methods in the literature to produce hydrogen. However, in order to be accepted as an alternative energy, it must have a renewable and sustainable-based process. In this context, water electrolysis is the only viable technology for large-scale 'green and clean' hydrogen production (Proost 2019). Water electrolysis is the process of separating water into hydrogen and oxygen by direct current. This technology has many advantages such as high efficiency and most importantly, it can be produced from renewable energy sources. This has revealed the necessity to investigate the hydrogen production from renewable energy sources in the Eastern Mediterranean region, which has a high renewable energy potential. This has been the most important motivation of this study.

III. Conclusions

In this study, the REP potential for the Eastern Mediterranean and the Aegean Sea was examined and techno-economic analysis was carried out. For this purpose, the REPs of the determined regions were analyzed for wind, solar and wave energy sources. Since the regions are located between low pressure and high pressure air currents, it is seen that wind energy densities are high. When the latitude effect and daily insolation are taken into account as the main criteria in determining the solar energy potential, it is seen that the energy density of the regions is high. In addition to this situation, wave energy in the region was also added. As a result, 19,679 GWh of green energy will be produced in the region. This energy will produce 400×10^3 kg of green hydrogen through electrolysis. This green hydrogen will be transported to the mainland as compressed or liquefied hydrogen. The transportation cost of liquefied hydrogen is 0.584 M$/km, while the transportation cost of compressed hydrogen is 0.14 M$/km. In case of transportation by pipelines, the cost is 0.96 M$/km.

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