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Investigation of Solar Energy Use in Agricultural Irrigation

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Abstract: ***The aim of in this article is to determine the advantages of systems that produce electrical energy from solar energy. The availability of solar energy for the electrical energy consumed in agricultural irrigation in the summer months in Edirne (Turkiye) was investigated. Photovoltaic system installation costs and payback periods have been calculated and it has been determined whether the installation of the system is economical or not. When the electrical energy used in the irrigation of agricultural areas in Edirne is met from the alternative energy system, the panel power required for the establishment of this system as 149.945, 250 kW and the amount of energy to be obtained from the system is calculated as 404.722.988, 00 kWh. Consequently; the payback period of the set up is calculated as 7 years. When it is accepted that the life of the solar system to be established is 25 years, it has been seen that it is economically possible to make agricultural irrigation with the electrical energy obtained from the solar systems to be established by using the state support for Edirne.***

Keywords: Agricultural irrigation, solar energy, photovoltaic systeme, cost

Nomenclature	Descriptions
Egi	Daily amount of electrical energy needed for agricultural irrigation (kWh)
Egk	Daily amount of electrical energy obtained from the sun (kW/day)
Ekt	Total amount of electrical energy obtained from the sun (kW)
Epg	Total panel power needed for agricultural irrigation (kW)
Et	Total amount of electrical energy consumed in agricultural irrigation (kWh)
Epdk	Energy Market Regulatory Authority
Gepa	Atlas of solar potential
Gts	Total number of days watered
Gets	Total number of days using solar energy for irrigation
Ggs	Daily sunshine duration (h)
Pg	Power of a panel
Tredaş	Trakya Electricity Distribution Corporation
Tedaş	Türkiye Electricity Distribution Corporation

1.Introduction

Today, solar energy is of great importance in meeting the energy needs all over the world. The decrease in the current energy resources that have been used in the world for many years, polluting the environment and negatively affecting the health of living things necessitated the use of renewable energy resources. The existence of energy resources of all countries and the way they obtain energy affect their economies. Today, one of the most important factors for countries to have a strong economy is to have domestic energy resources. It is necessary to obtain as much electricity as possible from the sun, which is an alternative energy. Solar energy systems can be installed both with large power and small power. Installation, maintenance and repair costs of these systems are reduced due to technological developments, and payback periods are shortened.

They found the cost of electricity generation per kWh with the generator using diesel fuel, and took the fuel price as 86, 55 c€/L. For a system of the same size, they found the unit kWh production cost with the generator to be 39 c€/kWh, while the solar system's unit kWh electricity production cost was only 13 c€/kWh [1].

The amount of renewable energy sources used in Turkey increased by 1.5% in the first quarter of 2020. It is also the only growing energy source. The installed power of solar power plants in Turkey is 6, 361 MW, and the generation is 9, 624 MWh [2].

In the study, in the installation of the systems; they found the equipment cost as 1, 25 €/Wp, other components and installation cost as 0, 037 €/Wp and the total cost of solar system installation as 1, 29 €/Wp [3].

In this study, considering the climatic conditions in the province of Edirne in the Marmara Region of Turkey, the current agricultural irrigation costs with mains electricity and the costs in case of the same agricultural irrigation with electrical energy obtained from photovoltaic facilities will be investigated. In the study, first the solar energy data of the region will be determined, then the materials required for the system installation will be calculated. In case of using polycrystal line and monocrystalline solar panels, necessary data will be calculated. According to these data, it will be determined whether the use of photovoltaic systems in agricultural irrigation is suitable for Edirne province and how many years the system will pay itself back.

2.Material and Method

2.1. Material

2.1.1. Geographical Location and Climate Structure of Edirne Province

Edirne is 41 meters above sea level and is located in the Thrace part of the Marmara Region. The continental climate is dominant in the province and geographically it consists of wide plains and low hills. The winter months are harsh and rainy when the Mediterranean climate is formed and a warm and rainy continental climate is formed. Spring is rainy and summer is hot and dry. During the year, June, July, August are the months with the highest temperature, December and January are the months with the lowest temperature, the average temperature is 23.4 °C in summer [4].

Geographical Location: The province located on the Thrace Peninsula; There is the Aegean Sea, Saros Bay and Koru Mountains in the south, the Istranca Mountains in the north, the Meriç Plain and the River in the west, and the Ergene Plain in the east. The province is located between 26º 30' East longitudes and 41º 40' North latitudes.80% of its land is suitable for agriculture [5].

2.1.2. Solar Energy Potential of Edirne Province

Edirne is very efficient in terms of solar energy potential as a geographical location.

-Total average annual sunshine duration = 2693, 7 hours/year
-Total average daily sunshine time = 7, 38 hours/day
-Total average annual radiation intensity = 1332, 25 kWh/m^2-year
-Total average daily radiation intensity = 3, 65 kWh/m^2-day.

These values are close to the Turkey average.

The solar radiation values of Edirne are given in Figure 1 [6].

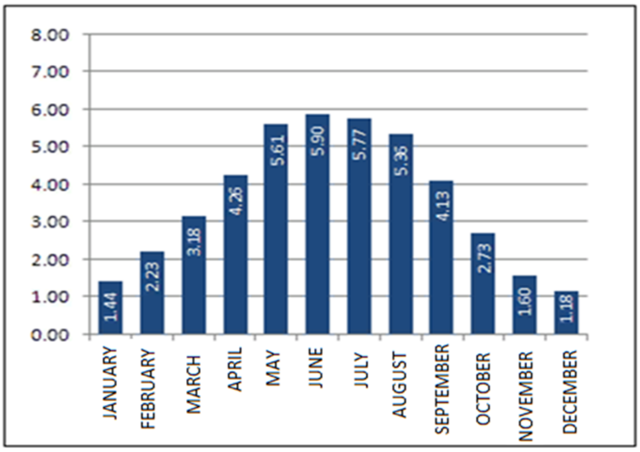

Figure 1: Global radiation values of Edirne province (kWh/m^2-day)

2.1.3. Sunbathing Times of Edirne Province

We see that the daily sunshine durations in Edirne and Türkiye average daily sunshine durations are very close to each other. The sunshine durations of Edirne province are given in Figure 2. The average sunshine duration is 10, 76 hours in June, July, August and September when irrigation is intense.

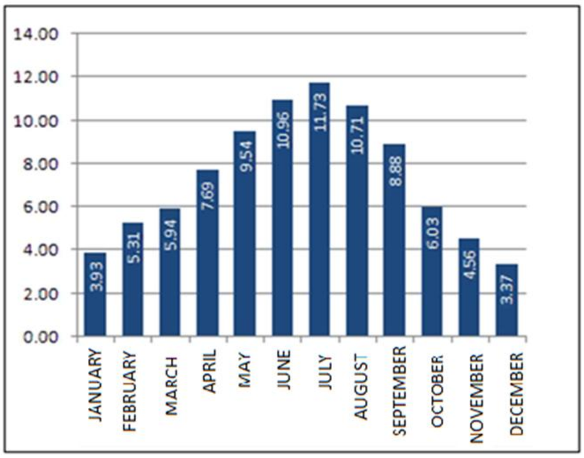

Figure 2: Sunbathing durations/hours of Edirne province

2.1.4. Edirne PV Type-Field Producable Energy

The amount of electrical energy that solar panels will produce annually in Edirne according to their structures is given in Figure 3. [6]. It is seen that the most efficient solar panel is the monocrystalline panel.

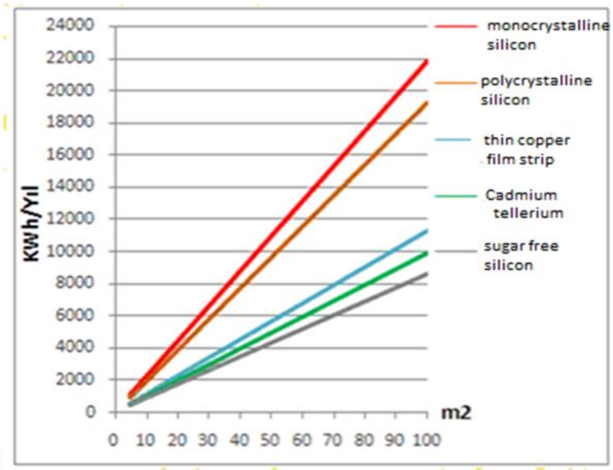

Figure 3: Edirne PV type-area generating energy (kWh-Year)

The amount of electrical energy consumed in agricultural irrigation in Edirne province in June, July, August and September of 2020 is given in Table 1.

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Table 1: Consumption of agricultural irrigation for the months of 2020-kWh [7]

Province	June 20	July 20	August 20	September 20
Enez+Havsa+İpsala	12.042.633, 78	13.761.983, 78	13.586.261, 25	7.147.170, 83
Keşan+Lalapaşa+Meriç	2.431.430, 84	4.209.787, 11	5.006.592, 61	3.449.270, 08
Merkez+Süloğlu+Uzunköprü	6.735.162, 88	10.837.989, 95	11.538.508, 29	6.108.047, 57
TOTAL	21.199.227, 52	28.809.760, 85	30.131.362, 16	16.704.488, 48

2.2. Method

2.2.1. Monthly Average Solar Energy Potential of Edirne Province

The monthly average solar energy potential was found by multiplying the global radiation values and the number of days of the months according to the months in Edirne in Figure 1.

2.2.2. Electricity Production by Month in Edirne Province

The amount of electrical energy produced by month was determined using the data of the Ministry of Energy and Natural Resources. The required panel power was found separately for each month by multiplying the daily sunshine duration and the number of days of the months (Figure 2) [6].

2.2.3. Daily Amount of Electricity Needed for Agricultural Irrigation in Edirne Province

In order to calculate the amount of electrical energy consumed in a day in irrigated agricultural lands (Eq.1), the total amount of electrical energy consumed in irrigation in June, July, August and September, when agricultural irrigation is the highest, was found by dividing 122 (Total number of days in these months). The electrical energy consumption values for the months are taken from Table 1.

$$Egi=Et/\,Gts \qquad (1)$$

2.2.4. Daily Amount of Electricity Obtained from the Sun in Edirne Province

Equation 2 is used to calculate the Daily Electricity Obtained from the Sun in Edirne Province. In this calculation, the monthly total electrical energy amount obtained in June, July, August and September is divided by the total number of days of these months by 122. The monthly electrical energy amounts obtained in June, July, August and September are given in Figure 1.

$$Egk=Ekt/\,Gets \qquad (2)$$

2.2.5. Total Panel Power Required for Agricultural Irrigation in Edirne Province

Equation 3 was used to find the total solar panel power required for the irrigated land. In this calculation, the amount of electrical energy needed daily in the irrigated agricultural land was found by dividing the amount of daily electrical energy obtained from solar energy.

$$Epg=Egi/\,Egk \qquad (3)$$

2.2.6. Daily Sunbathing Time for Edirne Province

The daily sunshine duration was found by summing the sunshine durations in June, July, August and September, when agricultural irrigation is the most, and dividing by the total number of these months. Values related to the sunshine duration of the months are taken from Figure 2.

2.2.7. Calculation of System Installation Cost for Edirne Province

2.2.7.1. Polycrystalline Panel Installation Cost

When calculating the installation cost when a Polycrystalline solar panel is used in the system installation, the installation cost per Watt is multiplied by the total solar panel power required for the agricultural irrigation land. The installation cost is taken as 0, 95 €/Wp when polycrystalline panel is used [8]. The unit kWh price for agricultural irrigation is 0, 88942 ₺ [9].

2.2.7.2. Monocrystalline Panel Installation Cost

When calculating the installation cost when a monocrystalline solar panel is used in the system installation, the installation cost per Watt is multiplied by the total solar panel power required for the agricultural irrigation land. The installation cost is taken as 0, 99 €/Wp when monocrystalline panel is used [8]. The unit kWh price for agricultural irrigation is 0, 88942 ₺ [9].

3.Results and Discussion

3.1. Monthly Average Solar Energy Potential of Edirne Province

The months with the highest amount of agricultural irrigation in Edirne are June, July, August and September. The average solar energy potential was determined as 177 kWh in June, 178, 87 kWh in July, 166, 16 kWh in August and 123, 9 kWh in September. The total solar energy potential of these months is calculated as 645, 93 kWh.

3.2. Daily Amount of Electricity Needed for Agricultural Irrigation in Edirne Province

The amount of electrical energy needed in one day in agricultural irrigation was found to be 793.810, 155 kWh. It calcaleted By dividing 96.844.839, 01 kWh, which is the total amount of electrical energy consumed in irrigation in June, July, August and September, by 122 (the total number of days). In the study of Düzenli [10], it is reported that the daily electrical energy requirement of an agricultural irrigation system with a total load of 2000 Watts is 4762, 6 Wh/day.

3.3. Daily Amount of Electricity Obtained from the Sun in Edirne Province

The daily amount of electrical energy obtained from solar energy 645.93 kW, which is the monthly total amount of electrical energy obtained in June, July, August and September, and the total number of days of these months is divided by 122 and calculated as 5, 294 kW/day.

3.4. Total Panel Power Required for Agricultural Irrigation in Edirne Province

The total solar panel power required for the agricultural irrigated land; 793.810, 155 kWh, which is the amount of electrical energy needed in a day in the irrigated agricultural land, was found as 149.945, 250 kWh by dividing by 5, 294, the daily electrical energy gained from solar energy. Annually, 404.722.988, 00 kWh of electrical energy is obtained from this system.

Düzenli found a total power of 1, 218 kW by using 12 solar panels with a power of 101, 5 Watt in order to make an agricultural irrigation system with a total load of 2000 Watts with a photovoltaic system [10].

3.5. Daily Sunbathing Time for Edirne Province

The total sunshine duration of June, July, August and September is 42, 28 h. This value was divided by 4 and the daily sunshine duration was calculated as 10, 57 h.

3.6. Cost of System Installation

3.6.1. Polycrystalline Panel Installation Cost

When polycrystalline solar panels are used in the system installation, the installation cost is found to be 142.447.987, 5 €, 1.356.104.841 ₺ by multiplying the installation cost per Watt, which is 0, 95 €, and the required panel power by 149.945, 250 W.

3.6.2. Monocrystalline Panel Installation Cost

When monocrystalline solar panels are used in the system installation, the installation cost is found to be 148.445.797, 5 €, 1.413.203.992, 2 ₺ by multiplying the installation cost per Watt, which is 0, 99 €, and the required panel power by 149.945, 250 W.

Erkoç, in his study, calculated the installation cost of solar power plants with a total power of 750 kW as 707.000 $ in Turkey, 5.323.710 ₺, and 636.700 $ in Germany [11]. It was taken as 1 $ = 7.53 ₺.

3.7. Annual Total Amount of Electric Energy Produced in the System

The panel power required in the system was calculated separately for each month by multiplying the daily sunshine duration and the number of days according to the months. By summing up the monthly productions, the annual electrical energy produced from the system was calculated as 404.722.988, 00 kWh.

Biçen, in his study, reported that the annual amount of electrical energy obtained from monocrystalline panels in a 23 kW photovoltaic facility is between 28.081 kWh/year - 32.239 kWh/year. He reported that the annual amount of electrical energy obtained from polycrystalline panels is between 26.209 kWh / year - 31.886 kWh /year [8].

3.8. Economic Analysis of System Installation

The economic analysis of the installation of the system has been made taking into account that the system is connected to the electricity grid. Because the system produces electrical energy throughout the year. Agricultural irrigation is mainly carried out in June, July, August and September, and the electrical energy produced in other months is given to the grid.

3.8.1. Economic Analysis Using Polycrystalline Panel

3.8.1.1. If Panels used in the System are Imported

A surplus of 307.878.149 kWh is generated from the annual 404.722.988, 00 kWh energy produced from the system, after 96.844.839, 01 kWh of energy is used for agricultural irrigation in 122 days. When the support fee is calculated by using the support fee of 0, 32 ₺/kWh [12] paid for solar energy;

404.722.988, 00 kWh-96.844.839, 01 kWh=307.878.149 kWh

307.878.149 kWh × 0, 32₺/kW= 98.521.007, 68 ₺

The unit price of 1 kWh electricity consumption is 0, 88942 ₺ [9].

Agricultural irrigation energy cost is calculated as 96.844.839, 01kWh×0, 88942 ₺/kWh = 86.135.736, 71 ₺. According to this; an annual support payment of 98.521.007, 68 ₺ from surplus energy and 96.844.839, 01 kWh energy cost to be used for 122 days, 86.135.736, 71 ₺ are saved.

Total Savings = 98.521.007, 68 ₺+86.135.736, 71 ₺=184.656.744, 4 ₺ annual savings.

If we divide the system cost by the total savings;

System payback period is

1.356.104.841 ₺÷184.656.744, 4 ₺/year=7, 34 years.

3.8.1.2. If the Panels used in the System are Domestic

A surplus of 307.878.149 kWh is generated from the annual 404.722.988, 00 kWh energy produced from the system, after 96.844.839, 01 kWh of energy is used for agricultural irrigation in 122 days. When the support fee is calculated by using the support fee of 0, 32 ₺/kWh [12] paid for solar energy is

404.722.988, 00 kWh-96.844.839, 01 kWh=307.878.149 kWh

307.878.149 kWh × 0, 32 ₺/kWh = 98.521.007, 68 ₺

When an additional support fee of 0, 08 ₺/kWh [12] is calculated when domestic panels are used;

307.878.149 kWh x0, 08 ₺/kWh=24.630.251, 92 ₺

The unit price of 1 kWh electricity consumption is 0, 88942 ₺ [9].

The energy cost to be paid for agricultural irrigation is calculated as 96.844.839, 01 kWh× 0, 88942 ₺/kWh = 86.135.736, 71 ₺.

According to this; an annual support payment of 98.521.007, 68 ₺ from surplus energy and 24.630.251, 92 ₺ from domestic panel usage, 96.844.839, 01 kWh energy cost to be used for 122 days, 86.135.736, 71 ₺ is saved.

Total Savings = 98.521.007, 68 ₺+24.630.251, 92 ₺+86.135.736, 71 ₺ =209.286.996, 3 ₺ annual savings.

If we divide the system cost by the total savings;

System payback period is

1.356.104.841 ₺ ÷209.286.996, 3 ₺/year=6, 47 years.

If we divide the system cost by the irrigation energy cost when the state support fee is not used when polycrystalline panels are used; system payback period

1, 356, 104, 841 ₺÷86, 135.736, 71 ₺ /year=15.74 years.

3.8.2. Economic Analysis Using Monocrystalline Panel

3.8.2.1. If the Panels Used in the System are Imported

A surplus of 307, 878, 149 kWh is generated from the annual 404, 722, 988.00 kWh energy produced from the system, after 96.844.839.01 kWh of energy is used for agricultural irrigation in 122 days. When the support fee is calculated by using the support fee of 0.32 ₺/kWh [12] paid for solar energy;

404, 722, 988.00 kWh-96.844.839.01 kWh=307, 87, 149 kWh

307, 878, 149 kWh × 0.32 ₺/kWh = 98, 521, 007.68 ₺

The unit price of 1 kWh electricity consumption is 0.88942 ₺ [9]

Agricultural irrigation energy cost is calculated as 96.844.839.01 kWh× 0.88942 ₺/kWh = 86.135.736.71 ₺.

According to this; An annual support payment of 98.521.007.68 ₺ from surplus energy and 96.844.839.01 kWh energy cost to be used for 122 days, 86.135, 736.71 ₺ are saved.

Total Savings = 98, 521.007.68 ₺+86.135, 736.71 ₺=184, 656, 744.4 ₺ annual savings.

If we divide the system cost by the total savings;

System payback period

1, 413, 203, 992.2 ₺÷184, 656, 744.4 ₺/year=7.65 years.

3.8.2.2. If the Panels Used in the System are Domestic

From the annual 404.722, 988.00 kWh energy produced from the system, after 96.844.839.01 kWh of energy is used for agricultural irrigation in 122 days, 307, 878, 149 kWh of energy surplus occurs.0.32 ₺/kWh [12] paid for solar energy. When the support cost is calculated using the support price;

404.722, 988.00 kWh-96.844.839.01 kWh=307.878.149 kWh

307, 878, 149 kWh × 0.32 ₺/kWh = 98, 521.007.68 ₺.

When domestic panels are used, additional 0.08 ₺/kWh [12]., when the support cost is calculated

307, 878, 149 kWh x0.08 ₺ /kWh=24, 630, 251.92 ₺

The unit price of 1 kWh electricity consumption is 0.88942 ₺ [9]

The energy cost to be paid for agricultural irrigation is calculated as 96.844.839.01 kWh×0.88942 ₺/kWh= 86.135.736.71 ₺.
According to this; an annual support payment of 98.521.007.68 ₺ from surplus energy and 24.630.251.92 ₺ from domestic panel usage, 96.844.839.01 kWh energy cost to be used for 122 days, 86.135, 736.71 ₺ is saved.

Total Savings = 98.521.007.68 ₺+24.630.251.92 ₺ +86.135.736.71 ₺=209.286.996.3 ₺ annual savings.

If we divide the system cost by the total savings;

System payback period

1, 413, 203, 992.2 ₺÷209, 286, 996.3 ₺/year=6.75 years.

If we divide the system cost by the irrigation energy cost when the state support fee is not used when monocrystalline panels are used;

System payback period

1, 413, 203, 992.2 ₺ ÷86, 135.736, 71 ₺/year=16.40 years

In earlier studies carried out in this field, the payback period of the photovoltaic system was calculated as 6 years

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[**13**] for system with power of 330 kWp, 11 years [**14**] for the system that produces an average of 8-10 kW of electricity per day, 5.1 years in the absence of greenhouse reduction support, and 4.8 years [**15**] with greenhouse gas reduction support. The payback period of the photovoltaic system has been also reported as 23 years [**16**], 14 years [3], 7.5 years in Turkey and 16 years in Germany [**11**] in some other studies.

4.Conclusions

Because of the constantly increasing energy demand and environmental pollution in the world, the use of renewable energy sources has increased day by day. The use of solar energy is becoming widespread, especially due to the increasing energy demand and environmental pollution. In countries that are financially strong, public institutions and organizations and the private sector invest for the installation of solar energy systems.

In this study, the technical and economic analysis of photovoltaic installationneeded for in irrigation of farmlandin Edirne province was investigated. The panel power required to meet the amount of electrical energy needed for irrigation of agricultural areas in Edirne from the sun is 149.945, 250 kW and the amount of energy to be win from the system as 404.722.988, 00 kWh was found. After 96.844.839, 01 kWh of this energy is used in agricultural irrigation, the remaining surplus is 307.878.149 kWh. In system setup; the installation cost was found to be 1.356.104.841 ₺ when polycrystalline solar panels were used, and 1.413.203.992, 2 ₺ when monocrystalline solar panels were used.

The payback period of the system when a polycrystalline solar panel is used in the system installation.; When the state support fee is used, it is 7, 34 years if the panels are imported, 6, 47 years if the panels are domestic and 15, 74 years if the state support fee is not used. The payback period of the system when monocrystalline solar panels are used in the system installation; when the state support fee is used, it is 7, 65 years. The panels are imported, 6, 75 years if the panels are domestic and 16, 40 years if the state support fee is not used.

When the system life is taken as 25 years, according to the system payback period, which was calculated as 7 years using the state support fee in the study it would be appropriate to make agricultural irrigation in Edirne with the electricity provided from solar energy. It has been observed that the type of panel to be used in the system installation is not very important in the payback period of the system. Giving government support to every application area where solar energy will be used is very important in terms of increasing system installations. Researches should be carried out in order to use photovoltaic systems in other application areas where electrical energy is used in Edirne. It is thought that the results obtained in this study will form the basis for different studies to be carried out in this field. In addition, in order to increase the use of photovoltaic systems, it is necessary to increase the awareness and importance of photovoltaic systems in every part of the society.

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