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# THE RENEWABLE ENERGY POTENTIAL OF TURKISH COASTS AND A CONCEPT DESIGN OF A NEAR SHORE SEA PLATFORM

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## ABSTRACT

There are several types of renewable energy platforms. Because of requirements of places, where platforms were built, every platform has different energy systems and qualities.
In this paper, the renewable energy potential of Turkish coasts was investigated according to different renewable energy types. It is aimed to find suitable places for a near shore renewable energy platform and create a concept design.
Firstly, the regions with highest energy potential according to four renewable energy types; wind, wave, current and solar; were determined and five different regions were selected to analyze. For each region, the power data of the different energy types were converted to same unit and the regions were ranked with respect to these results.
Then the existing platform types and alternative energy conversion systems were examined and for each energy type a conversion system was chosen according to the characteristics of selected region. Finally, a concept near shore platform was designed with selected systems.

***Keywords:*** *Renewable Energy, Near Shore Sea Platform, Turkish Coasts, Wind Energy, Current Energy, Wave Energy, Solar Energy*

## INTRODUCTION

Nowadays, environmental pollution becomes one of the most important problems all over the world. In addition, fossil fuels are diminishing rapidly day by day. Both of these reasons have made important to use alternative energies and led to significant developments in renewable and clean energy technologies. The purpose of this study is to demonstrate the potential of renewable energy sources of Turkey and create a concept design of a floating platform that is convenient for Turkey's coasts.

Turkey is a country surrounded on three sides by sea and have a long coastline. Therefore it is thought to be suitable for a floating renewable energy platform which can be include several types of renewable energy systems together, especially related with sea.

There are several types of renewable energy and renewable energy systems. In this paper, the most significant renewable energy types; wind, wave, current and solar, will be discussed. And for each type of renewable energy, a type of energy converter system will be selected according to reasons to be determined.

Analyzing the renewable energy potential of Turkey will reveal the high potency locations for the desired platform. And the determined conditions of the locations will guide to select the convenient energy converter technology.

## RENEWABLE ENERGY POTENTIAL OF TURKEY

To be able to determine the renewable energy potential of Turkey, general information and maps were given according to four renewable energy types; wind, wave, current and solar energy. The main aim of this study is to find the most convenient location for a floating renewable energy platform. For this reason, five different regions were selected to analyze and to be able to make a comparison, the power data of the different energy types were converted to same unit and the regions were ranked with respect to these results.

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### Wave Energy Potential

Wave energy per unit area is directly proportionate to density of water, acceleration of gravity and square of wave height [1].

$$\bar{E} = \frac{1}{8}\rho g H^2 \ \left( {}^{J}/_{m^2} \right) \tag{1}$$

**Table 1.** Mean wave energy values of Turkey

| REGION | Mean H (m) | Mean T (s) | Mean Energy (J/m²) | Mean Power (W/m²) |
|---|---|---|---|---|
| **BLACKSEA** | 5,2 | 2,57 | 33972,88 | 13176,80 |
| **MARMARA** | 2,1 | 4,50 | 5540,69 | 1229,47 |
| **AEGEAN** | 2,8 | 5,19 | 9850,12 | 1897,38 |
| **MEDITERRANEAN** | 4,8 | 7,58 | 28947,31 | 3815,63 |

Wave properties were obtained from previous studies in literature [2] and mean wave energy values of Turkish seas were calculated using Equation 1.

### Wind Energy Potential

Wind energy is directly proportionate to air density and cube of wind speed [3].

$$P = \frac{1}{2}\rho V^3 A \ \ (W) \tag{2}$$

The aim of this study is to design a compact near shore platform with relatively small dimensions. Wind velocities on Turkey seas were taken from REPA (wind energy potential atlas) [4]. The data have been measured at 50m height. To obtain more reasonable results, wind speeds at 10m height was used during the power density calculations according to Equation 2. Results are given in Table 2. To convert wind velocity values from 50 meters to 10 meters, Equation 3 has been used. In this equation,
$V_r$ is calculated velocity, $V_{rref}$ is measured velocity, $H_r$ is calculated height, $H_{rref}$ is measured height,
$\mu$ is Hellman coefficient equals 0.25 in our place [5]

$$V_r = V_{rref} \cdot \left( {}^{H_r}/_{H_{rref}} \right)^{\mu} \tag{3}$$

**Table 2.** Power density (according to wind speeds)

| Velocity (m/s) (h:50m) | Velocity (m/s) (h:10m) | Power Density (W/m²) |
|---|---|---|
| 4 | 3,40 | 350 |
| 4,5 | 3,83 | 390 |
| 5 | 4,25 | 430 |
| 5,5 | 4,68 | 470 |
| 6 | 5,10 | 510 |
| 6,5 | 5,53 | 550 |
| 7 | 5,95 | 600 |
| 7,5 | 6,38 | 640 |
| 8 | 6,81 | 680 |
| 8,5 | 7,23 | 720 |
| 9 | 7,66 | 770 |
| 9,5 | 8,08 | 810 |
| 10 | 8,51 | 850 |

Wind velocity distribution of Turkey was given in Figure 1. It also includes wind velocities on coastlines. Data in Figure 1 represents the annually average values for wind velocities.

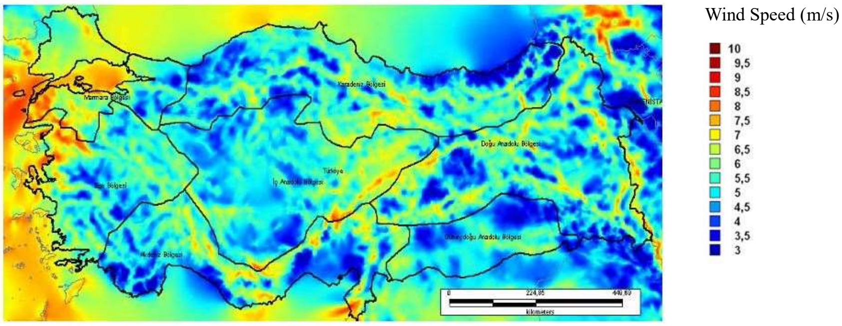


**Figure 1.** Wind velocity distribution of turkey at 50m height [4]

## Current Energy Potential

Current potential energy is directly proportionate to density of current and cube of current velocity [6].

$$P = \frac{1}{2}\rho V^3 A \ \ (W) \tag{4}$$

Current velocities for all seas of Turkey were determined by dates [7]. By using Equation 4, mean current power density was found according to current speeds.

**Table 3.** Current power density

| Velocity (knot) | Velocity (m/s) | Power Density ($W/m^2$) |
|---|---|---|
| 0 | 0 | 0 |
| 0,5 | 0,25 | 8,71 |
| 1 | 0,51 | 69,75 |
| 1,5 | 0,77 | 235,43 |
| 2 | 1,02 | 558,06 |
| 2,5 | 1,2 | 1089,97 |
| 3 | 1,54 | 1883,47 |
| 3,5 | 1,80 | 2990,89 |
| 4 | 2,05 | 4464,54 |
| 4,5 | 2,31 | 6356,73 |
| 5 | 2,57 | 8719,80 |

## Solar Energy Potential

Potential solar energy is directly proportionate to sunshine duration of regions. Annual solar radiation map of Turkey is given in Figure 2 (per unit area). Colors of the map represent total annually average values.

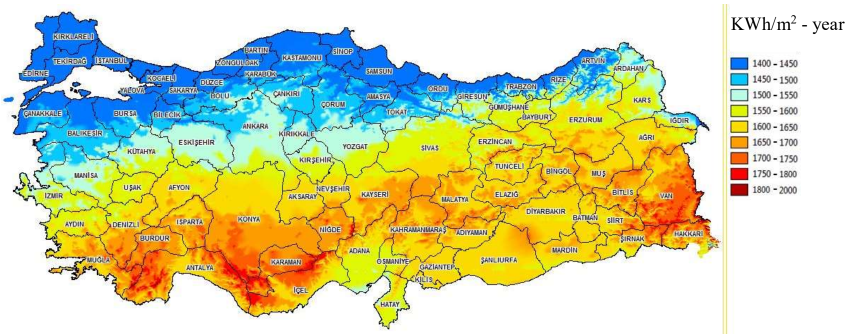


**Figure 2.** Solar radiation map of turkey (KW/m2-year) [8]

### Determination of Suitable Location for Concept Design

In this section, the region with the highest power density according to different renewable energy types will be determined.

As shown in Table 1, Black Sea region of Turkey has the highest potential according to the wave energy.

As a result of the research which is fulfilled for wind energy in previous chapter, some coastal regions were determined with high potential of wind energy from Figure 1: Hatay in Mediterranean region, Aegean outlet of Dardanelles in Aegean region, and coast of Kastamonu in Black Sea region.

**Table 4.** Wind power density for specified regions

| Region | (h:50m) Velocity (m/s) | (h:10m) Velocity (m/s) | Power Density @10m ($W/m^2$) |
|---|---|---|---|
| Kastamonu | 7,5 | 6,38 | 640 |
| Çanakkale | 9 | 7,66 | 770 |
| Hatay | 9,5 | 8,08 | 810 |

As a result of the research which was made for current energy in previous chapter, the regions with high potential of current energy were determined as Black Sea and Marmara outlet of Bosporus and Aegean outlet of Dardanelles. The current speeds and power densities of these regions are given in Table 5.

**Table 5.** Current energy power density in specified regions

| Region | Velocity (knot) | Velocity (m/s) | Power Density ($W/m^2$) |
|---|---|---|---|
| Istanbul (Marmara) | 4 | 2,05 | 4464,54 |
| Istanbul (BlackSea) | 2 | 1,02 | 558,06 |
| Çanakkale | 3 | 1,54 | 1883,47 |

Solar energy is thought in secondary importance, hence the solar power density of Hatay, Çanakkale, İstanbul and Kastamonu, which are in possession of the high power density for the other three energy types, were determined. There is no primary importance of solar system on region determination, even so, by using the data which is gained from Figure 2, potential solar energy of these regions were calculated and given in Table 6.

**Table 6.** Current energy power density in specified regions

| Region | Total Solar Irradiance ($KWh/m^2$-year) | Annual Sunshine Duration (h) | Power Density ($W/m^2$) |
|---|---|---|---|
| Kastamonu | 1400 | 2362,2 | 592,66 |
| Istanbul | 1400 | 2410,8 | 580,72 |
| Çanakkale | 1400 | 2768,7 | 505,65 |
| Hatay | 1600 | 2973,3 | 538,12 |

In Table 7, power density results of selected regions are given comparatively for 4 types of renewable energy.

**Table 7.** Comparison of power densities of selected regions

| | Kastamonu | Istanbul (Marmara) | Istanbul (Blacksea) | Çanakkale | Hatay |
|---|---|---|---|---|---|
| Wave ($W/m^2$) | 12338,25 | 1229,47 | 12338,25 | 1897,38 | 3815,63 |
| Wind ($W/m^2$) | 640 | 640 | 640 | 770 | 810 |
| Solar ($W/m^2$) | 592,66 | 580,72 | 580,72 | 505,65 | 538,12 |
| Current ($W/m^2$) | 0 | 4464,54 | 558,06 | 1883,47 | 235,43 |
| Total ($W/m^2$) | 13570,92 | 6914,73 | 14117,03 | 5056,51 | 5399,19 |

Power density values are given on a map alternatively (Figure 3). From this map can be seen the compared regions and their power density values. Additionally, to be able to rank the regions easily, a scoring system was applied. Each 500W/m2 have been graded as 1 point correspondingly and total score of selected regions were indicated on map.

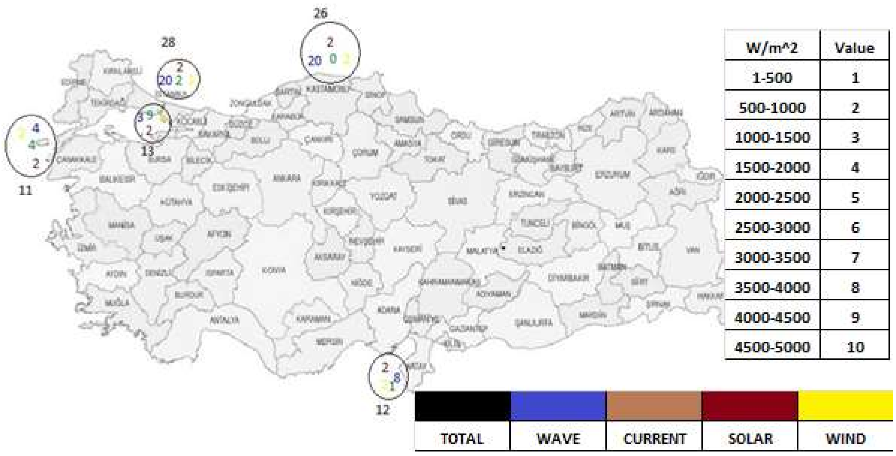


**Figure 3.** Turkey's power density evaluation map

As a result of the feasibility study, the most suitable location for desired platform is confirmed as Black sea outlet of Bosporus.

## CONCEPT DESIGN

In this part, the type and renewable energy converter systems for desired platform will be determined.

### Determination of the platform type

When examined the previous studies, in general, these platforms could be divided into two types: nearshore and offshore.

**Offshore Systems** Offshore systems contain various renewable energy systems which is established on a floating platform at a certain distance of seashore. These systems can produce large-scale energy which is up to 500 meters at the present time. Setup costs of these systems are high. To this respect, these systems are established on areas have high energy potential.

**Nearshore Systems** These systems are established in 20-30 depth. Nearshore systems have small-size, initial investment and maintenance cost are low. They produce low-level energy. In addition, due to their small size, they can increase amount of generated energy by establishing side by side such as wind farms.

A comparison of the type of platforms is given in Table 8.

**Table 8.** Comparison of platform type

| | **OFFSHORE** | **NEARSHORE** |
|---|---|---|
| **Size** | LARGE | SMALL |
| **Capital Cost** | HIGH | LOW |
| **Power Capacity** | HIGH | LOW |
| **Installation** | HARD | EASY |
| **Depth (m)** | >60 | 20-25 |
| **Distance from shore** | AWAY | NEAR |

The location of the platform is one of the key factors to define the type of platform. In consequence of the feasibility study in last part, location of the platform has been determined as Black Sea outlet of Bosporus. The selected region is a closed sea and have relatively low energy potential in comparison with oceans and have continuous maritime traffic. Hence, a small-size near-shore platform would be more effective. Low capital costs and easy installation requirements are also other advantages for desired concept.

## Determination of the renewable energy systems

To design the concept platform, suitable energy systems has to be specified for each type of renewable energy. Desired concept, the conditions and potency of selected region and limitations play significant role on selection of the systems.

## Determination of Wind Turbine

Features of Black Sea outlet of Bosporus in terms of wind energy can be listed as follows:

- Mean wind speed 6.4m/s @10m height, 7.5.m/s @50m height
- Region is open to maritime traffic
- Platform type will be nearshore
- Wind potential is low

According to general features of system; due to low wind speed, a system with low operating speed must be selected. Because the region is open to maritime traffic, system must be a small-size. Because the system is close to the shore, noise must be less. Due to low wind potential, system must be low cost.

**Table 9.** Comparison of wind turbines

| | **Horizontal Axis WT** | | | **Vertical Axis WT** | |
|---|---|---|---|---|---|
| | **Single Wing** | **Duble Wing** | **Trio Wing** | **Savonius** | **Darrieus** |
| **Capital Cost** | HIGH | HIGH | LOW | LOW | LOW |
| **Noise** | HIGH | HIGH | LOW | LOW | LOW |
| **Wind Velocity Sublimit** | HIGH | LOW | HIGH | LOW | LOW |
| **Tower necessary** | EXIST | EXIST | EXIST | NON | NON |

As shown Table 8, Vertical Axis Wind Turbines have a lot of advantages in comparison with Horizontal axis. The speed and direction of the wind is not important for VAWT and have quite small dimensions compared to HAWT. In this study, Darrieus type VAWT is selected for the concept design.

### Determination of Wave Turbine

Features of Black Sea outlet of Bosporus in terms of wave energy can be listed as follows:

- Mean wave height is 2.1m, and period 4.5 s
- In our country, wave potential is generally low
- Region is open to maritime traffic.
- System will be nearshore

According to power density results and concept design, wave energy system will be the significant part of the platform and the main part of the structure. Osprey wave turbine system was selected because this system are cheap, useable combine other systems, and this systems are using near shore and they don't need so much wave energy potential.

### Determination of Current Turbine

Features of Black Sea outlet of Bosporus in terms of wave energy, can be listed as follows:

- Mean current velocity 2-3m/s
- Current potential energy is not too high
- Current is not unidirectional

As seen from above, in selected region, the current is multi-directional and has low speed. Hence, selected turbine could catch the current from each direction and convert low speed currents to the energy.

**Table 10.** Comparison of current turbines

| | **HACT** | **VACT** |
|---|---|---|
| **Capital Cost** | HIGH | LOW |
| **Rotation Axis** | HORIZONTAL | VERTICAL |
| **Efficiency** | HIGH | LOW |

Although they have low efficiency, Vertical Axis Current Turbine (Savonius type) is selected because they have two half-cylinder-shaped and oppositely placed blades with big blade area, so they can work with even very low speed and multi-directional currents.

### Determination of Solar Energy System

The topside of the platform could be covered by solar panels. According to the platform geometry, the area and arrangement of the photovoltaic panels will be designed.

### Concept Near-shore Renewable Energy Platform

In this work, it is aimed to create a near-shore renewable energy platform for specified location. The design should be relatively small-sized because it would be situated close to the coastline. To be able to obtain energy from 4 different renewable energy sources; wind, wave, current and solar, it should include suitable energy converter systems, as selected in previous chapter.

It is decided to use an Osprey type turbine for wave energy, a Darrieus type wind turbine, Savonius type current turbines and solar panels. An illustration of the concept platform is given in Figure 4. The most important feature of Darrieus and Savonius type turbines is their small size. Both of them can work with any flow independently of speed and direction.

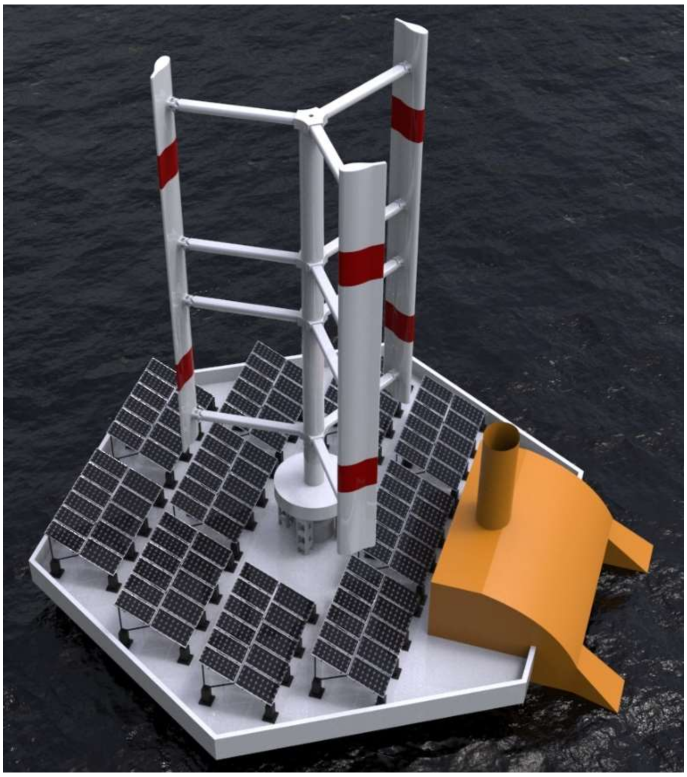

**Figure 4.** Concept near-shore renewable energy platform

The deck of the platform is covered with solar panels. All panels are adjustable according to the sunlight. Hexagonal geometry of the main structure allows to easily create farms with combining two or more platforms together (Figure 5).

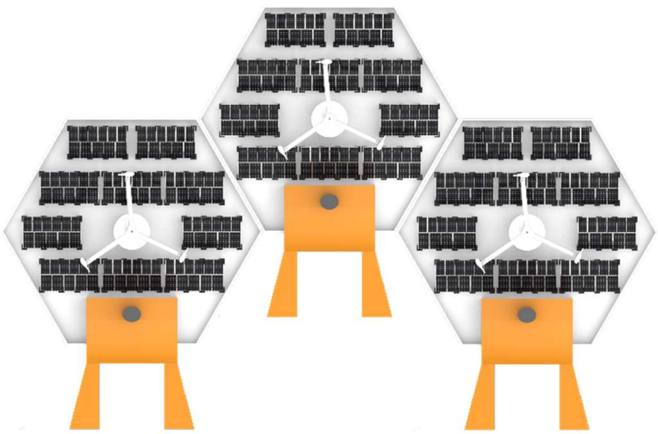

**Figure 5.** Advantage of hexagonal geometry

Arrangement of the different type of the renewable energy converters on the platform is given in Figure 6.

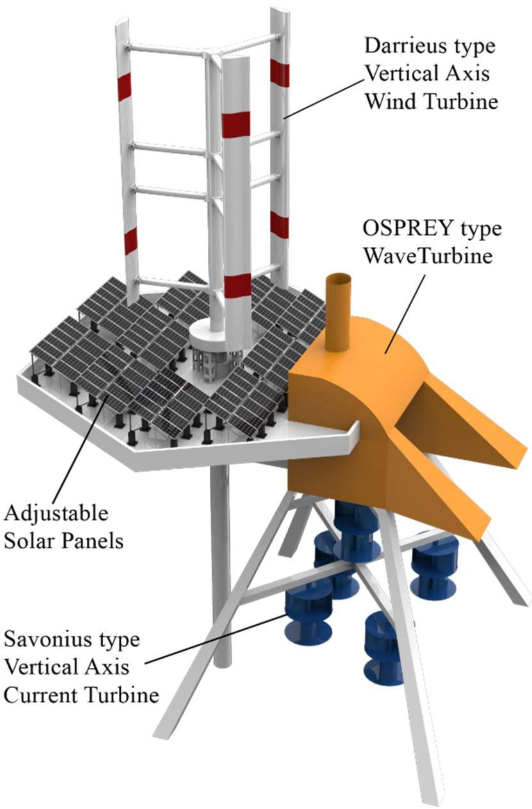


**Figure 6.** Components of the renewable energy platform

## CONCLUDING REMARKS

Renewable energy technologies are one of the most important topic all over the world and the role of the renewable energies in energy sector is increasing day by day. In this paper, correspondingly to the development in the world, the renewable energy potential of Turkey was investigated.

Firstly, a literature review was realized to find the available data for four different types of renewable energy; wind, wave, current and solar. The results of the research were used to define a suitable location for a floating renewable energy platform with highest renewable energy potential. The power densities for each type of renewable energy was calculated and converted to same unit to be able to rank selected regions according to their scores.

Finally, nearshore renewable energy platform concept was created with selected renewable energy converter systems for the selected region. As mentioned previous chapters, selected systems have minimal operational and maintenance costs according to other types of their class. All systems have their own energy converting mechanism and could work separately. Obtained energy can be stored in several ways, directly as electricity or hydrogen as a result of hydrolysis of sea water.

Several samples of floating renewable energy platforms can be found. However, in general, they have designed for offshore applications with relatively larger dimensions [9]. Typically, near shore platforms are designed to obtain energy for 1 or 2 types of renewable energy sources. In this study, it is aimed to create a concept that can be obtained energy from four different renewable energy sources.

This study could be evaluated a reference and a starting point for further similar studies. This concept can be evolved into more specific concepts according to specific regions with dominant renewable energy source. In this case, the concept could be developed more efficient, feasible and perfectly suited to the conditions of the all kind of regions.

Writers are planning to improve the concept design and calculate the installed capacity of the platform in future works. There are several current studies about both technology and materials of new type renewable energy converters [10]. To develop the concept, further studies should be realized in details to be able to select the most suitable and efficient renewable energy converters to the whole system. It is also planned to make feasibility analysis firstly according to selected region.

## NOMENCLATURE

| | |
|---|---|
| E | Energy |
| ρ | Density |
| g | Gravity Acceleration |
| H | Wave Height |
| T | Wave Period |
| J | Joule |
| N | Newton |
| m | Meter |
| s | Second |
| P | Power |
| V | Volume |
| A | Area |
| W | Watt |
| h | Height |
| HAWT | Horizontal Axis Wind Turbine |
| WAWT | Vertical Axis Wind Turbine |
| HACT | Horizontal Axis Current Turbine |
| VACT | Vertical Axis Current Turbine |
| REPA | Wind Energy Potential Atlas |
| GEPA | Solar Energy Potential Atlas |

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