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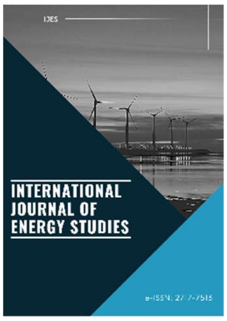


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# Turkey's wave energy potential: A PESTLE Analysis

**Mehmet Çeçen***

**Ilgın Vocational School, Selcuk University, Konya, Turkey, ORCID: 0000-0003-2344-3018*

*(*Corresponding Author:mehmet.cecen@selcuk.edu.tr )*

**Highlights**

- Turkey energy mix.
- Renewable energy share in installed capacity.
- Wave energy.
- PESTLE analysis.

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## ABSTRACT

Turkey's energy landscape is characterised by a dynamic fusion of nonrenewable and renewable sources, which are crucial for meeting the nation's electricity demands. Sources, such as natural gas and coal derivatives, ensure grid stability, while renewables, such as hydroelectric, solar, and wind power, underscore Turkey's commitment to sustainability. Although there are currently no grid-connected wave energy plants, initiatives such as the OREN Ordu Energy project demonstrate the country's growing interest in wave energy. Turkey aims to integrate wave energy into its renewable energy mix, with the help of supportive regulations and incentives. This will bolster resilience and reduce environmental impact. However, successful integration requires overcoming regulatory hurdles, technological advancements, and environmental concerns. This study discusses the potential of wave energy and the importance of increasing the rate of renewable energy, with a PESTLE analysis.

**Keywords:** Turkey, Energy mix, Renewable energy, Wave energy, PESTLE

## 1. INTRODUCTION

The importance of renewable energy is increasing due to a combination of factors, including the depletion of traditional energy sources, increasing energy demand, and increasing prices of natural gas and coal [1, 2]. The global surge in renewable energy consumption reflects a shift towards sustainability, an improved energy structure, and increased energy security. Despite challenges such as rising oil prices, investment in renewable energy promotes sustainable economic growth and energy security [3, 4].

Wave energy is a renewable energy source that harnesses the power of ocean/sea waves to generate electricity [5]. This promising renewable energy source has the potential to significantly contribute to the global energy mix and reduce the dependence on fossil fuels. Unlike other renewable energy technologies, wave energy is relatively untapped and in the early stages of development. Despite its potential, wave energy faces challenges in terms of cost and technological maturity [6-7]. The levelised cost of energy (LCOE) for wave energy is higher than that for conventional energy sources. However, research is ongoing to develop low-cost wave energy conversion technologies and optimise wave energy systems. With continued advances in wave energy conversion technologies, wave energy has the potential to play a crucial role in transitioning to a sustainable and low-carbon energy future [8-9].

Turkey, with its extensive coastline along the Aegean, Mediterranean, and Black Seas, has significant wave energy potential [10]. Studies have shown that Turkey has a relatively high potential ranging from 4--17 kW/m, with potential at specific sites such as Riva and Foça [10--11]. Turkey's geographical location offers environmental benefits and great potential for wave energy. The selection of plant sites and converter types in Turkey is crucial for their development and use [12-13].

PESTLE analysis is a pivotal instrument for evaluating the environmental, social, economic, technological, and legal aspects of a given environment [14-16]. Turkey has significant potential in terms of renewable energy, with solar photovoltaics (PVs) accounting for 4.7% of electricity generation. The country has 9.425 GW of solar power plants installed, with 9353 different types. A PESTLE analysis was conducted to assess Turkey's solar energy potential, with the Konya and Diyarbakır regions identified as promising areas [17]. It offers a comprehensive framework for assessing the potential benefits and drawbacks of various energy sources, such as renewable energy. However, it is imperative to consider external factors when conducting a PESTLE analysis, as it can provide valuable insights into the challenges faced by the renewable energy sector. It is of paramount importance to conduct a comprehensive PESTLE analysis to guarantee the most effective and sustainable utilisation of renewable energy resources [18].

This study employs a PESTLE analysis to evaluate the wave energy potential of Turkey within the context of existing installed capacity, incentives and support. Section II provides an overview of the energy status of Turkey. Section III outlines the incentives for renewable energy in Turkey. Section IV presents an analysis of the wave energy status of Turkey. Section V offers a PESTLE analysis of the potential of wave energy in Turkey. Finally, Section VI presents the conclusion.

**Table 1**. Installed Capacity and Production by Energy Sources [19, 20].

<table>
<tr><th>Fuel Type</th><th>Type</th><th>Installed Capacity (MW)</th><th>12-Month Production (MWh)</th></tr>
<tr><td>Natural Gas</td><td rowspan="10">Nonrenewable</td><td>25,365</td><td>72,601,608</td></tr>
<tr><td>Lng</td><td>2</td><td>0</td></tr>
<tr><td>Lignite</td><td>10,192</td><td>42,351,430</td></tr>
<tr><td>Stone Coal</td><td>841</td><td>3,624,539</td></tr>
<tr><td>Asphaltite Coal</td><td>405</td><td>1,189,215</td></tr>
<tr><td>Imported Coal</td><td>10,374</td><td>68,676,705</td></tr>
<tr><td>Fuel Oil</td><td>260</td><td>1,018,936</td></tr>
<tr><td>Diesel</td><td>1</td><td>1,062</td></tr>
<tr><td>Naphtha</td><td>5</td><td>0</td></tr>
<tr><td>Waste Heat</td><td>389</td><td>764,856</td></tr>
<tr><td>Biomass</td><td rowspan="6">Renewable</td><td>2,031</td><td>6,995,259</td></tr>
<tr><td>Geothermal</td><td>1,691</td><td>11,017,098</td></tr>
<tr><td>Hydro (Dam Type)</td><td>23,282</td><td>39,216,008</td></tr>
<tr><td>Hydro (River Type)</td><td>8,306</td><td>17,833,628</td></tr>
<tr><td>Solar</td><td>10,272</td><td>16,404,345</td></tr>
<tr><td>Wind</td><td>11,566</td><td>34,527,871</td></tr>
<tr><td>Total</td><td>Mix</td><td>104,981</td><td>317,933,574</td></tr>
</table>

## 2. TURKEY ENERGY STATUS

### 2.1. Nonrenewable Energy Sources

As shown in Table 1, Turkey's electricity generation is based on a variety of nonrenewable energy sources, each with a different contribution to the country's energy portfolio. This study describes the installed capacity shares and production contributions of these sources over a 12-month period.

Figure 1 shows the installed capacity by source, whereas Figure 2 shows the 12-month production of the same sources.

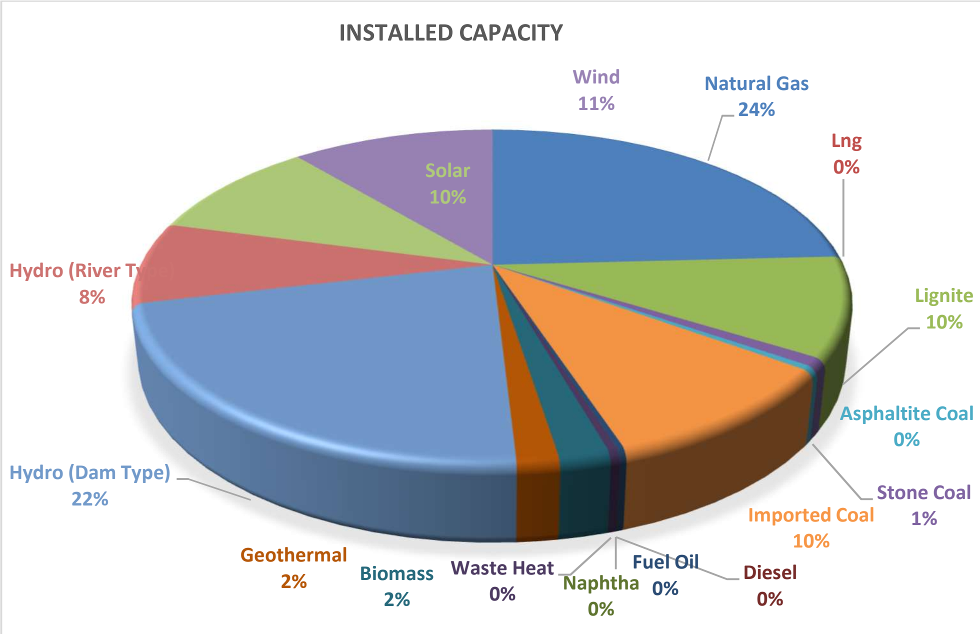


**Figure 1**. Installed capacity by sources [19]

Turkey's electricity generation profile shows a diverse range of nonrenewable energy sources, each playing a different role in the country's energy portfolio. Natural gas emerges as a dominant force, with a significant share of 24.16% of installed capacity and 22.84% of 12-month electricity generation. Lignite, an abundant domestic resource, has a notable share of 9.71% of installed capacity and contributes a substantial 13.32% to total electricity generation, highlighting its key role. Bituminous coal, despite its modest share of installed capacity (0.80%), contributes 1.14% to 12-month electricity production, serving as a complementary energy source. Asphaltitic coal, with a small share of installed capacity (0.39%), makes a limited contribution to production (0.37%), indicating its marginal impact. Imported coal emerges as a significant contributor, with a substantial share of 9.88% of installed capacity and a notable contribution of 21.60% to total 12-month electricity production, which is essential to meet energy demand. Fuel oil, although marginal in terms of installed capacity at 0.25%, contributes a modest 0.32% to total electricity generation. Diesel, with negligible installed capacity, plays an insignificant role in electricity generation. The lack of data on naphtha requires comprehensive assessments to clarify its role and potential impact in the national energy context. Waste heat, despite its limited share of installed capacity (0.37%), plays a niche role by contributing 0.24% to 12-month electricity production, acting as a complementary energy source.

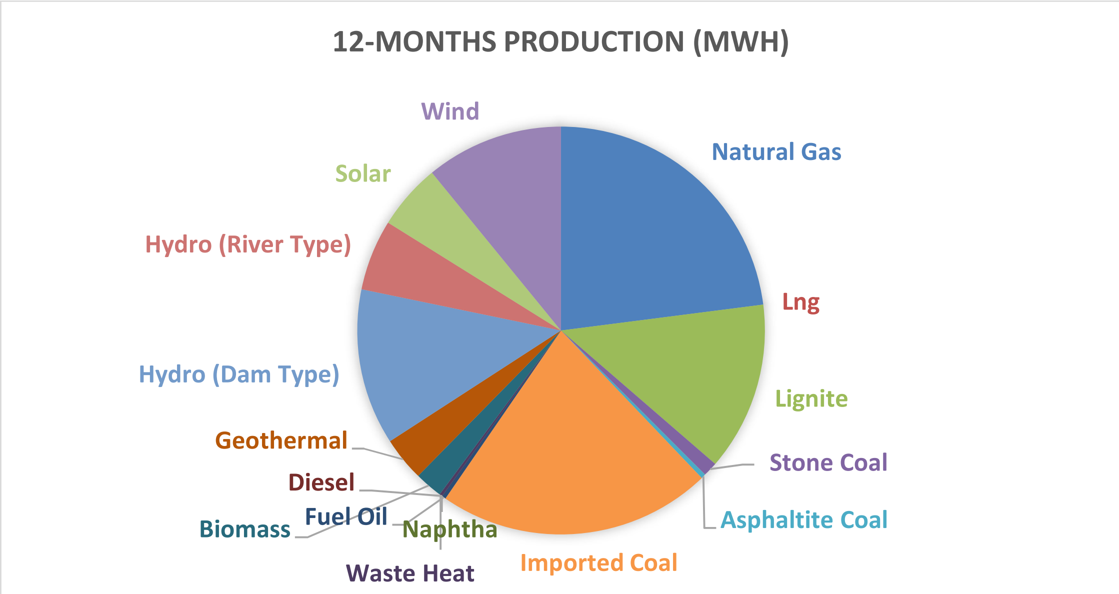


**Figure 2**. Electric energy production rates after sorting for 12 months [20]

### 2.2. Renewable Energy Sources

Table 1 also shows Turkey's electricity generation from diverse renewable energy sources. This study highlights their respective installed capacity shares and production contributions over a 12-month period.

In Turkey's quest for a diversified and sustainable energy portfolio, renewable energy sources play a key role and contribute significantly to the country's electricity generation. Biomass, although having a relatively modest share of installed capacity of 1.93%, contributes 2.20% to the total 12-month electricity production, providing a renewable and environmentally friendly energy alternative. Geothermal energy, which harnesses the Earth's heat, is promising, with an installed capacity share of 1.61% and a notable production contribution of 3.47% over the period considered, indicating significant potential for expansion. Hydropower, mainly from dams, has a dominant share of installed capacity at 22.18%, but its share of production is 12.33%, reflecting the delicate balance between hydropower potential, operational efficiency and environmental considerations. In combination with dam-type plants, river-type plants account for 7.91% of the installed capacity and contribute 5.61% of the total 12-month electricity production. Solar energy, despite a significant share of 9.78% of installed capacity, contributes 5.16% to production, highlighting the intermittent nature of solar resources and the need for technological development. Wind energy stands out with an 11.02% share of installed capacity and a significant production contribution of 10.86%, demonstrating its reliability and growing importance in meeting energy needs. This illustration highlights the complex dynamics of Turkey's renewable energy landscape, which is characterised by resource diversity, technological advancement and political imperatives. Continued investment in renewable energy infrastructure, along with supportive regulatory policies, remains critical to harnessing the abundant renewable resources and promoting sustainable energy development in Turkey.

### 2.3. Total Energy Mix

In assessing Turkey's energy landscape, a comprehensive examination of both nonrenewable and renewable energy sources reveals a nuanced mix of traditional and emerging energy solutions. The nonrenewable segment, which includes natural gas, coal derivatives and oil-based fuels, is a cornerstone of Turkey's energy infrastructure, providing stability and reliability to the national grid. In particular, natural gas holds a pivotal position, dominating both installed capacity and production, whereas imported coal is another significant contributor, reflecting Turkey's reliance on diverse energy resources, both domestic and international. Despite the presence of modest contributors such as fuel oil and diesel, there remains potential for optimisation and diversification within the nonrenewable energy sector to improve overall efficiency and sustainability.

In contrast, renewable energy sources represent a dynamic and expanding segment of Turkey's energy matrix, including biomass, geothermal, hydropower, solar and wind. Despite their comparatively smaller share of installed capacity, renewables collectively make a significant contribution to electricity generation, highlighting Turkey's commitment to sustainability and climate goals. The dominance of hydropower, especially from dams, is noteworthy and underlines the importance of this renewable source in the energy mix. Solar and wind energy, despite their intermittent nature, have considerable potential and require strategic integration and grid management solutions to maximise their effectiveness. Geothermal energy, although modest in terms of installed capacity, shows promising production contributions, indicating continued investment in this renewable resource. The last row of Table 1 shows the total energy mix installed capacity and total production values.

The integration of nonrenewable and renewable energy data presents Turkey with a diverse energy landscape that requires a balanced approach to sustainable development. While nonrenewable sources remain essential to meet immediate energy needs, the growing importance of renewables signals a shift toward a more sustainable and resilient energy ecosystem. To successfully manage this transition, policymakers and stakeholders must prioritise investments in renewable energy infrastructure alongside grid modernisation and energy efficiency initiatives, ensuring alignment with Turkey's long-term development goals while mitigating environmental impacts.

## 3. INCENTIVES FOR RENEWABLE ENERGY IN TURKEY

Wave energy and other renewable energy sources in the Turkish electricity market are not subject to separate legislation. From a legal perspective, the support of wave energy for electricity generation and the promotion of investments in wave energy are usually assessed in conjunction with other forms of renewable energy [21, 22].

Renewable energy legislation and incentives in Turkey are structured around three production and application models: unlicensed, licenced and renewable energy resource area (YEKA) production. Under the unlicensed model, individuals or legal entities can produce electricity without a licence, with the installed capacity increasing from 500 kW to 5 MW as of 9 May 2019 [23-25]. Most power plants with a capacity of 5 MW or more operate under the licenced production model, which requires prelicensing applications for wind and solar plants. Capacity allocation by the Turkish Electricity Transmission Corporation (TEIAS) and public notices are prerequisites for installation [23, 26].

The YEKA model, introduced by the Regulation on Renewable Energy Resource Areas on 9 October 2016, aims to encourage renewable energy investments, increase production, promote the use of local equipment and contribute to research and development activities. The YEKA incentives differ from those of other renewable energy projects, with a duration of 15 years instead of 10 [27].

Governments often establish support mechanisms to encourage the use of renewable energy and meet emission targets. Various incentives are used, including tariff-based incentives, local content support, land supply, net metering and investment incentives.

### 3.1. Tariff-Based Incentives

The first tariff-based incentives were introduced by Law No. 5346. Installations commissioned before 1 January 2021 will benefit for up to 10 years. These tariffs were updated by a presidential decree on 30 January 2021 [23, 30].

### 3.2. Local Content Support

YEKA-licenced plants receive support for local product content, with a minimum of 55% local content required for plants commissioned before 2021. The support is fixed at 8 TL/kWh for five years from 1 July 2021 to 31 December 2025 [30].

### 3.3. Land Supply

State-owned land under the Ministry of Finance can be used for renewable energy production, with an 85% reduction in permit, lease and usage fees for the first ten years, including existing energy transmission lines [24].

### 3.4. Net Metering

Introduced by Law No. 5346, net metering is applied monthly for residential subscribers up to 10 kW and for industrial, commercial and lighting subscribers for rooftop applications. The one-off payment for the excess active energy is valid for ten years from the date of commissioning of the installation [23, 25].

### 3.5. Investment Incentives For Solar and Wind Projects

The incentive scheme is updated periodically and was last amended on 24 February 2022. It provides interest/profit sharing support for solar and wind energy investments within specified regions and contract power limits. Under the latest amendments, industrial and agricultural facilities can invest up to twice the contracted power without interest/profit-sharing support [31-35].

These incentives reflect Turkey's commitment to expanding the use of renewable energy, meeting emissions targets and encouraging domestic production and investment.

## 4. WAVE ENERGY STATUS OF TURKEY

There are no grid-connected wave power plants in operation in Turkey. However, there are pilot studies and experimental studies for measurement purposes. Figure 3 shows the Wave Energy Potential Atlas of Turkey.

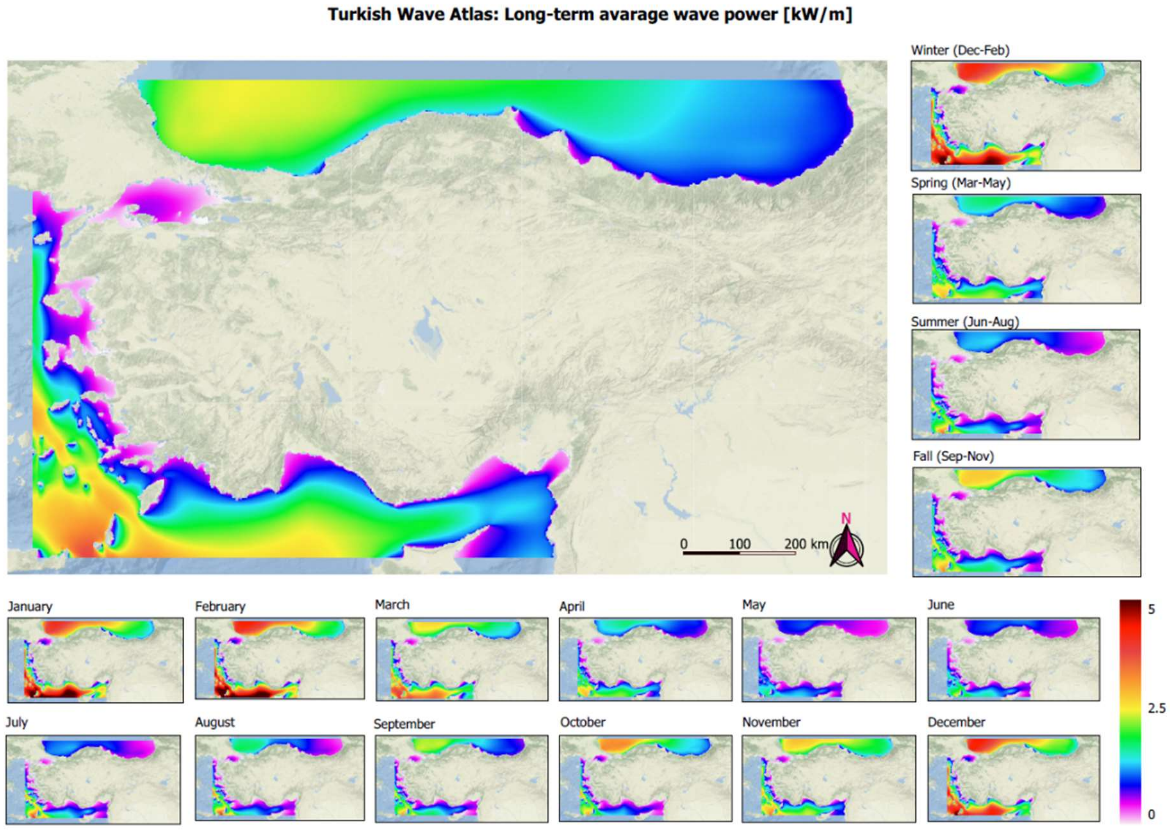


**Figure 3**. Wave Energy Potential Atlas (DEPA) of Turkey [36]

In Turkey's first large-scale wave energy project, OREN Ordu Enerji, a subsidiary of the Ordu Metropolitan Municipality, announced details of the wave energy power plant it plans to build in the city. The 77MW plant is subject to positive results from feasibility studies and obtains the necessary licences and permits. Construction will begin with a 4 megawatt pilot station, followed by the development, maintenance and operation of the remaining 73 megawatts of capacity. With an estimated investment of approximately $150 million, the project will be "Turkey's first grid-connected wave power plant and the world's largest wave power plant when our Ordu facility is completed" [37].

### 4.1. Wave Energy Conversion Technologies

Wave energy conversion technologies are essential for harnessing mechanical energy from ocean waves and converting it into electricity. Various types of wave energy converters have been developed to facilitate this process. These technologies are generally classified into three groups according to their distance from shore [38];

- **Shoreline converters**: Energy-generating installations are installed on or buried beneath coastlines. Compared with alternative converters, they are more straightforward to construct and upkeep. Furthermore, they do not necessitate extensive water connections or lengthy underwater cables. However, the wave regime with lower power results in rather limited generation of wave energy. The proliferation of these converters is hindered by various variables, including coastline geology, tide levels, and concerns over shore protection. For example, oscillating water column (OWC) devices are widely used because of their cost-effectiveness and efficiency [39].
- **Nearshore converters**: These converters are implemented at water depths ranging from 10--25 m, and different OWC designs are used in these systems.
- **Offshore converters**: These converters utilise offshore devices at sea depths above 40 m. These systems necessitate lengthy electrical cables.

Research in this field has highlighted the importance of optimising control strategies for wave energy converters to improve their efficiency. Different control strategies have been proposed, especially for small fixed-referenced wave energy converters, to enhance their energy conversion capabilities [40]. Moreover, advancements in technology have led to the exploration of innovative approaches such as liquid metal magnetohydrodynamic (MHD) generation systems for wave energy conversion, enabling the direct transformation of wave energy into electrical energy [41-42].

## 5. PESTLE ANALYSIS OF THE POTENTIAL OF WAVE ENERGY IN TURKEY

In 2022, Turkey's National Energy Plan was prepared and announced. According to the plan presented by the Ministry for the period 2020--2035, primary energy consumption is projected to increase to 205.3 Mtoe, with electricity consumption reaching 510.5 TWh and its share of final energy consumption reaching 24.9%. Energy intensity is projected to decrease by 35.3%, whereas installed electricity capacity is projected to increase to 189.7 GW, including 52.9 GW of solar energy, 29.6 GW of wind and 7.2 GW of nuclear energy. The share of intermittent renewables in electricity generation is expected to reach 34.2%, with renewables accounting for 54.7%. In addition, flexibility measures include 7.5 GW of battery capacity, 5.0 GW of electrolyser capacity and 1.7 GW of demand response. Taking into account unforeseen events such as global crises and pandemics, further measures can be taken to ensure energy security and meet the needs of the electricity grid [43].

Within the framework of Turkey's National Energy Plan until 2035, the inclusion of wave energy is a strategic imperative to diversify the energy mix, ensure energy security and mitigate the impact of unforeseen global and regional crises such as pandemics, geopolitical tensions and fluctuating energy supply demands.

Integrating wave energy into the national energy plan offers several benefits. First, it contributes to reducing dependence on conventional energy sources, increasing energy diversification and thereby strengthening resilience to supply disruptions. Second, wave energy is a renewable and environmentally sustainable alternative, in line with Turkey's commitments to combat climate change and reduce greenhouse gas emissions. Third, the use of wave energy promotes innovation and technological advancement in the renewable energy sector, stimulating economic growth and creating employment opportunities in research, development and implementation.

A PESTLE analysis examines the political, economic, social, technological, legal and environmental factors that may affect a particular industry or sector. In the case of Turkey's wave energy potential, this study adapts the analysis to focus specifically on the wave energy potential.

### 5.1. Political Factors

#### 5.1.1. Government policies and regulations

Turkey's regulatory framework for renewable energy, including wave energy, is comprehensive and structured to encourage the development of different production models. These models include the unlicensed model, the licenced model and the Renewable Energy Resource Areas (YEKA) model, each offering different opportunities for investors [21-22,25-26]. The unlicensed model permits individuals and entities to generate electricity without a licence, whereas the licenced model applies to power plants with a capacity exceeding 5 MW. The YEKA model encourages investment in renewable energy, promotes the use of local equipment, and supports research and development. Turkey offers a range of incentives for renewable energy investments, including fixed tariffs for facilities commissioned before 1 January 2021, local content support programmes, state-owned land, net metering schemes, and investment incentives for solar and wind projects [30-34].

#### 5.1.2. Political support and stakeholder engagement

Turkey is integrating wave energy into its renewable energy strategies, recognising its potential contribution to the energy landscape. The YEKA program incentivises investment in wave energy projects, increasing their viability within Turkey's energy framework. Despite political risks and uncertainties, Turkey's commitment to sustainable energy development is evident through collaborative engagement, adherence to targets, and strategic integration into national plans.

### 5.2. Economic Factors

#### 5.2.1. Investment environment

Turkey's commitment to renewable energy, particularly in the emerging wave energy sector, is backed by legislative incentives and government initiatives. The regulatory framework offers flexibility and opportunities for investment, with unlicensed, licenced, and YEKA production models providing attractive opportunities. However, challenges such as regulatory uncertainties and permitting issues may persist. Turkey's wave energy projects must demonstrate economic viability compared with conventional sources, highlighting its potential for sustainable energy development.

#### 5.2.2. Market dynamics and demand

Turkey's growing demand for sustainable energy solutions presents opportunities for the integration of wave energy technologies. By strategically investing in and implementing a supportive regulatory framework, Turkey can accelerate wave energy adoption and position itself as a leader in marine renewable energy. The country's electricity market operates liberally, with feed-in tariffs encouraging renewable energy use. However, challenges such as grid integration and competition from other renewable sources remain. Innovative solutions and collaborative stakeholder engagement are needed to overcome these barriers and harness wave energy potential.

### 5.3. Social Factors

#### 5.3.1. Public perception and acceptance

Understanding public attitudes and addressing concerns through stakeholder engagement and environmental impact assessment is critical to the successful integration of wave energy. Effective strategies involve involving local communities and environmental groups from the outset of a project and fostering cooperation and trust, which ultimately increases the legitimacy of the project. In addition, assessing social benefits is crucial, as wave energy projects can provide benefits such as job creation, community empowerment and local economic development, in line with Turkey's socioeconomic objectives. By prioritising stakeholder engagement and recognising social benefits, Turkey can more effectively address potential challenges and build support for sustainable wave energy initiatives.

#### 5.3.2. Stakeholder collaboration

Stakeholder interests and concerns highlight the importance of working with a wide range of stakeholders, including local communities and industry players, to ensure that wave energy projects succeed. The implementation of inclusive consultation mechanisms and participatory decision-making frameworks is essential to promote transparency and foster sustainable partnerships. Turkey's commitment to renewable energy, including wave energy, is evident through its supportive policies and collaborative efforts. To fully realise the potential of wave energy in Turkey's energy transition, addressing economic, political and social factors through stakeholder engagement and strategic investment remains paramount.

### 5.4. Technological Factors

#### 5.4.1. Research and development

Turkey is fostering a dynamic landscape in wave energy conversion technologies, with research institutions, universities, and private companies exploring various concepts such as oscillating water columns, point absorbers, and attenuators. The focus is on improving device efficiency, reliability, and survivability in harsh marine environments. Technical challenges such as mooring systems, wave-grid integration, and maintenance strategies are being addressed to improve performance and cost-effectiveness. Collaboration among academia, industry, and the government is essential for technology commercialisation and market adoption, leading Turkey toward a sustainable wave energy future.

#### 5.4.2. Infrastructure and grid integration

Assessing the infrastructure requirements and grid integration challenges of wave energy projects highlights the multifaceted nature of this renewable energy source. The wave energy infrastructure comprises various components, including wave energy converters (WECs), grid connection systems and onshore/offshore devices, each of which requires careful consideration in terms of design, deployment and operation. Wave energy is by nature intermittent, making grid integration difficult. Advanced control algorithms, energy storage solutions and grid reinforcement measures are needed to ensure stability and reliability. In addition, compliance with grid connection standards is essential to ensure interoperability and security across different projects and grid environments, thereby facilitating market growth and technology adoption. Financing mechanisms such as grants and public–private partnerships, together with a supportive regulatory framework, play a key role in encouraging investment, streamlining project development processes and catalysing the growth of the wave energy industry in Turkey.

### 5.5. Legal Factors

#### 5.5.1. Regulatory framework

Turkey's regulations for wave energy development include licensing, permitting, environmental impact assessment (EIA), and land use guidelines. Licensing ensures that safety, environmental, and technical standards are met while permitting permitting site selection to minimise environmental impact. EIAs assess environmental risks and propose mitigation measures. Land use regulations balance conservation and development interests. Legal risks and compliance requirements are critical, with international legal frameworks influencing Turkey's wave energy development. Adherence to international standards ensures alignment with best practices and environmental protection goals. Understanding and navigating the regulatory framework is crucial for sustainable development.

#### 5.5.2. Policy support and incentives

Government policies and incentives are key to driving wave energy investment in Turkey, with mechanisms such as feed-in tariffs (FITs) providing stable revenues and tax incentives reducing project costs. However, regulatory uncertainties and market challenges hamper the sector's growth. Streamlining regulations, upgrading grid infrastructure and improving technology readiness are essential, along with strengthening stakeholder engagement and capacity building. In conclusion, policy recommendations, regulatory reforms and capacity-building initiatives are essential for Turkey's wave energy sector to realise its potential for a sustainable energy future.

### 5.6. Environmental Factors

#### 5.6.1. Environmental impact assessment

Assessing the environmental impacts of wave energy projects, including potential effects on marine ecosystems, coastal habitats and biodiversity, can identify risks such as noise pollution, habitat alteration and collision hazards. Measures such as comprehensive site assessments, low-noise technology and stakeholder engagement can mitigate these impacts and ensure sustainable development in line with regulations and international standards.

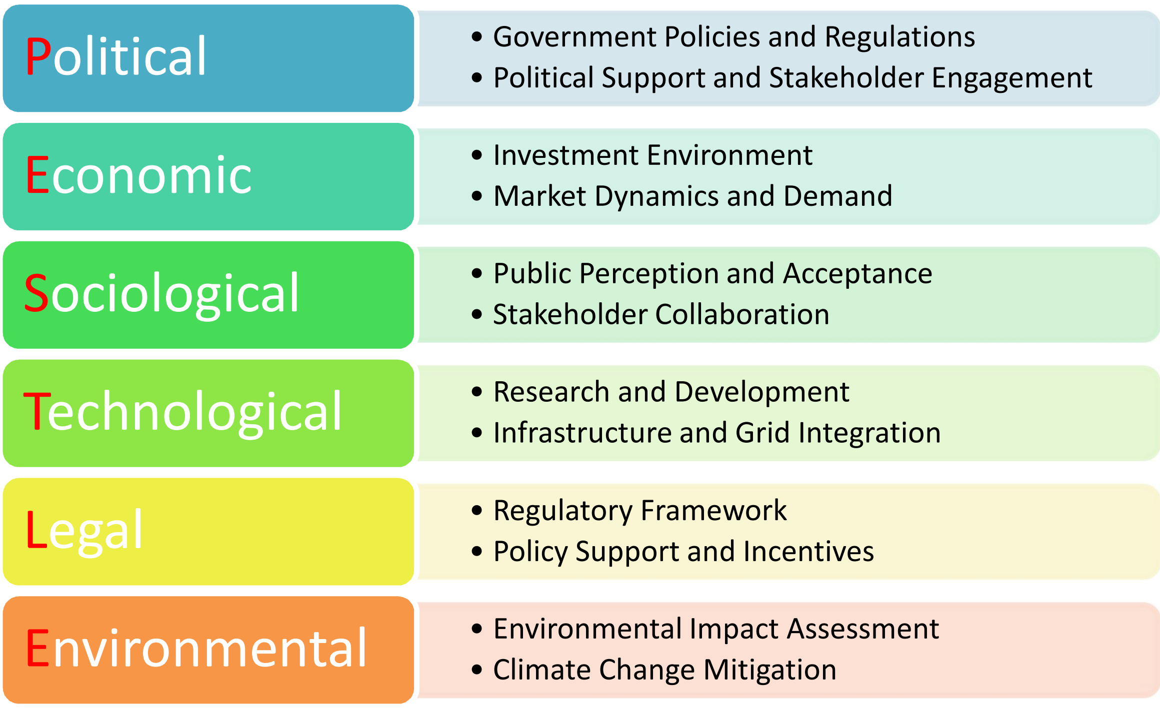


**Figure 4**. Turkey wave energy PESTLE analysis

#### 5.6.2. Climate change mitigation

The role of wave energy in mitigating the effects of climate change and promoting a low-carbon energy transition lies in its ability to reduce greenhouse gas emissions and diversify energy sources. Cobenefits such as improved air quality and resilience to climate-related hazards further enhance its contribution to environmental protection and public health. Aligning with renewable energy targets and climate change adaptation strategies will ensure that wave energy development in Turkey supports national commitments and promotes sustainable development in the face of climate change.

This PESTLE analysis provides a comprehensive understanding of the various factors influencing Turkey's wave energy potential, covering political, economic, social, technological, legal and environmental dimensions. By systematically assessing these factors, policy makers, investors and stakeholders can develop informed strategies and policies to promote sustainable wave energy development in Turkey. Figure 4 shows a summary of the PESTLE analysis.

## 6. CONCLUSION

In conclusion, a framework of political, economic, social, technological, legal and environmental factors positions Turkey's wave energy potential to play a significant role in the country's transition to renewable energy. The government's comprehensive regulatory structure, including various production models and incentives, demonstrates its commitment to promoting the development of renewable energy, including wave energy. Collaborative efforts among stakeholders, including government agencies, industry players and research institutions, facilitate knowledge sharing and technological advancement, which are essential for sustainable energy growth.

Despite the lack of grid-connected wave energy devices to date, pilot studies and test projects have shown progress in harnessing this renewable resource. The proposed OREN Ordu Enerji project, with its ambitious capacity and investment plans, highlights the potential for wave energy to make a significant contribution to Turkey's energy mix. However, challenges remain, including regulatory uncertainties, technological readiness and environmental considerations. Overcoming these challenges will require continued investment in research and development, infrastructure development and stakeholder engagement. Ensuring social acceptance and environmental sustainability through transparent decision-making and thorough impact assessments is critical to the successful deployment of wave energy projects.

PESTLE analysis reveals various factors influencing Turkey's wave energy potential, including political, economic, social, technological, legal and environmental considerations. Collaborative efforts between government agencies, industry stakeholders and research institutions are critical for addressing regulatory uncertainties, encouraging investment and advancing technology readiness in the wave energy sector. In addition, stakeholder engagement, environmental impact assessments and compliance with international standards are essential to ensure sustainable development and mitigate potential risks associated with wave energy projects.

Turkey is poised to capitalise on its wave energy potential, leveraging its diverse energy portfolio and supportive regulatory environment to move towards a more sustainable and resilient energy future. By harnessing the power of waves, Turkey can reduce its dependence on fossil fuels, mitigate the effects of climate change, and promote economic development while ensuring energy security for future generations.

## NOMENCLATURE

| | |
|---|---|
| LCOE | levelised cost of energy |
| PVs | solar photovoltaics |
| YEKA | renewable energy resource area |
| TEIAS | Turkish Electricity Transmission Corporation |
| DEPA | wave energy potential atlas |
| OWC | oscillating water column |
| MHD | magnetohydrodynamic |
| WECs | wave energy converters |
| EIA | environmental impact assessment |
| FITs | feed-in tariffs |

## DECLARATION OF ETHICAL STANDARDS

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

## CONTRIBUTION OF THE AUTHORS

**Mehmet Çeçen:** Conceptualization, Analysis; Methodology; Visualization; Writing; Editing.

## CONFLICT OF INTEREST

There is no conflict of interest in this study.

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