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RENEWABLE ENERGY SCENARIO IN ELECTRICITY SYSTEM FOR ISPARTA PROVINCE THE YEAR 2030

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ABSTRACT: In recent years, many challenges have emerged globally, such as climate change, energy supply security, and air pollution. The biggest reason for these problems is increased energy demand and the dependence on fossil fuels for energy. Increasing concerns about the adverse effects of fossil fuels have led to increased investments in renewable energy sources for electricity generation. While the transition to 100% renewable energy systems continues, there are also concerns about sustainability, cost and storage areas. In this study, energy planning for 2030 for the province of Isparta was carried out using the EnergyPLAN program. In the energy scenario of 2030, biomass was used to ensure sustainability by accepting the energy balance. A methodology for technical and economic modeling of 100% renewable energy systems in 2030 was presented. The results showed that the CO_2 emission amount, 0.231 Mt in 2020, decreased to 0.096 Mt by 2030 year. It has been seen that the adverse effects of fossil fuels can be eliminated with the increase in the use of renewable energy systems. As a result of the study, it has been shown that the transition to 100% renewable energy systems for the year 2030 in Isparta province can be realized theoretically.

Keywords: 100% renewable energy systems, EnergyPLAN, Energy modelling

1. INTRODUCTION

Global energy demand is rapidly increasing and is mainly met by fossil energy sources. Due to the limited availability of fossil fuels and their negative effect on the environment, significant changes in energy systems and new approaches are needed to meet the world's increasing energy demand without harming the environment, society, the economy, and the well-being of future populations. To reduce and eliminate these negative impacts, it is necessary to increase the use of renewable energy sources and to use existing energy efficiently. [1].

Energy systems should be designed with regional energy sources in mind. In addition, they should be able to meet the region's various energy needs (electricity, heating, cooling, etc.). Since renewable energy sources are intermittent, the energy system must have energy storage and different energy sources. The energy system should ensure the use of waste heat and utilize renewable energy sources in the most efficient way for a carbon neutral future. [2]. At the same time, the planned energy system should allow energy management. Therefore, the energy system should have renewable energy sources, smart energy grids, energy conversion technologies, energy storage technologies, energy management, and different outputs [2]. The energy systems of the future should include these features and be sustainable energy systems [3]. Many factors negatively affect the transition process to renewable energy systems. The most important factors affecting this process are integrating renewable energy into existing systems and ensuring sustainability. Technical analysis is necessary to obtain this information. Practical and easily accessible software tools are preferred because it is difficult to integrate renewable energy sources and create a specific model for each integration in the technical analysis [4]. Many analysis tools such as EnergyPLAN, LEAP, SAM, and Pvsyst are used for energy modeling [5–8].

Lund and Mathiesen [9] have created scenarios for Denmark to switch to 100% renewable energy systems for two years. The detailed system design was carried out in the scenarios. They created the scenarios of 2030 year with a 50% renewable energy system consisting of biomass, wind, wave, and solar energy combinations, and 2050 year with a 100% renewable energy system. As a result, they found that 100% renewable energy supply based on domestic sources is physically possible. Connoly et al. [10] present different scenarios for Ireland's 100% renewable energy system. In this study created scenarios by considering the energy system's electricity, heat and transportation sectors. Next, they modeled three different (biomass, hydrogen, and electricity) 100% renewable energy systems, each focusing on a different source. According to the scenarios created for Ireland, they have obtained results showing that they can switch to 100% renewable energy systems in the future. Emre Leblecioglu et al. [11] created a 50% renewable energy system simulation for 2023 year for Turkey in their study. The main objective of this study is to use 50% renewable energy in electricity generation. They analyzed the 2018 and 2023 year scenarios regarding renewable energy share, CO_2 emissions, and costs. As a result of the study, it was determined that with the increase in the installed power of renewable energy systems, the CO_2 emission decreased, and it required a high cost.

Menapace et al. [12] have designed 100% smart renewable energy systems for the city of Bolzano. In this study, a new methodology for proper planning of urban energy systems is proposed to achieve 100% renewable smart energy systems. In another study, Icaza et al. [13] models a 100% renewable energy system for the year 2050 for the city of Cuenca in Ecuador. Again, through software tools, transition processes to 100% renewable energy systems have been simulated in many countries and cities [14], [15]. There are few studies on renewable energy systems for the province of Isparta [16-19]. These studies are related to the determination of wind and solar energy potential of Isparta province. However, in reviewing the literature, no modeling study was found in which 100% of the energy demand of Isparta province will be met by renewable energy sources in the coming years.

The ultimate goal of this study is to investigate technically and economically the scenario in which the electricity demand in 2030 is met by 100% renewable energy sources, with the addition of additional renewable energy sources to the existing electricity system in Isparta. The sources added to the existing system in this study are given below:

- Solar power capacity
- Wind power capacity
- Biomass energy capacity
- Hydropower capacity

The EnergyPLAN program is used to first analyze the electricity system of the current reference year and then to increase the capacities of the renewable energy system for the scenario of the year 2030. The contribution of this study includes:

- Modeling the current electricity system of Isparta to determine the deficit in electricity consumption.
- Increase the potential of using renewable energy sources to solve the electricity problem of Isparta province.
- Ending the use of fossil fuels and reducing carbon emissions in Isparta Province.
- Meeting the electricity consumption in Isparta province in 2030 from 100% renewable energy sources.

Although this study aims to solve the electricity problem of Isparta, the transmission and distribution network is not examined in this study. The work flow diagram is shown in Figure 1.

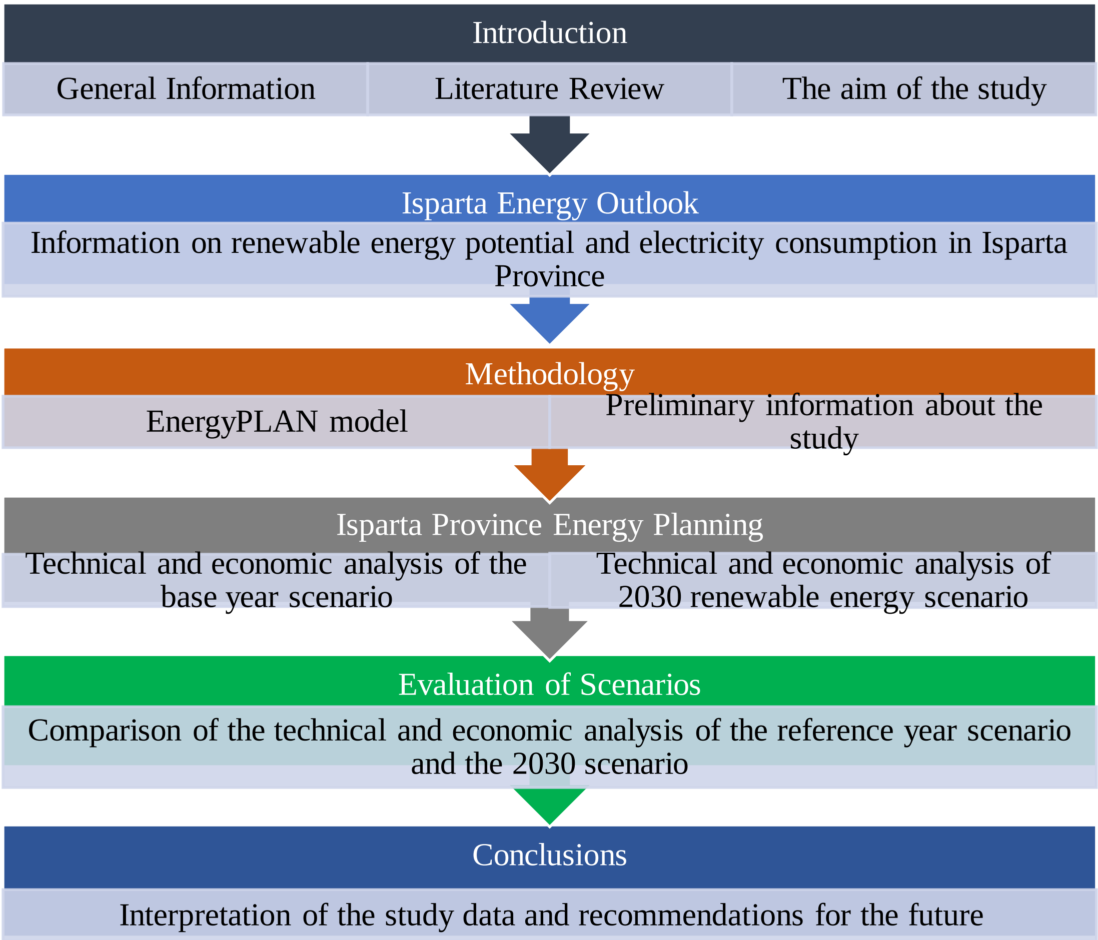

Figure 1. Article flow diagram

2. ISPARTA ENERGY OUTLOOK

Turkey's energy demand is increasing every year, and a large part of this demand is met by fossil fuels. This situation increases Turkey's dependence on foreign energy. To reduce the dependence on foreign energy and the use of fossil fuels, studies on renewable energy sources are conducted [20-22]. According to these studies, it is seen that Turkey is a country rich in renewable energy sources such as hydropower energy, solar, wind, biomass and geothermal

[23]. Research on renewable energy sources is conducted at both national and regional levels. The province of Isparta is located in the Mediterranean region, in the transition zone between the continental and Mediterranean climates. The summers are hot and dry, and the winters are cold and rainy. Isparta province is one of the provinces with high renewable energy potential due to its geographical location. According to the wind energy potential atlas report prepared in the electrical works study department, it is stated that the wind speed should be 7 m/sec in the field for wind energy to be a low-cost investment in Isparta province [16]. Figure 2 shows the wind speed distribution in Isparta province.

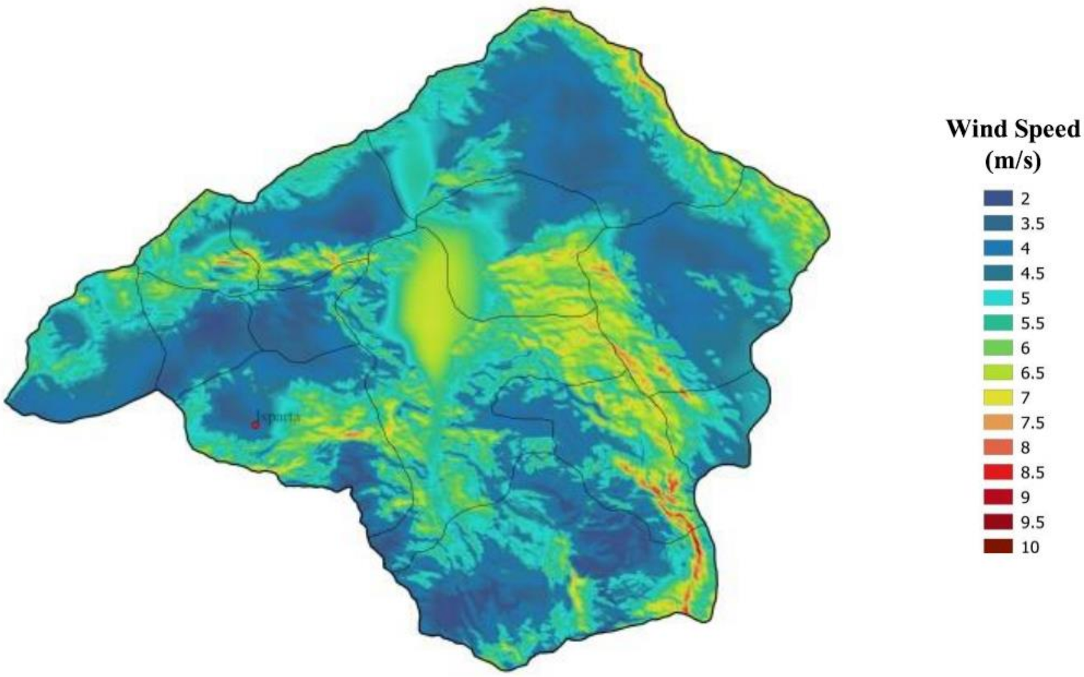

Figure 2. Wind speed distribution map of Isparta province [24].

Isparta is one of the provinces with great potential for solar energy in Turkey. In Isparta province, the average annual sunshine duration is 2858 hours and the average annual solar energy potential is 1,612 KWh/m^2-year [25]. Figure 3 shows the solar radiation map of Isparta province.

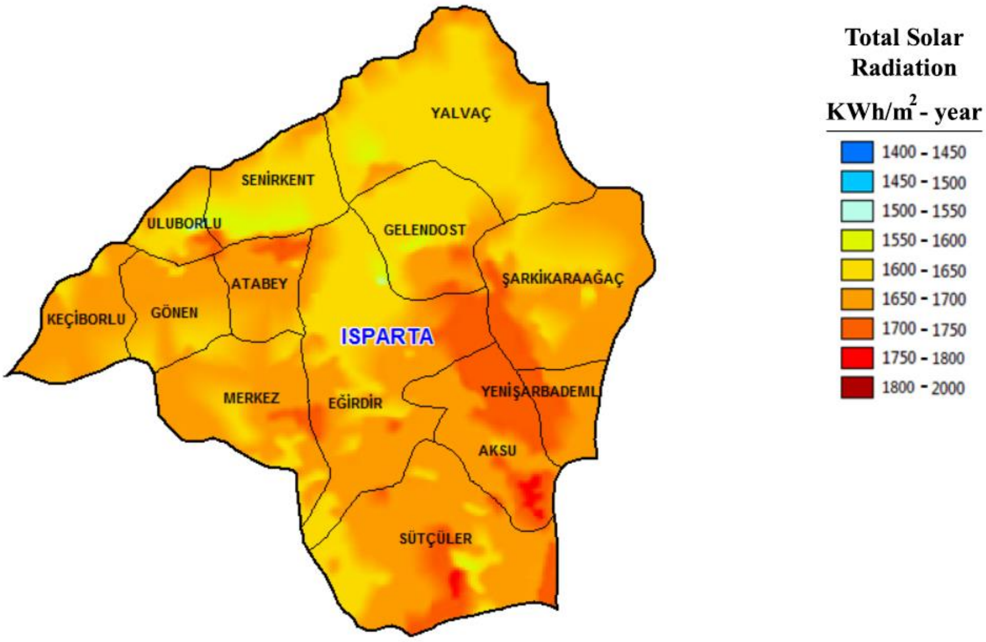

Figure 3. Solar radiation map of Isparta province [25].

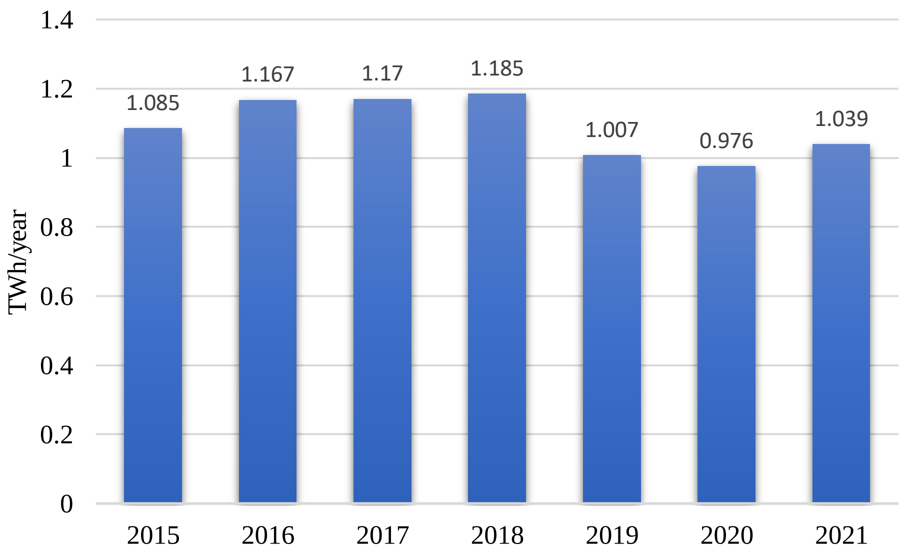

Figure 4. Electricity consumption amount between 2015-2021 in Isparta province [26].

As can be seen in Figure 4, new energy sources are needed to meet the changing demand for electricity. It is important to meet these electricity needs from local and renewable energy sources to reduce dependence on foreign energy, minimize environmental damage, and be cost effective. Figure 5 shows the estimated electricity consumption for Isparta province until 2030, according to the estimated demand reports of the Turkish Electricity Distribution Company.

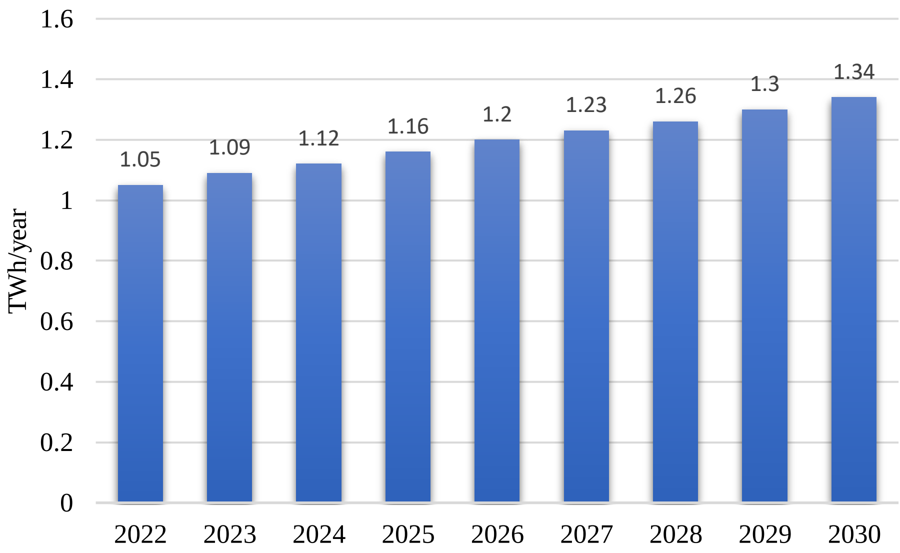

Figure 5. Estimated electricity consumption in Isparta province between 2022 and 2030 [27].

Looking at the estimated electricity consumption data, the annual electricity demand of Isparta province is increasing until 2030. In 2030, as modeled in this study, the electricity consumption is expected to be 1.34 TWh/year, an increase of 37% [27].

3. METHODOLOGY

In this study, the EnergyPLAN program, one of the modeling tools commonly used in the literature, was used for the transition to renewable energy. EnergyPLAN is a program that was developed at Aalborg University in Denmark in 1999. EnergyPLAN is a program that simulates the operation of national energy systems hourly, including the electricity, heating, cooling, industry, and transport sectors. EnergyPLAN is a user-friendly tool consisting of a series of tabs. The main aim of the tool is to support in the development of national or regional energy planning strategies by simulating the entire energy system. All thermal, renewable, storage and conversion systems, as well as transportation and costs (with additional cost option) can be modeled with EnergyPLAN. It is a decisive input/output tool. General inputs; demands, renewable energy sources, power station capacities, costs, and different regulatory strategies for import/export and surplus electricity generation. Outputs are energy balances and the resulting annual productions, electricity imports/exports, fuel consumption, and total costs, including income from electricity exchange. Finally, EnergyPLAN optimizes the operation of a given system, as opposed to tools that optimize investments in the system [28]. Figure 6 shows the main inputs and outputs of the EnergyPLAN model.

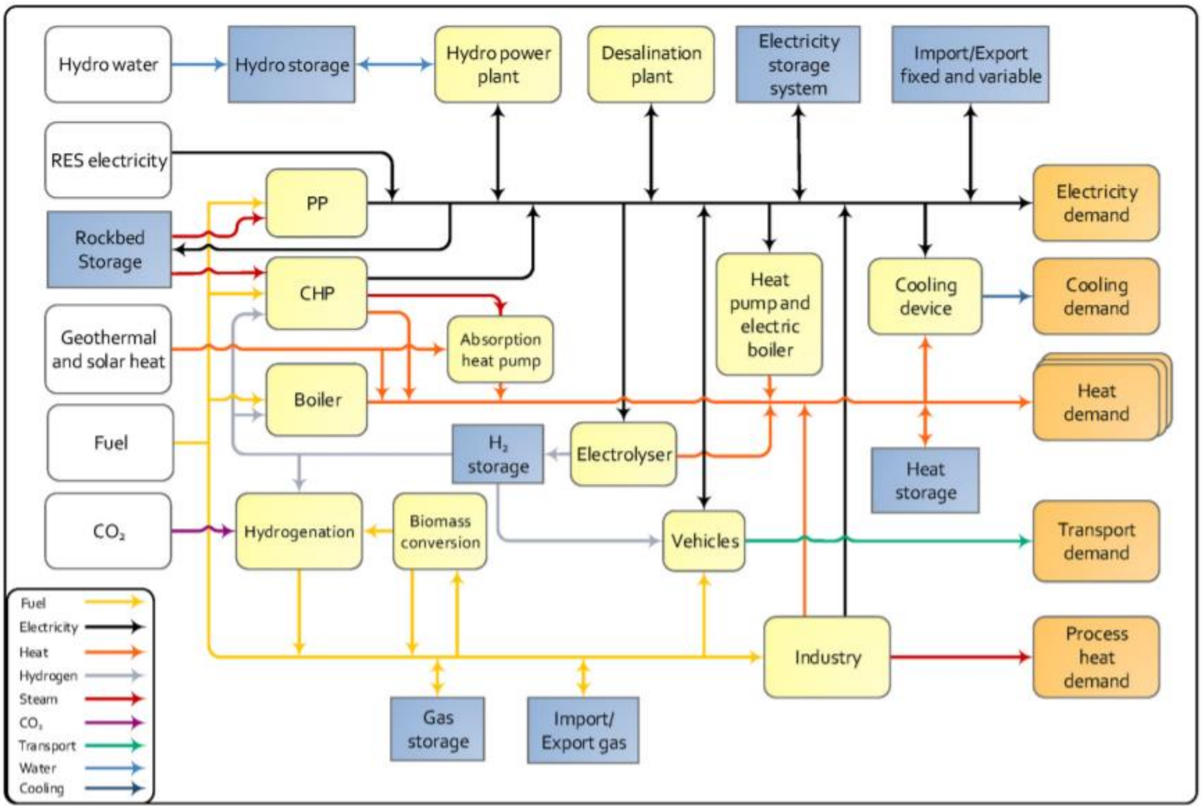

Figure 6. Structure of the EnergyPLAN model [28].

Before the models were created, a reference model was created to accurately analyze and compare Isparta's energy system The year 2020 was chosen as the reference due to actual data availability. A scenario was created for the reference year. The data obtained for the reference state created in the EnergyPLAN program were compared with the actual data. As a result of the comparison, it was determined that the error margin of the program was 3% on average. According to the literature, the reference situation created in EnergyPlan reflects the actual situation with an acceptable error rate. With this result, it has been shown that the EnergyPlan program can be used in energy system modeling in the coming years. After proving the accuracy of the reference model, the scenario for the year 2030 was created for Isparta province. This study aims to evaluate the technical and economic aspects of the modeling, which envisions that the electricity system of the province of Isparta will be powered by 100% renewable energy. For the scenario of the year 2030, some assumptions were made about the energy demand and supply capacities, and the renewable energy potentials were examined. Biomass potential has been investigated to ensure sustainability.

4. ISPARTA PROVINCE ENERGY PLANNING

4.1. 2020 Reference Scenario and Validation

In 2020, Isparta's electricity consumption was 0.976 TWh/year and electricity generation was 0.684 TWh/year. Of this, 0.284 TWh/year was generated by hydropower, 0.241 TWh/year by solar power, and 0.159 TWh/year by wind power plants. The remaining 0.292 TWh/year of Isparta's energy demand were met by fossil fuel power plants from various regions. The installed power capacity of Isparta is 422.83 MW in 2020. Of this capacity, 270.83 MW is from licensed installed power plants (hydro, solar, wind, biomass, etc.) and 152 MW is from unlicensed installed solar power plants. [26].

The reference energy model is the current energy system for the year 2020, and the main aim of this model is to compare it with the scenario created for the year 2030. The energy data for the year 2020 were taken from the Energy Market Development Authority (EPDK) and the Electricity Market Operation Joint Stock Company (EPIAS) and adapted to the format of the EnergyPLAN program [26], [29]. The EnergyPLAN software analyzes installed power capacities and hourly data to obtain the most realistic average output. The electricity demand in 2020 is 0.98 TWh/year. According to the sources, the installed power capacities of Isparta in 2020 are shown in Figure 7.

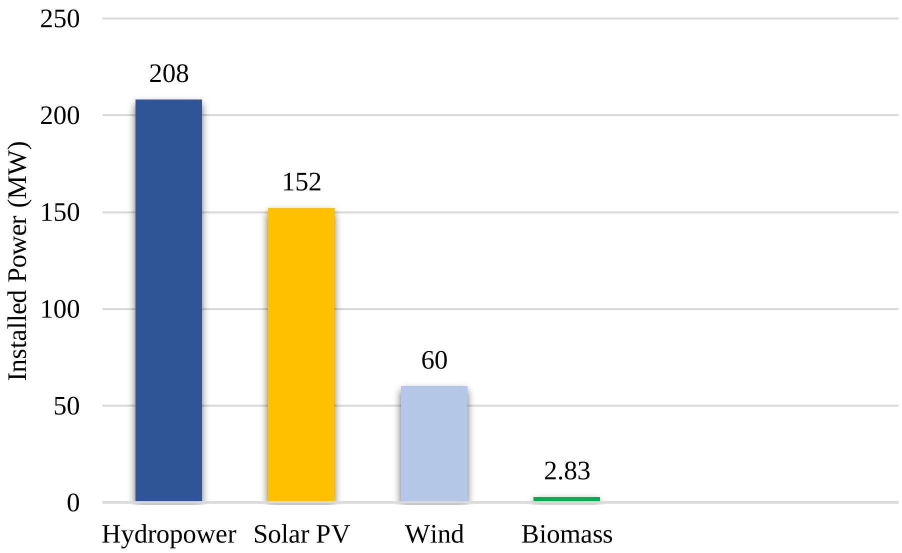

Figure 7. Installed power plant in Isparta province in 2020 [26].

As can be seen in Figure 7, according to the sources, the installed electricity capacities in 2020 are composed of 208 MW hydropower, 152 MW solar, 60 MW wind, and 2.83 MW biomass power plants. The main purpose of the reference scenario is to validate the model against its actual operation in 2020 and compare it to the year 2030 scenario. The model created in EnergyPLAN was compared with the technical data obtained from EPDK and EPIAS. The result of the comparison is shown in Table 1.

Table 1. Comparison of actual data and EnergyPLAN Data.

Consumption and production	EPIAS and EPDK Data (TWh/year)	EnergyPLAN Data (TWh/year)	Difference
Consumption	0,976	0,980	%0.41
Hydropower	0,284	0,290	%1.38
Solar PV	0,241	0,250	%3.6
Wind	0,157	0,160	%1.87
Naturel Gas-Coal	0,292	0,280	%4.1

As can be seen in Table 1, the differences between the results obtained by the EnergyPLAN software and those obtained by EPIAŞ and EPDK are acceptable. The results show the usefulness of the EnergyPLAN model for the technical simulation of the electric system, the technical analysis of the 100% renewable electricity system and its validity in studying its effects. In addition to the technical analysis of the electricity system, it is also necessary to make an economic analysis. The estimated costs of the capacity of the power system in Isparta was determined in the EnergyPLAN software using average values. While performing the cost analysis, the installed power plant costs, operation-maintenance costs, and percentage rates in 2020 were used. Fixed operating costs are costs such as employee salaries, facility overhead and scheduled maintenance. Variable operating costs include fuel, water, chemicals, energy, catalysts, and waste generated at the plant, etc. costs include.

Table 2. 2020 Power Plant Prices [30].

Sources	Installed Cost (USD/kW)	Fixed Operation and Maintenance Cost (USD/kW)	Fixed Operational Maintenance Cost (%)
Hydropower	1870	40	%1,5
Solar PV	793	13	%1,1
Wind	1600	26	%2
Naturel Gas	670	11	%1,2
Coal	3500	40	%1,1
Biomass	2850	125	%3

The average unit costs of the power plants are shown in Table 2. These values are defined in the EnergyPLAN program for the calculation of the reference scenario costs.

Table 3. Reference scenario cost table.

Costs	Quantity (MUSD)
Variable Costs	67
Fixed Operating Costs	9
Investment Cost	613
Total Cost	689

The costs in Table 3 are calculated using the installed power plant and operation maintenance costs according to the sources. The values were entered into EnergyPLAN software, and the cost for all power plants installed in Isparta province in 2020 was calculated as 689 MUSD (Million United States dollar).

4.2. Renewable Energy Scenario For 2030

An electricity system scenario for the year 2030 was prepared for the province of Isparta. While making regional energy modeling for 2030, some assumptions were made. These assumptions are listed below:

• Estimated electricity consumption data from TEIAS for Isparta Province the year 2030.
• No electricity imports.
• Increase in source capacity according to the potential of the energy source.
• Calculation of sustainable biomass amount.

In this scenario, renewable energy capacity was increased by reducing fossil fuel electricity generation and using regional sources. When it comes to the year 2030 of Isparta province, the production capacity of the existing system has been ensured to meet the demand Figure 8 shows the estimated installed capacity of power plants in Isparta province for the year 2030. The 2030 scenario is designed to meet this year's electricity demand entirely from local and renewable sources. The power plant capacities have been increased. As a result of the research, while the highest increase in installed power occurred in solar energy, the highest increase in percentage was realized in biomass energy.

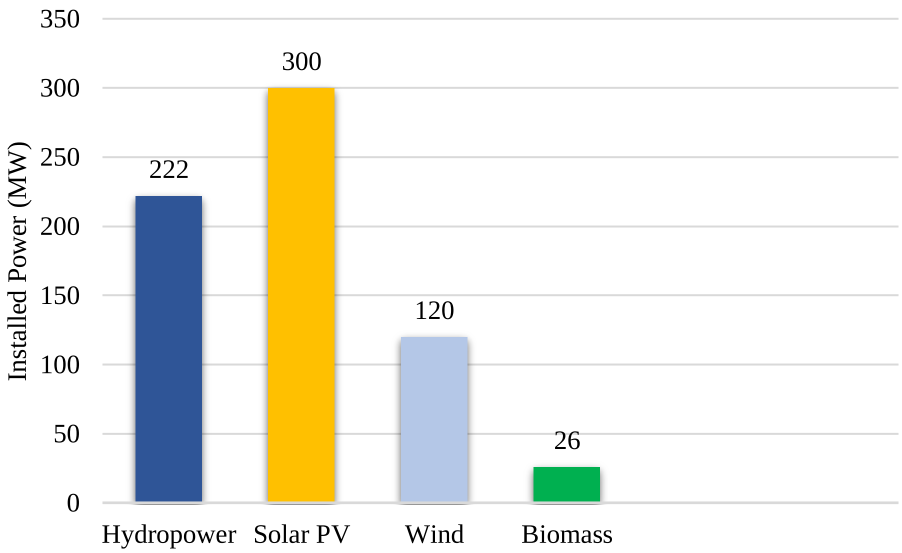

Figure 8. Estimated installed power of Isparta province in 2030.

The increase in hydroelectric power plants has been realized by adding the power plants under construction or built. The increase in capacity of solar, wind and biomass energies was increased using realistic approaches and taking into account environmental (area and duration of installation), social and economic (installation, maintenance and operating costs) data, apart from the power plants under construction or planned. In the scenario created for 2030, the assumptions above were made using completely local and renewable energy sources.

Table 4. Electricity production and estimated electricity consumption by sources in 2030.

Supply and demand	Production and Consumption data for 2030 (TWh/year)
Electricity Consumption Demand	1,34
Hydropower	0,40
Solar PV	0,48
Wind	0,32
Biomass	0,14

Table 4 gives the annual estimated amount of produced electricity according to the sources in the 100% renewable energy scenario. As a result, since the existing power plants meet all the electricity needs, the import of electricity from outside has been terminated.

Table 5. Prices of Power Plants [31].

Sources	Installed Cost (USD/kW)	Fixed Operation and Maintenance Cost (USD/kW)	Fixed Operational Maintenance Cost (%)
Hydropower	1269	40	%1,5
Solar PV	572	13	%1,1
Wind	1355	26	%2
Biomass	2543	125	%3

After performing the technical analysis, the economic analysis of 2030 was made. For the transition to 100% renewable energy, a new power plant capacity of 249 MW was installed in addition to the existing capacity. The increase in installed power capacity causes new investment costs. The unit costs are shown in Table 5, and the investment costs of newly established power plants have been calculated. A total investment cost of approximately 325 MUSD is required to establish a 249 MW power plant.

5. EVALUATION OF SCENARIOS

In this study, only the part of the EnergyPLAN software that includes the technical and economic analysis of the electric system was used. A reference scenario and a 100% renewable energy scenario for 2030 were made for the electricity system. A comparison of the two scenarios is given in Table 6.

Table 6. Comparison of the capacities created in the scenarios.

Sources	Reference Scenario (MW)	Renewable Energy Scenario for 2030 (MW)	Difference (%)
Hydropower	208	222	%6.7
Solar PV	152	300	%97.3
Wind	60	120	%100
Biomass	2,83	26	%818
Naturel Gas-Coal	59	0	-%100

As shown in Table 6, increases have occurred in hydropower, solar, wind, and biomass power plants. The electricity system of Isparta province is 100% renewable and based on local sources. In the reference scenario created for 2020, electricity produced from renewable energy corresponds to 0.684 TWh/year, 70% of the total electricity produced, while the amount of electricity produced from renewable energy for 2030 constitutes 100% with 1.34 TWh/year. In addition, the fossil fuel capacity shown in the reference scenario in Table 6 indicates the capacity required to meet the amount of electricity imported in 2020. In Figure 9 and Figure 10 show the distribution of total daily electricity generated from renewables energy by sources for the reference year and the year 2030 scenario.

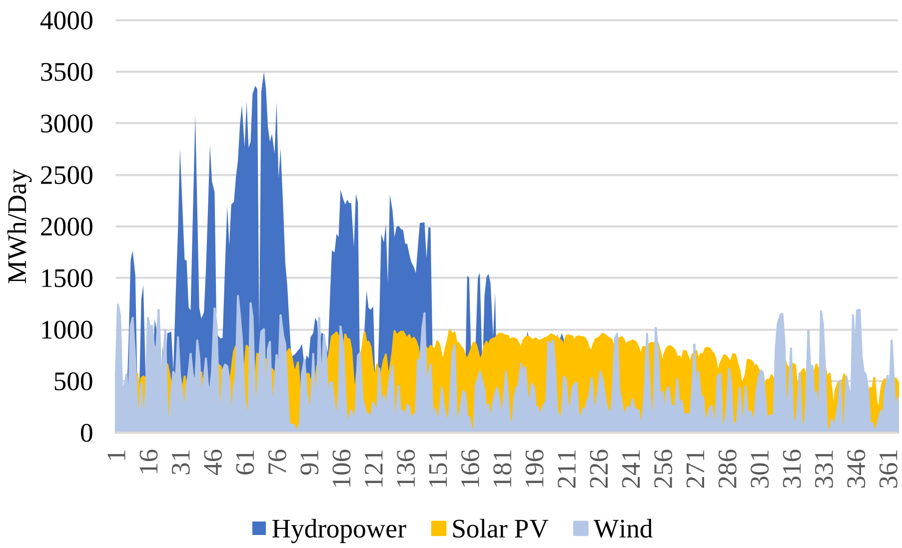

Figure 9. Distribution of daily electricity generation by sources for 2020 in Isparta province. [29].

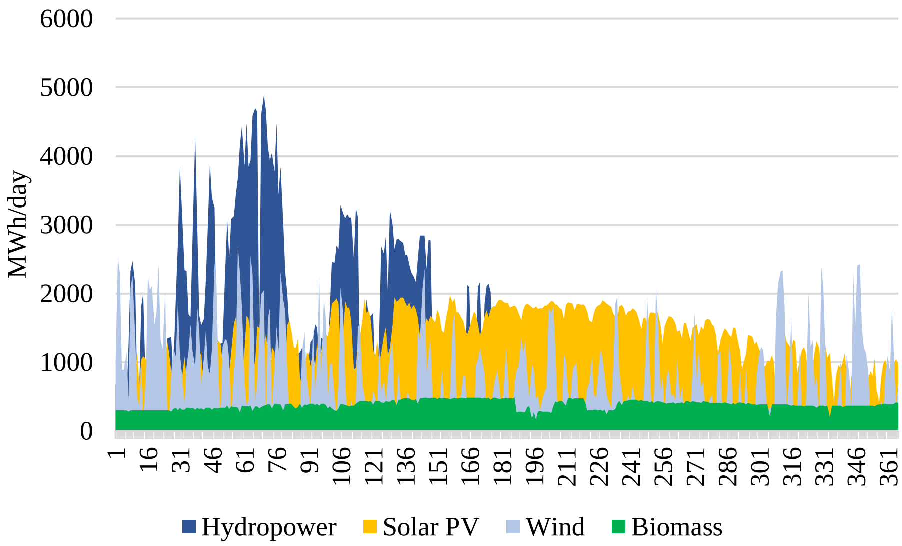

Figure 10. Distribution of estimated daily electricity production for 2030 in Isparta province by sources.

One of the aims of the study is to reduce CO2 emissions. Reducing emissions is one of the main objectives of the Paris Climate Agreement and clean energy planning. In this study, the CO2 emissions of the scenarios prepared for 2020 and 2030 were compared. The result of this comparison is shown in Table 7.

Table 7. Comparison of carbon emissions.

Greenhouse Gas	Reference Scenario (Mt)	Renewable Energy Scenario for 2030 (Mt)	Difference (%)
CO_2 Emission	0,231	0,096	-%58.4

As shown in Table 7, the CO2 emission value, which was 0.231 million tonnes in 2020, was reduced to 0.096 million tonnes in 2030 by the scenario created in EnergyPLAN. The amount of carbon emissions in 2020 was calculated considering the coal source. The economic analysis of the scenarios created includes installation, variable, fixed operating, and maintenance costs. Establishing and integrating new power plants in the transition to renewable energy requires new investments. For the transition to 100% renewables in 2030, the necessary cost analysis for the construction and maintenance of new power plants was performed. These costs are shown in Table 8.

Table 8. Increasing capacity cost calculations for 2030 compared to the reference year.

Sources	Capacity Change in 2030 (MW)	Unit Cost (MUSD/MW)	Total cost (MUSD)
Hydropower	14	1,27	21
Solar	148	0,57	99
Wind	60	1,35	95
Biomass	23,17	2,54	67
Naturel Gas-Coal	0	0	0
		Total	282

The costs shown in Table 8 show the costs of newly established power plants in relation to sources in the transition to 100% renewable energy systems. The total scenario cost created to reach the 2030 year targets is 282 MUSD. The annual total cost was obtained by dividing the total cost of 2030 year by 10. The annual investment cost to achieve a 100% renewable energy system is 28.2 MUSD. I In this study, CO2 taxes, electricity transmission and distribution costs are not included in the calculation. While performing the economic analysis of the scenarios, the calculation was made by considering the system installation, operation, maintenance, and variable costs.

6. CONCLUSIONS

Today, the world has begun to reshape energy use and consumption. The interest in renewable and local sources of energy generation is increasing day by day due to independence in energy, fluctuating fuel prices, and rising CO2 emissions. Increasing greenhouse gas emissions and energy crises in recent years have accelerated the transition to renewable energy systems. Turkey is a country dependent on foreign energy and fossil fuels. Therefore, transitioning to renewable energy and reducing dependence on imported fuels has become imperative. These studies continue at both national and local levels. The main purpose of the studies at the local level is to propose new scenarios for the appropriate design of local energy systems, which is the transition to 100% renewable energy systems. These scenarios are generally evaluated in terms of the smart energy systems concept (intersectoral integration), sustainable systems that balance production and consumption. Sustainability is one of the biggest problems in renewable energy systems due to the intermittent of renewable energy sources. Bioenergy is used to eliminate this disadvantage in renewable energy systems. Bioenergy is an excellent alternative to fossil fuels (biomass instead of coal, biogas instead of natural gas, and biofuels instead of oil). The biggest problem with bioenergy is its availability; therefore, its excessive use in energy systems is not recommended. When planning renewable energy systems, it is crucial to identify the bioenergy potential, generate it, and organize its use well. In this study, the technical and economic analysis of Isparta province for the transition to 100% renewable energy systems for the year 2030 was carried out. When the scenario for the province of Isparta is examined from a technical point of view, it has been determined that the area where the new hydropower, biomass, solar, and wind power plants will be established and the required amount of sources are appropriate.

The capacity of biomass power plants was established at 26 MW by calculating the sustainability level. While the province of Isparta met 32% of its electricity needs from fossil fuels in 2020, the use of fossil fuels was ended by 2030. Therefore, CO_2 emissions decrease from 0.231 Mt to 0.096 Mt. The CO_2 emission here is due to biomass energy. In addition, this study shows that it is possible to reduce CO_2 emissions by reducing the use of fossil fuels. The total cost of the transition to 100% renewable energy was 325 MUSD. In addition, another way to ensure sustainability in renewable energy systems is through energy storage systems. Due to the intermittent nature of renewable energy systems, changes will inevitably occur in the future balance of production and consumption. It is believed that this situation may lead to difficulties in meeting the energy needs that the current system requires. Energy storage systems are of great importance for the existing system to easily meet the energy demand in possible situations. Storage systems ensure that energy is used when and in the desired amount. This situation provides sustainability in energy by being used in cases where production is insufficient. There are no existing storage systems in the province of Isparta. In this study, energy storage systems are not integrated into the 100% renewable energy scenario. This reason is storage systems require a high amount of investment, time, and planning. Energy storage systems are needed in higher-capacity renewable energy systems. As a result, although using renewable energy systems provides many advantages, it causes high investment costs. Clean energy planning for the future needs to be thoroughly researched and planned from technical, economic, environmental and political aspects.

7. ACKNOWLEDGEMENTS

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Conflict of Interest

No conflict of interest was declared by the authors.

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