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PRODUCTION PERFORMANCE AND COST ANALYSIS OF 60 KWP GRID-CONNECTED PHOTOVOLTAIC SYSTEM IN AYAŞ

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Abstract: The Ankara University Ayaş Horticulture Research and Application Station was chosen as the study area for this investigation. It is situated in the Uğurçayırı neighborhood of Ayaş district, in the center of the districts of Ayaş, Güdül, Beypazarı, and Polatlı. Saplings, vegetables, fruits, clover, medicinal, and spice plants are all produced on the 406-hectare land. The analysis employed a variety of solar energy potential sources, including Ayaş, GEPA (2023), MGM HELİOSAT (2021), PVGIS (2021), IRENA (2021), Solar Med Atlas (2021), NASA SSE (2021), SOLARGIS (2019), Global Solar Atlas, and NREL data. In addition, the design cost of a 60 kW photovoltaic system connected to the grid in Ayaş and the daily average/annual total production values according to months were calculated, taking into account the installed solar energy capacity and production values of the Ministry of Energy in the area. Ayaş's annual solar radiation is 1628 kWh/m2. The average daily electricity production is 252 kWh, and the total annual production is 91980 kWh. A 60 kW PV system's installation cost is 50150 USD. The system has a six-year repayment period. Furthermore, the PV system will mitigate 59.7 kilograms of CO_2 emissions annually.

Keywords: Photovoltaic, Solar energy, Solar panel, Cost analysis

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1. Introduction

Today, energy consumption and environmental impacts cause varying concerns on a global scale. While traditional energy sources lead to significant problems such as greenhouse gas emissions and environmental pollution, their limited nature also creates uncertainties for future energy supply (Arutyunov and Lisichkin, 2017). This situation requires societies and industries to turn to more sustainable and environmentally friendly approaches in energy production and consumption. In this context, the interest and need for renewable energy sources are increasing day by day. Solar energy stands out as one of the most significant of these renewable resources (Qazi et al., 2019). Photovoltaic systems that generate electrical energy using sunlight stand out as an environmentally friendly energy source and are increasingly preferred. These systems operate with the sun's natural light, which is an unlimited source of energy, and as a result, they do not create any side effects or environmental pollution. Furthermore, the fact that they are independent of natural resources and do not have fuel costs during the operation of solar energy systems offers additional advantages (Khan et al., 2016).

Photovoltaic (PV) systems are technological systems that convert sunlight into electrical energy. These systems receive sunlight through solar panels and generate electricity through semiconductor materials in photovoltaic cells. This process allows direct and clean conversion of sunlight into electricity, which makes photovoltaic systems a clean and renewable source of energy. The decrease in costs during the installation and operation of photovoltaic systems enables the spread of solar energy technology to a wider audience. While advances in technology increase efficiency in production processes, material costs also decrease (Smets et al., 2016).

According to TurkStat's Agricultural Statistics (2016), vegetable production is carried out in a total area of 24935 ha in Ayaş, Beypazarı, Güdül, and Polatlı districts. In the same districts, the area planted for cereals and other plant production is 275788 ha, and fruit growing is carried out on an area of 2390 ha. In this context, the production performance and cost analysis of the 60 kWp photovoltaic system installed in Ayaş and connected to the grid are of significant importance from both a local and general perspective. This study will be a significant step in order to ascertain the potential of solar energy in the Ayaş region and how this potential can be evaluated economically. The goal of this study is to assess the solar energy potential in the Ayas region, analyze the production performance of the existing 60 kWp photovoltaic system, and assess the system's cost-effectiveness. This analysis will help to increase the use of solar energy resources in the region and accelerate the transition to renewable energy.

The study's findings will serve as a valuable guide for encouraging the use of solar energy in Ayaş and similar regions, increasing energy efficiency, and ensuring environmental sustainability. This analysis will provide valuable information to decision-makers, investors, and interested parties during the transition to renewable energy.

1.1. Solar Power in the World and Europe

Due to climate change and global warming, environmental problems, and ever-increasing energy needs around the world, there is a rapid trend towards solar energy, which is a clean and sustainable energy source without any raw material cost. Table 1 indicate the increase in global renewable energy capacity over the years. Global renewable energy capacity has increased by 84.36% since 2014, reaching 3372 GW (IRENA, 2022).

The increased use of renewable energy sources not only provides environmental benefits but also creates great business opportunities from an economic point of view. In particular, the use of solar energy technologies, such as photovoltaic systems, allows for a wide range of job opportunities. It increases the demand for the workforce to work in many stages, such as the production, transportation, installation, maintenance, and repair of system components. In the process of producing components of photovoltaic systems, factories producing solar panels, inverters, mounting structures, and other equipment, as well as providers of raw materials used in the production of materials, offer job opportunities. According to Table 2, the global workforce in this sector reached 13.7 million people by 2022 from 7.3 million between 2012 and 2022 (IRENA, 2023a).

According to the IRENA Renewable Energy Generation Costs 2022 Report (IRENA, 2021), the total installation costs of photovoltaic systems have decreased considerably over the years due to technological developments. As can be seen in Table 3, the installation cost of the 1 kW photovoltaic system, which was $5124 in 2010, decreased to $876 in 2022.

Table 1. Global renewable energy capacity

Renewable Energy Global Production Capacity (GW)									
	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production Capacities (GW)	1829	1965	2006	2179	2351	2537	2799	3064	3372

Table 2. Global workforce

Global Job Opportunity											
Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Workforce (millions)	7.3	8.5	9.5	10.0	10.1	10.5	11.0	11.5	12.0	12.7	13.7

Table 3. PV system installation and electricity production trends for 2010-2022 (IRENA, 2023b)

Total Installation Cost (USD/kW)			Electricity cost (USD/kWh)		
2010	2022	Percentage change	2010	2022	Percentage change
5124	876	-83%	0.445	0.049	-89%

As can be seen in Table 4, the costs for electricity generation after installation have also decreased significantly over the years. When PV system, wind turbines installed on land and sea and concentrated solar energy systems are compared, it is seen that the biggest decrease in the cost of 1 kWh electricity generation is in photovoltaic systems. The production cost, which was 0.445 USD for 1 kWh in 2010, decreased to 0.049 USD in 2022 (Table 4).

In the European Union countries, an increase of 40% was observed in solar energy installations in 2023 compared to 2022. Compared to the 40 GW solar installation installed in 2022, new solar capacity of 55.9 GW was reached across the EU27 in 2023. With this growth in solar energy in 2023, the total solar energy capacity of the European Union, which was 207 GW in 2022, increased by 27% to 263 GW in 2023 (Figure 1).

Table 4. PV system electricity production costs for the years 2010-2022 (IRENA, 2023b)

Electricity Generation Costs of PV Systems (USD/kWh)												
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0.445	0.332	0.248	0.191	0.172	0.129	0.113	0.089	0.075	0.066	0.059	0.051	0.049

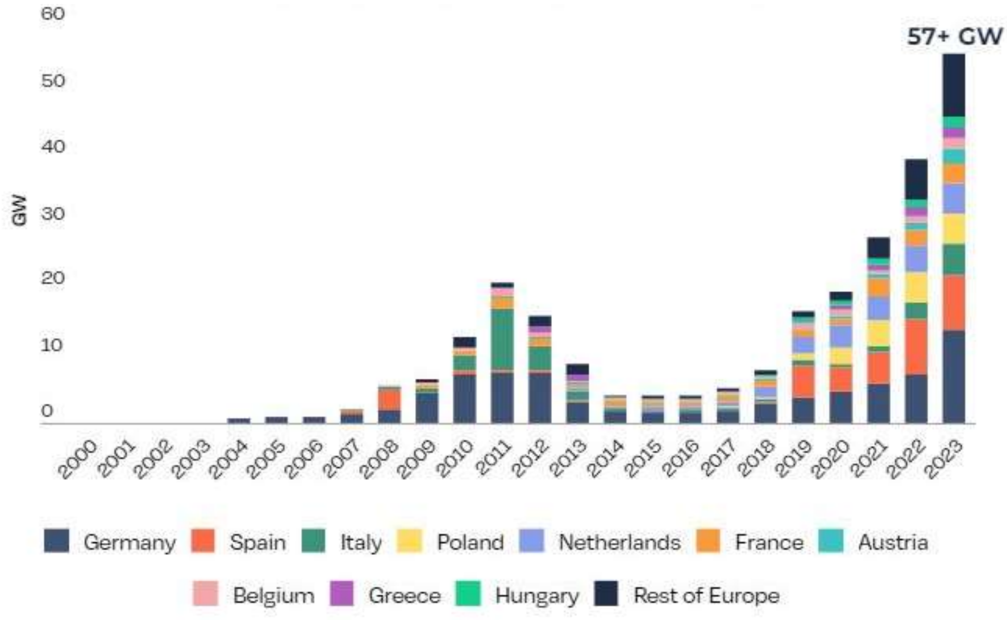

Figure 1. PV installation capacity in EU 27 countries between 2000-2023 (Source: Pv Europe, 2023).

1.2. Renewable Energy and Solar Energy in Türkiye

In recent years, Türkiye has made a rapid shift towards renewable energy sources. The progress made in the field of solar energy is especially remarkable. Throughout the country, there is a significant increase in the installed power and production values related to solar energy. In recent years, Türkiye has increasingly discovered and utilized its high solar energy potential. The geographical location of our country ensures that sunlight is abundant and continuous, especially in the Mediterranean and Aegean regions. This enables solar energy systems to operate effectively and achieve high efficiency. The Energy Market Regulatory Authority (EMRA) provided the data in Table 5. According to Table 5, as of the end of 2022, the installed power of renewable energy (hydro, wind, solar, geothermal, and biomass) is 56005.73 MW, and its share in the total installed power is 53.95%. Licensed and unlicensed solar installed power is 9425.44 MW, and its share in total production is 9.08% (EMRA, 2023).

The share of renewable energy sources (including hydraulic) in total installed power over the years has increased to 42.1% in 2019, 40.2% in 2020, 50.02% in 2021, and 53.95% in 2022 (EMRA, 2023). In the four years from 2019 to 2022, there is a continuous increase in the share of renewable energy sources in the total installed power. This increase may be the result of strategic changes in the country's energy policies and investments. The use of renewable energy sources and their installed power may have increased rapidly due to the incentives of the government and the private sector for renewable energy. In particular, the more pronounced increases seen in 2021 and 2022 could be attributed to a greater focus of government and investors on renewable energy. In this period, it is seen that large-scale investments in renewable resources such as solar energy and wind energy have increased, and these investments have triggered the increase in installed power.

Table 5. Installed power and production values by resource as of the end of 2022 (EMRA, 2023)

Source type	Total Installed Power* (MW)	Ratio (%)	Total Production* (MWh)	Ratio (%)
Hydraulic	31571.48	30.41	67194934.69	20.71
Wind	11396.17	10.98	35140858.14	10.83
Solar	9425.44	9.08	15435661.31	4.76
Geothermal	1691.34	1.63	10918764.88	3.36
Biomass	1921.31	1.85	9080038.21	2.80
Renewable	56005.73	53.95	137770257.22	42.45
Natural gas	25732.79	24.79	70827228.33	21.83
Lignite	10191.52	9.82	44745695.96	13.79
Imported coal	10373.80	9.99	63259657.34	19.49
Coal	840.77	0.81	3242363.27	1.00
Asphaltite	405.00	0.39	1568085.50	0.48
Fuel oil	251.93	0.24	718653.16	0.22
Naphtha	4.74	0.00	0.00	0.00
LNG	1.95	0.00	0.00	0.00
Diesel	1.04	0.00	2385741.41	0.74
Thermal	47803.53	46.05	186747424.97	57.55

2. Materials and Methods

The most important component in the installation of the solar energy system (sizing of photovoltaic solar panels, selection of inverter, installation cost cabling, etc.) is the correct determination of the solar energy potential of that place. The best way to determine a region's solar potential is to make healthy, regular measurements over many years. However, where measurement cannot be made or sufficient data cannot be obtained, different calculation methods and algorithms have been developed to determine the solar energy potential. These methods are often based on remote sensing and satellite data. Satellite data is an important source for such analyses, as they have high temporal and spatial resolution. This data can be used to measure a number of factors, such as solar radiation, cloud cover, atmospheric conditions, and other relevant parameters. Data produced by reliable and expert organizations in this field were used all over the world, where solar energy measurements were not made around Ayaş.

To determine the solar energy potential of Ayaş, data from several sources were used, including the Ministry of Energy's GEPA (Solar Energy Potential Atlas), HELIOSAT from the General Directorate of Meteorology, PVGIS by the European Commission Joint Research Center (EC JRC), the Global Atlas from the International Renewable Energy Agency (IRENA), the Solar Med Atlas (2021) for Mediterranean countries, NASA's Solar and Meteorology data (NASA SSE, 2021), as well as data from SOLARGIS (2019), the Global Solar Atlas, and the National Renewable Energy Laboratory (NREL), funded by ESMAP and published by the World Bank Group.

Solar energy potential data were analyzed statistically on a daily basis by annual total and months. In addition, according to the data of the Ministry of Energy's Energy Market Supervisory Authority (EMRA), the electricity generation values generated per solar installed power were also analyzed in practice. Considering these data, the solar energy potential and the electrical energy to be generated by the 60 kW photovoltaic system were determined as low, average and high scenarios.

In current market conditions, cost-benefit analysis was performed and the return-of-investment period of the system was calculated. In addition, the amount of CO_2 emissions to be avoided thanks to the electrical energy to be produced by the photovoltaic system was calculated by evaluating it in terms of its positive contribution to global warming and climate change.

2.1. Ayaş's Solar Power Potential

According to different sources, Ayaş's solar energy potential is given in Table 6. According to GEPA, the average daily solar radiation is 4.0, the total annual solar radiation is 1448 kWh/m^2 and it is the lowest value among different sources. According to MGM Heliosat (2021), the monthly average is 4.4, and the annual total is 1594 kWh/m^2. According to PVGIS (2021), the daily average of Ayaş's solar radiation is 4.4 and the annual total is 1600 kWh/m^2, while according to PVGIS CM SAF (The Satellite Application Facility on Climate Monitoring), the daily average is 5.0 and the annual total is 1847 kWh/m^2. This value is the highest solar energy potential of all sources. According to PVGIS, the electrical energy to be generated by the PV system for Ayaş will be around 1436 kWh, and according to PVGIS CM SAF, it will be around 1643 kWh.

For Ayaş, the average daily global solar radiation, sunshine time and the total annual energy amounts that the PV system can produce are given in Figure 3. According to 10 different solar energy potential atlas, the solar radiation of Ayaş is 1628 kWh/m^2. The data range increases to an average of 1668 kWh/m^2 when we remove the historical NASA SSE (1983-2005) and GEPA.

Table 6. Daily average and annual total solar energy potential of Ayaş according to different sources

Daily average and annual total sunshine intensity by months (kWh/m²)													
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	Total
GEPA	1.7	2.4	3.7	4.7	6	6.3	6.3	5.6	4.6	3.2	1.9	1.4	4.0	1448
MGM Heliosat	2.0	2.9	4.1	5.3	6.4	6.6	6.8	6	4.7	3.3	2.3	1.9	4.4	1594
PVGIS	2.0	3.0	4.0	4.9	5.9	6.4	6.8	6.3	5.3	3.7	2.5	1.8	4.4	1600
PVGIS CMSAF	2.3	3.7	4.6	5.6	6.1	6.5	7.2	7.2	6.3	4.8	3.8	2.4	5.0	1847
IRENA	2.0	3.0	4.0	5.0	5.9	6.5	6.9	6.4	5.3	3.7	2.5	1.8	4.4	1613
Solar Med Atlas	2.0	2.9	4.2	5.3	6.4	6.9	7.3	6.6	5.2	3.6	2.5	1.9	4.6	1680
NASA SSE	1.8	2.5	3.7	4.5	5.7	6.4	6.8	6	4.8	3.3	2.1	1.5	4.1	1495
SOLARGIS	2.1	3.2	4.3	5.3	6.3	6.9	7.3	6.8	5.7	3.9	2.7	1.9	4.7	1717
Global Solar Atlas	2.1	3.1	4.2	5.2	6.2	6.7	7.1	6.6	5.5	3.8	2.6	1.8	4.6	1674
NREL	2.2	3.5	3.7	4.5	5.3	6.1	6.9	6.8	6.2	3.9	2.5	1.5	4.4	1616
Average	2.0	3.0	4.1	5.0	6.0	6.5	6.9	6.4	5.4	3.7	2.5	1.8	4.5	1628

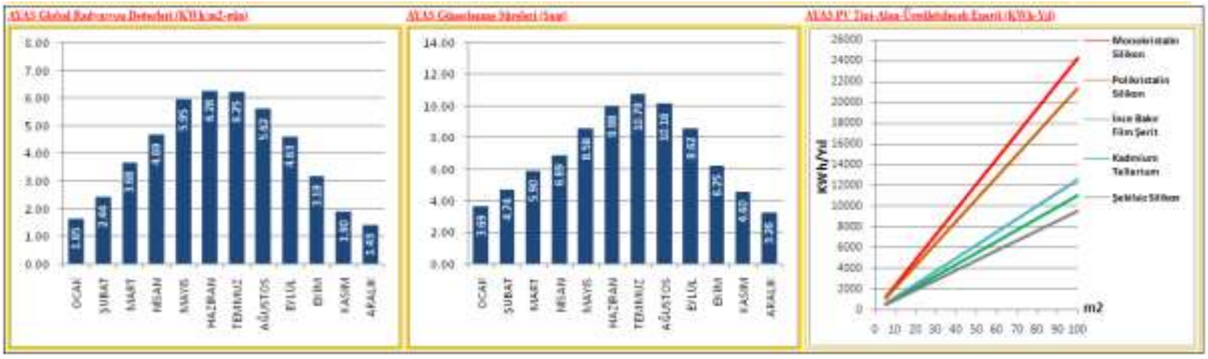

Figure 2. GEPA Ayaş daily average global solar radiation, sunshine duration and annual total energy amounts that the PV system can produce by month (Source, GEPA, 2023).

3. Results

3.1. Design and Cost of 60 Kw Photovoltaic System to be Installed in Ayaş

The system to be installed will be designed as an on-grid system. In on-grid systems, first of all, DC electrical energy generated from the panels is converted into AC mains voltage through inverters, and the electricity converted into AC voltage is connected to the city network through the bidirectional meter. More than the required use of the generated electricity is supplied to the network through the system, and in cases where the generated electricity is insufficient, the required amount of electricity is withdrawn from the network. Offsetting is made by calculating the amount of electricity supplied to and received from the network on a monthly basis.

Since on-grid systems do not have battery systems as in off-grid systems, the initial installation costs will be cheaper and the maintenance costs after installation will be less. In addition, according to the type of batteries used in off-grid systems, the costs of renewing the batteries once every 3-4 years will be added to the cost.

3.2. Solar Panel Angle

The majority of the SPP power plants established in Türkiye are fixed-angle power plants established by considering the optimum sunshine angle. When these angles are adjusted on a seasonal or monthly basis in a single plane, the electrical energy produced can also increase by up to 10 percent. In addition, efficiency can be maximized with a two-plane solar tracking system, as the sun's rays change angles from sunrise to sunset. However, considering the initial installation cost of such a system, the maintenance cost and the electrical energy that it will spend on itself again, it is not considered very economical and therefore not very preferred.

Monthly, seasonal and annual optimum panel angles for Ayaş district are given in Table 6. Accordingly, the most suitable panel angle per year is 34 degrees. If the panel angles are to be changed seasonally, angles of 23° for spring, 6° for summer, 49° for autumn and 62° for winter are best suited. If panel angle adjustment is to be made twice a year, 15° panel angles are optimum for spring and summer seasons and 55° for autumn and winter seasons. In addition, it has been calculated that changing the angle of inclination on an annual, seasonal and monthly basis will contribute 5-10% (Koçer, 2016).

Table 6. Optimum PV panel angles of Ayaş district by months (°)

Month	PV Panel Angles
January	64
February	56
March	41
April	23
May	7
June	1
July	3
August	17
September	34
October	51
November	62
Range	67
Annual	34

3.3. Solar Panel Type

Monocrystalline and polycrystalline solar panels are widely used in the production of electricity from solar energy. The main function of both monocrystalline and polycrystalline solar panels is to convert energy from the sun into electricity. The main difference between the two technologies is the type of silicon solar cell they use: monocrystalline solar panels have solar cells made of a single silicon crystal and are black (Taşçıoğlu et al., 2016). In contrast, polycrystalline solar panels have solar cells that are formed by melting many pieces of silicon together and are in bluish tones. Since a monocrystalline cell consists of a single crystal, the electrons that produce electrical flow have more space to move (Gangaraju, 2022). As a result, monocrystalline solar cells are more efficient than polycrystalline solar cells. Monocrystalline solar panels are more expensive than polycrystalline solar panels. The service life of both panels is more than 25 years. However, the efficiency of monocrystalline solar cells is above 23%, while the efficiency of polycrystalline solar cells is below 20%. As in efficiency, monocrystalline solar panels perform better than polycrystalline models in terms of temperature coefficient. The temperature coefficient of a panel is essentially a measure of how well it performs at high temperatures (near-zero percentages are better), so monocrystalline solar panels perform better at high temperatures. Therefore, monocrystalline solar panel will be used in the system to be installed (Energysage, 2024).

3.4. Approximate Cost for 60 kW PV System

For 60 kW PV system, 132 455 watt monocrystalline panels are sufficient. In addition, the approximate cost for inverter, installation cost, cables, cable ducts, bidirectional meter, switchgear materials, labor, projecting etc. expenses for 60 kW is given in Table 7.

Table 7. Approximate Cost of 60 kW PV System Installation (Source: Solarenerjin, 2022)

	Unit Cost	Total Cost (USD)	Average Cost (USD)
132 units of 455W Monocrystalline panels	0.40-0.45$/w	24000-27000	25500
60kW on grid inverter	0.08-0.10 $/w	4800-6000	5400
Constriction Cost	0.06-0.07 $/w	3600-4200	3900
AC, DC cables, cable ducts, grounding, meter, panel and switchgear materials		6000-7200	6600
Labor		2500-3000	2750
Engineering, TEDAŞ Follow-up		2500-3000	2750
Intermediary company profit		3000-3500	3250
TOTAL		46400-53900	50150

3.5. Power Generation Performance of 60 kW PV System in Ayaş

According to the installed power and electricity production values of solar energy in 2021:

The average daily electricity production corresponding to 1 kW installed power is = 1701/365 = 4.7 kWh. When we consider the production values in 2020 (annual electricity production 1686 kWh), 2021 (annual electricity production 1701 kWh) and 2022 (annual electricity production 1638 kWh), the average daily electricity production is 4.6 kWh. Assuming that the solar energy potential of Ayaş is around 10% lower than the average of Türkiye, the daily electricity production of 1 kW installed power around Ayaş will be around 4.2 kWh and its annual production will be 1533 kWh. In this case, the daily and annual electricity production of the 60 kW photovoltaic system:

- Annual FV Production (kWh) =Installed Power (kW) *Annual FV Production(kWh/1 kW)
- Annual FV Production=60*1533=91980 kWh
- Daily Average PV Production=91980/365= 252 kWh

The daily average values of the electricity to be generated by the 60 kW PV system by months are given in Table 8. While making the calculation here, a proportional distribution was made by taking into account the daily average solar radiation values by months.

Table 8. Daily average electricity production of a 60 kW system by months (kWh)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Daily Avg. Production (kWh)	113	169	232	282	339	367	390	362	305	209	141	102

However, if the solar energy potential of GEPA was taken into account in the calculations, the annual electricity production for 1 kW PV installed power would be around 1300 kWh. In this case, the electricity production of the 60 kW PV system would also be around 78000 kWh per year. This production value is 10-20% below the other solar energy potential sources and the production values obtained in the application offered by EMRA.

If the Global Solar Atlas (1549 kWh per year), Solar Med Atlas (1614 kWh per year), PVGIS (1436 kWh per year) and PVGIS CM-SAF (1643 kWh per year) photovoltaic electricity generation values are taken into account in the system installation, an average of 1560.5 kWh will be produced per year per 1 kW installed power. In this case, the annual electricity production of the 60 kW system:

- Annual FV Production (kWh) =Installed Power (kW) *Annual FV Production (kWh/1 kW)
- Annual FV Production=60*1560.5=93630 kWh
- Daily PV Production=93630/365= 256.5 kWh

According to the electricity tariffs table to be valid from 1/1/2024 approved by EMRA (2024), if the annual 91980 kWh electricity to be produced by the fv system is purchased from the supplier company, the cost will be as follows:

- Electricity tariff for agricultural irrigation is TRY 2.37 per kWh
- Up to 30 kWh per day for public and private services sector (900 kWh per month) TRY 2.79
- For the public and private services sector, over 30 kWh per day (over 900 kWh per month) TRY 3,70

Considering that 50% of the electricity consumed annually is used in agricultural irrigation (45990 kWh), 50% (45990 kWh) is used in the enterprise;

For consumption of 45990 kWh spent in agricultural irrigation;

45990*2.37=TRY 108996

When the 10800 kWh portion of the 45990 kWh electricity spent by the enterprise is calculated as TRY 2.79, the remaining 35190 kWh portion is calculated as TRY 3.70;

10800*2.79=TRY 30132

A total of TRY 269331 will be saved annually from 35190*3.70=TRY 130203.

3.6. Cost-Benefit Analysis

The average installation cost of the 60 kW PV system is approximately $50150. However, expenses such as periodic maintenance and cleaning of the panels are not included in this cost. However, considering that the life of the system is 25-30 years, there will be a decrease in the energy produced as the system efficiency will decrease depending on the years. However, it is inevitable that there will be an increase in energy prices.

The average installation cost of the 60 kW PV system is $50150, and the equivalent of 91980 kWh of electricity at the rate of $ (1$ = TRY 32) is $8416. Accordingly, the amortization period of the system is 50150/8416 = 5.96, which is approximately 6 years.

The carbon emissions generated for the purpose of electricity generation vary greatly from the primary source. While wind and solar energy attract attention as the source of electricity production that causes the least greenhouse gas emissions, lignite and coal are the primary sources that generate the most greenhouse gas emissions.

According to the greenhouse gas emission reduction calculations to be provided by the Turkish National Electricity Grid Emission Factor prepared by the Ministry of Energy, it is stated that 0.6488 tons of CO2 emissions will be avoided for every 1 MWh of electricity to be produced by solar or wind power plants (Ministry of Energy and Natural Resources, 2024). It generates 91980 kWh of electricity annually in Ayaş. Accordingly:

0.6488 tons of CO_2/MWh* 91.980 MWh=**59.7** CO_2 emissions will be avoided.

As a result of these calculations:

According to different sources, the annual solar energy potential of Ayaş is 1628 kWh/m^2 on average. This is quite a high value and indicates that the solar energy potential of the region is quite high. High solar energy potential can increase the efficiency of solar energy systems and improve the return on investment.

The cost of the 60 kW fv system is $50150, and the annual electricity production is 91980 kWh. The high annual production of this system is an important indicator of the efficiency and profitability of the investment. High annual production increases the system's potential in electricity generation and thus its revenue. An annual generation such as 91980 kWh constitutes a significant part of the amount of electricity provided by the system, which increases the potential of the system owner to generate electricity revenue.

The amortization period of the system is 6 years. Determining the amortization period as 6 years shows how long the investment will take to deduct its cost and turn it into profit. amortization period refers to the return period of the investment. That is, when the system covers its cost within 6 years, the revenue generated in the following years is purely profit. This accelerates the profitability and return of the investment. The amortization period of 6 years is generally a very competitive period for photovoltaic systems. A shorter amortization period allows for a faster return on investment and accelerates the investor's process of turning a profit. Therefore, the realization of amortization in a period of 6 years indicates that this system can be an economically sound and attractive investment. This shows that solar energy systems are an economically attractive option and can provide significant savings in the long term.

59.7 tons of CO2 emission will be avoided annually. This is a very significant environmental impact. Photovoltaic systems are technological systems that convert sunlight into electrical energy. These systems receive sunlight through solar panels and generate electricity through semiconductor materials in photovoltaic cells. This process, unlike traditional energy production methods based on fossil fuels, does not cause greenhouse gas emissions or produces very small amounts of emissions. Traditional energy production methods cause large amounts of carbon dioxide and other greenhouse gases to be released into the atmosphere during the combustion of fossil fuels. These greenhouse gases accumulate in the atmosphere, creating a greenhouse effect and contributing to climate change. However, the use of photovoltaic systems can significantly reduce or eliminate these greenhouse gas emissions. No fuel is required to be burned during the operation of photovoltaic systems and no harmful emissions to the atmosphere are released during operation. That is, solar-powered photovoltaic systems do not directly cause any negative effects on the environment. Therefore, the use of photovoltaic systems is an important step in terms of environmental sustainability and an effective tool in combating climate change. With the use of photovoltaic systems, it contributes to the reduction of greenhouse gas emissions and the prevention of carbon dioxide emissions in energy production. This shows that photovoltaic systems not only provide energy security and economic benefits, but also play an important role in terms of environmental protection and combating climate change.

5. Conclusion

This study was carried out to evaluate the solar energy potential in the Ayas region, analyze the production performance of the existing 60 kWp photovoltaic system and evaluate the cost-effectiveness of the system. As a result of the study, the following results were obtained:

- The lifetime of the system is at least 25 years (25-30 years); The lifetime of photovoltaic systems is usually determined to be at least 25-30 years. This longevity increases the long-term profitability of the investment and ensures the sustainability of the systems.
- Solar energy, a clean, non-exhaustible and sustainable energy source, is a clean, inexhaustible and sustainable energy source. Sunlight is provided free of charge every day, and the use of this resource relies on a limited and environmentally friendly resource, such as fossil fuels.
- Lack of raw material expenses for production; lack of raw material expenses for the production of solar energy systems contributes to the reduction of environmental impacts and helps protect natural resources.
- It is not affected by the increase in energy supply security and energy prices; Solar energy systems use locally produced energy and therefore increase energy supply security. Furthermore, electricity from solar power systems is not affected by fluctuations in energy prices, thus making energy costs more predictable.
- Since it will reduce greenhouse gas emissions, its positive impact on climate change and global warming; the use of solar energy systems contributes to the reduction of greenhouse gas emissions. This plays an important role in combating environmental problems such as climate change and global warming.

As a result, the installation of solar power systems is very useful in terms of economic, environmental and energy supply security. These systems provide a clean and sustainable energy source, operate without raw material costs, increase energy supply security, and reduce environmental impacts by reducing greenhouse gas emissions. Therefore, the use of solar power systems is an important step towards a sustainable energy future..

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	H.Y.Ö.	R.Ö.
C	50	50
D	60	40
S		100
DCP	70	30
DAI	50	50
L	60	40
W	70	30
CR	30	70
SR	50	50
PM	40	60

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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