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Technical and Economic Analysis of Electricity Production with Solar Panels: Bursa Example[A]

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Abstract: Nowadays, technology is rapidly evolving. The overuse and adverse effects of fossil fuels have also accelerated the work in the field of renewable energy. Considering that the sun is an endless source of energy, it is inevitable to produce clean and sustainable power. In this case, the use of photovoltaic facilities by small and medium-sized enterprises is also economically effective. To this end, world states constitute various incentive mechanisms. Monocrystalline and polycrystalline panels are commonly used in photovoltaic plants. In this study, considering various incentive mechanisms samples were examined a photovoltaic plant in Turkey. In addition, the technical and economic analysis of electrical energy production from the photovoltaic solar power plant was conducted. In this study, technical and economic analysis of a 23 kW photovoltaic plant to be installed in small and medium enterprises in Bursa province, which is obtained from our country market, has been examined. From the technical point of view, the annual energy production obtained from the plant consisting of monocrystalline panels varied between 28081 kWhyear^{-1} and 32239 kWhyear^{-1} and the total energy production obtained during the economic life varied between 617838 kWhxyear^{-1} and 709250 kWhxyear^{-1}. Annual energy generation from the plant consisting of polycrystalline panels was between 26209 kWhyear^{-1} and 31886 kWhyear^{-1} and the total energy production was between 524179 kWhxyear^{-1} and 637720 kWhyear^{-1} and less than the monocrystalline plant.

Keywords: Cost, energy, photovoltaic, renewable, solar.

[A] This study was produced from Tuğba Biçen's Master Thesis. No ethics commission permission is required in this manuscript. The manuscript has been prepared in accordance with publication and research ethics.

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Güneş Panelleri İle Elektrik Üretiminin Teknik ve Ekonomik Analizi: Bursa Örneği

Öz: Günümüzde teknoloji hızla gelişiyor. Fosil yakıtların aşırı kullanımı ve olumsuz etkileri de yenilenebilir enerji alanındaki çalışmaları hızlandırmıştır. Güneşin sonsuz bir enerji kaynağı olduğu düşünüldüğünde, temiz ve sürdürülebilir enerji üretmek kaçınılmazdır. Bu durumda, fotovoltaik tesislerin küçük ve orta ölçekli işletmeler tarafından kullanılması da ekonomik olarak etkilidir. Bu amaçla dünya devletleri çeşitli teşvik mekanizmaları oluşturmaktadır. Monokristalin ve polikristalin paneller, fotovoltaik tesislerde yaygın olarak kullanılmaktadır. Bu çalışmada, çeşitli teşvik mekanizmaları göz önünde bulundurularak Türkiye'deki bir fotovoltaik tesis örnekleri incelenmiştir. Ayrıca fotovoltaik güneş enerjisi santralinden elektrik enerjisi üretiminin teknik ve ekonomik analizi yapılmıştır. Bu çalışmada, Bursa ilinde küçük ve orta ölçekli işletmelerde kurulacak olan 23 kW'lık bir fotovoltaik santralin ülke pazarından temin edilerek teknik ve ekonomik analizi incelenmiştir. Teknik açıdan bakıldığında monokristal panellerden oluşan tesisten elde edilen yıllık enerji üretimi 28081 kWhyıl^{-1} ile 32239 kWhyıl^{-1} arasında, ekonomik ömür boyunca elde edilen toplam enerji üretimi ise 617838 kWhxyıl^{-1} ile 709250 kWhxyıl^{-1} arasında değişmektedir. Polikristal panellerden oluşan tesisten yıllık enerji üretimi 26209 kWhyıl^{-1} ile 31886 kWhyıl^{-1} arasında, toplam enerji üretimi ise 524179 kWhxyıl^{-1} ile 637720 kWhyıl^{-1} arasında ve monokristal santrale göre daha az olmuştur.

Anahtar Kelimeler: Maliyet, enerji, fotovoltaik, yenilenebilir, güneş.

Introduction

Today, the world population is increasing. Due to this increase in population, the reserves of fossil energy resources are gradually decreasing, harmful wastes are released into the atmosphere and, such events as global climate change occur at the same time. The dependence of the world on fossil fuels to meet the demands of energy results in high CO_2 emissions, air pollution and greenhouse gases (Dinçer, 2011; Magazzino et al., 2021; Ayhan Arslan et al., 2021). While many developed and developing countries take various measures to get under control these negative impacts within certain limits, they try to minimize the problems of climatic and fossil energy by turning to renewable energy sources and increasing their efficiency (Hua et al., 2016; Jeong et al., 2018).

When renewable energy is thought as globally, carbon dioxide emissions which are because of energy-related, from fossil fuels and industry remained almost constant due to a decrease in coal use worldwide, increased energy efficiency and the use of renewable energy in 2016 (UNECE, 2017). It is observed that developed and developing countries have strengthened their infrastructure by implementing renewable energy policies. While renewable energy accounted for 18.2% of the total global energy consumption in 2016, modern renewable energy accounted for approximately 10.4% (REN, 2018). In recent years, there have been significant increases in renewable energy capacity, which is a part of the energy sector. This increase of capacity is also supported by the intervention carried out by private sectors (Han et al., 2021). Such as The United States (USA), Germany, China and India promote the use of renewable energy sources through the private sector and sign protocols in this context and formwork plans (REN, 2016).

Although Turkey is a poor country on fossil energy sources, it has rich renewable energy sources. Import dependency in Turkey is in progress (Gençoğlu, 2002; Taşkın and Vardar, 2021). Use of renewable energy in Turkey is supported by the government and private sector policies in recent years. “Energy efficiency law” was enacted, 2007, in order to increase awareness about energy and to provide energy production, distribution and consumption with the correct applications. Then “The Energy Efficiency Strategy Document” came into force in 2012 (Book, 2016). The main purpose of energy policies was to meet the energy requirements of the increasing population and the economy with the least cost (Çapik et al., 2012).

The total installed capacity of renewable energy resources in Turkey increased from 13607 MW in 2007 to 38908 MW in 2017 (Anonymous, 2018). The end of 30 June 2018, Turkey's total electrical power is 87138 MW which is composed of 46443 MW renewable energy sources (Anonymous, 2018a).

Influenced by the progress experienced in solar energy technology in the world it has also accelerated the case studies in this area of Turkey. Though capacity which was installed is 4980 MW, electricity generated from solar energy in Turkey is 7508 GWh the end of November 2018 (Anonymous, 2018b). As in many countries, there are mechanisms to support solar power plants in Turkey along with other renewable energy facilities. Among these prominent support mechanisms are agricultural supports, development agencies, Small and Medium Enterprises Development (KOSGEB) etc. organizations. Moreover, the Agricultural and Rural Development Support Institution (TKDK), which supports EU projects, is one of the important mechanisms in this regard.

The aim of this study was to make a technical and economic analysis of electrical energy which can be obtained from photovoltaic plants which can be installed in small and medium enterprises by taking into consideration various incentive mechanisms in Bursa province. In this context, the solar energy characteristics of the region have been determined. Then, a sample solar power plant was taken into consideration and energy production parameters were determined. When the monocrystalline and polycrystalline solar panels are used in the sample plant, we investigated the total production costs and the cost of the facility.

Materials and Methods

In this study, the photovoltaic plant which is produced by the support of Bursa Eskişehir Bilecik Development Agency (BEBKA) in the Mediha Hayri Çelik Science High School (MHCFL) located in İnegöl was taken as an example. Bursa Uludag University (BUU) meteorological station and the General Directorate of Meteorology (MGM) Osmangazi meteorological station data on solar radiation was obtained. The solar radiation meter (pyranometer) and data logging equipment at the BUU meteorological station were used. In the study, daily, monthly and annual average solar radiation intensity was calculated by using 2016 and 2017 solar radiation intensities obtained from the meteorology station in BUU Faculty of Agriculture Research and Application Farm (40° 13´ 41.3112" and 28° 51´ 39.0708").

Arithmetic mean equation was used in the calculation:

$$\text{Arithmetic Average} = \text{Total of Terms}/\text{Number of Terms} \quad (1)$$

The amount of energy that solar panels can produce is calculated by the following equation (Mertens, 2011):

$$E = I(Wm^{-2}) \cdot A(m^2) \cdot t(h) \cdot \eta \quad (2)$$

Turkey applied to 0.133 $ of 1 kWh (Anonymous, 2005) energy purchase price for solar power plants. However, since the cost analysis was calculated over Euro, 1 kWh was calculated as 0.1142 €.

Total electricity generation and total revenue for the polycrystalline plant are calculated as follows:

Annual energy production x 20 years = Total energy production

Annual energy production x 20 years x 0.1142 € = Total income

If the plant is monocrystalline, total electricity generation and total revenue are calculated as follows:

Annual energy generation x 22 years = Total energy production

Annual power generation x 22 years x 0.1142 € = Total income

The self-repayment period of the system was found with the following equation:

$$\text{Payback Period} = \text{Total System Cost}/\text{Annual Income} \quad (3)$$

As a result of the data obtained from the calculations, if the facility in the MHCFL, which is supported by BEBKA, is established in small and medium enterprises under the current conditions, the cost of the system is analyzed with many different scenarios. The equation used in the calculation of credit costs is given below (Okka, 2006):

$$A = P \cdot [((1+i)^n \cdot i)/((1+i)^n - 1)] \quad (4)$$

Table 1. Scenario definitions

Scenario	State Support Rate	Credit Status	Loan Interest Status
A1	%0	-	-
A2	%0	√	%1
A3	%0	√	%2
A4	%0	√	%3
B1	%50	-	-
B2	%50	√	%1
B3	%50	√	%2
B4	%50	√	%3
C1	%75	-	-
C2	%75	√	%1
C3	%75	√	%2
C4	%75	√	%3

In A1, B1 and C1 scenarios, it is accepted that the investor does not use credit. In the scenarios A2, B2, and C2, the investor used a 1% interest rate loan. In A3, B3 and C3 scenarios, the investor received 2% interest. In the A4, B4 and C4 scenarios, the investor is assumed to use a loan with an interest rate of 3%. In terms of state support; In the scenarios A, the investor does not receive support from the government; In the B scenarios, the investor received 50% support from the government and in the C scenarios it was accepted that the investor received 75% support from the government (Table 1).

Results and Discussion

The average solar radiation intensity taken from BUU meteorological station and MGM Osmangazi meteorological station are compared annually and the hours of sunshine obtained from MGM Osmangazi meteorological station in 2016 and 2017 are shown in graphs. Afterward, a sample solar power plant was taken into consideration and energy production and cost analysis of the plants by using monocrystalline and polycrystalline solar panels were performed. The obtained data were given as tables and figures.

The average monthly hours of sunshine for 2016 and 2017 in Bursa province taken from the General Directorate of Meteorology are shown in Figure 1.

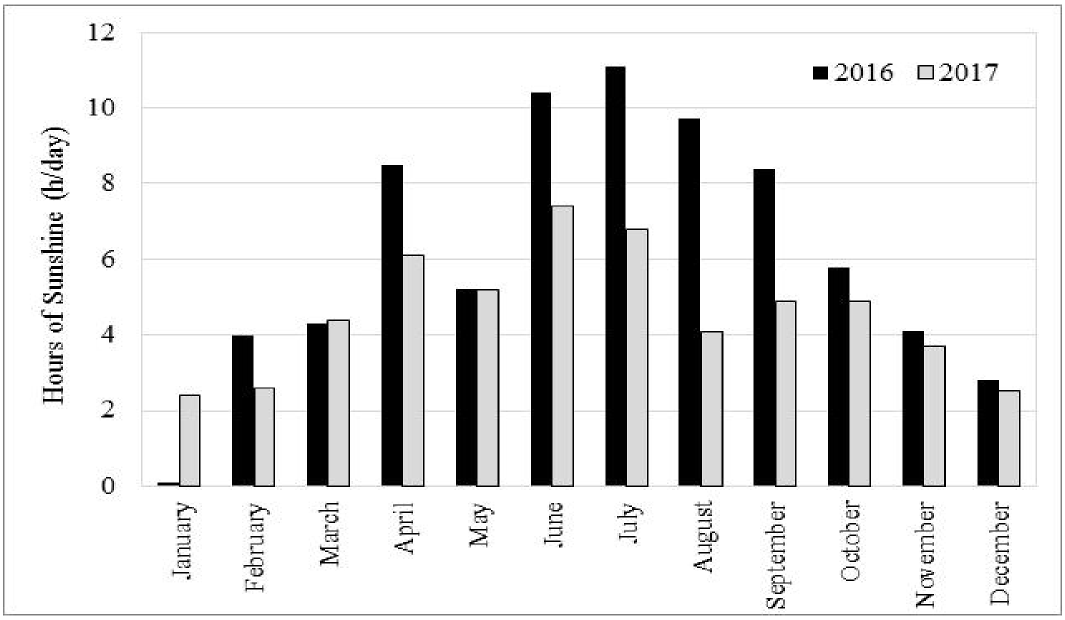

Figure 1. *Hours of sunshine in Bursa (hour/day)*

In 2016, Bursa has the highest sunshine duration with an average of 11.1 hours/day in July, while the lowest average sunshine duration is 0.1 hd^{-1} in January. The highest sunshine duration in Bursa in 2017 was determined as 7.4 hd^{-1} in June and the average sunshine duration on average was 2.4 hd^{-1} in January.

The solar radiation intensity (Wm^{-2}) and calculated solar energy (kWhm^{-2}) values obtained from the pyranometer in the meteorological station located on the BUU Görükle campus were given below (Figure 2).

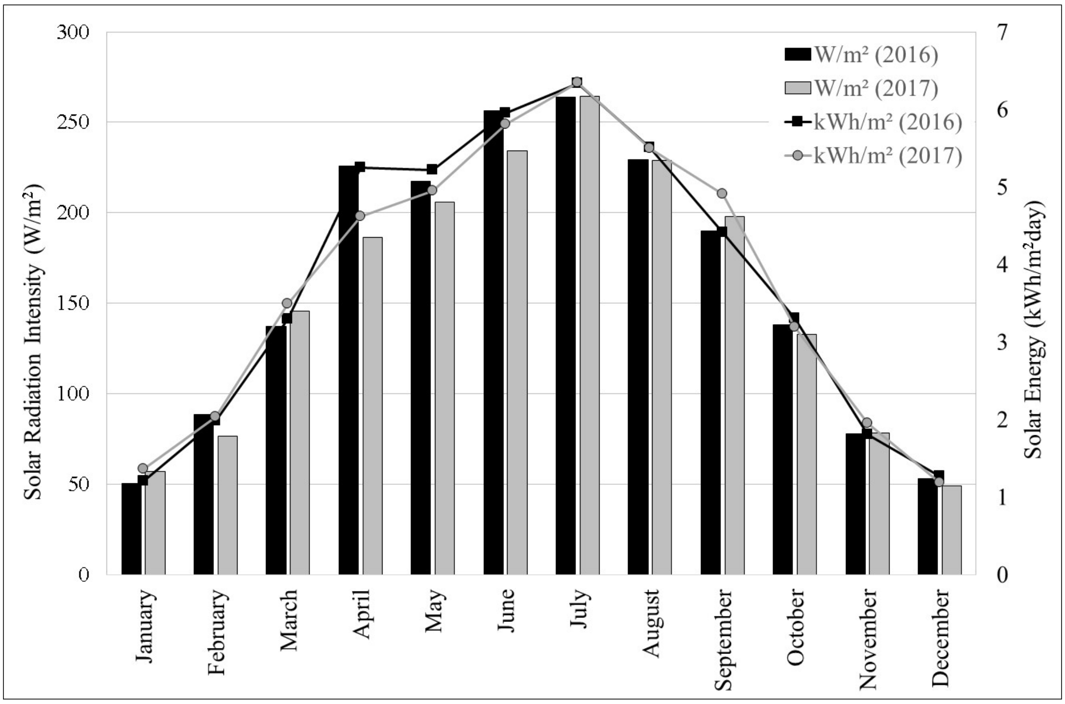

Figure 2. *Solar radiation density and potential solar energy distribution*

According to the data which is made up of monthly solar radiation density in 2016, the highest solar radiation was 263.8 Wm^{-2} in July and the lowest solar radiation density was 50.2 Wm^{-2} in January. In 2017, the highest solar radiation density was 264.3 Wm^{-2} in July and the lowest solar radiation density was 49.3 Wm^{-2} in December. According to the data which is composed of monthly solar radiation density in 2016, the highest solar radiation was 6.3 kWhm^{-2} in July and the lowest solar radiation density in January was 1.2 kWhm^{-2}day^{-1}. According to those of in 2017, the highest solar radiation density was 6.3 kWhm^{-2}day^{-1} in July while the lowest solar radiation density was 1.2 kWhm^{-2}day^{-1} in December.

The solar energy intensity (Wm^{-2}) and calculated solar energy values obtained from Solar energy potential atlas (GEPA), BUU meteorological station and MGM Osmangazi meteorological station were given below. Figure 3 showed the solar radiation intensity and the potential solar energy (kWhm^{-2}day^{-1}) in Figure 4.

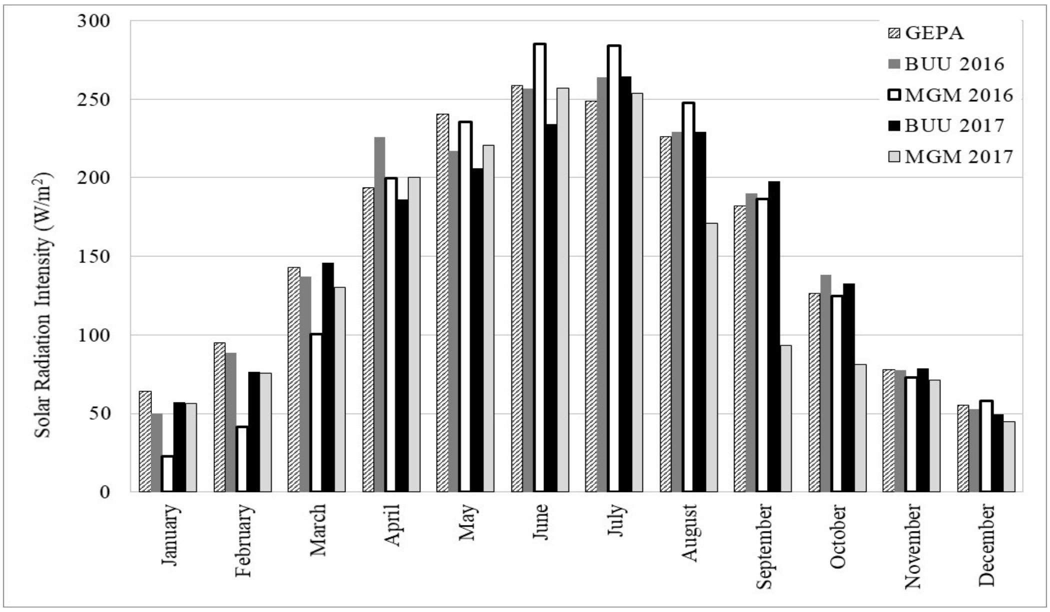

Figure 3. *Comparison of solar radiation intensity values*

In the comparison with the obtained solar radiation intensity values (Figure 3), the highest value of data of GEPA was 258.3 Wm^{-2} in June and the lowest value was 55 Wm^{-2} in December. When the those of BUU meteorological station were examined, the maximum solar radiation intensity in 2016 and 2017 was determined as 264.3 Wm^{-2} in July. In 2016, the lowest value was 50.2 Wm^{-2} in January and the lowest in 2017 was 49.3 Wm^{-2} in December. In the data obtained from the MGM Osmangazi meteorological station, the highest radiation intensity was 285 Wm^{-2} and 257 Wm^{-2} in 2016 and 2017, respectively. The lowest solar radiation value at the MGM Osmangazi meteorological station was 23 Wm^{-2} in January 2016 and 45 Wm^{-2} in December 2017.

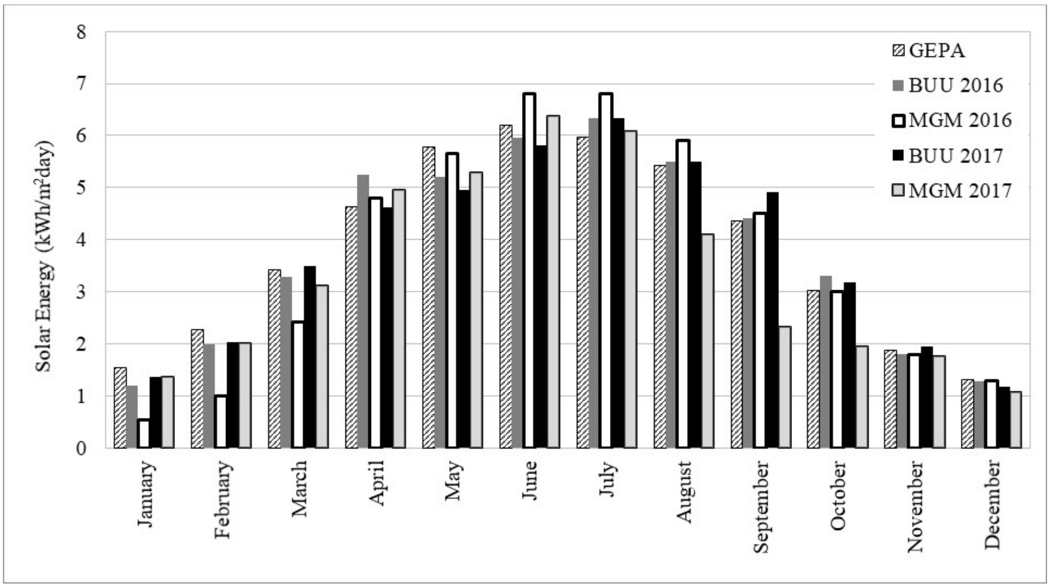

Figure 4. *Potential solar energy distribution*

In the comparison of the calculated potential solar energy, the highest value reached by the data of MGM was 6.8 kWhm^{-2}day^{-1} in June and the lowest value was 1.3 kWhm^{-2}day^{-1} in December. When the those of BUU meteorological station were examined, monthly solar radiation energy of 2016 and 2017 was determined as 6.3 kWhm^{-2}day^{-1} in July. The lowest value of 2016 was 1.2 kWhm^{-2} in January and the lowest in 2017 was 1.2 kWm^{-2} in December.

According to the data obtained from the MGM Osmangazi meteorological station, the highest potential solar energy was 6.8 kWhm^{-2}day^{-1} in June and July 2016, and in June 2017 it was 6.4 kWhm^{-2}day^{-1}. The lowest potential solar energy value was 0.54 kWhm^{-2} in January and 1.1 kWhm^{-2} in December 2017.

Electricity generation values of solar plants

Electricity production values which can be obtained from two different solar power plants consisting of polycrystalline and monocrystalline photovoltaic panels, which was obtained from the MGM Osmangazi meteorological station and BUU meteorological station, were examined by using the solar radiation data in 2016 and 2017.

Figure 5 showed the comparison of the electricity generation values of the plant consisting of polycrystalline panels and the monocrystalline panels in Figure 6.

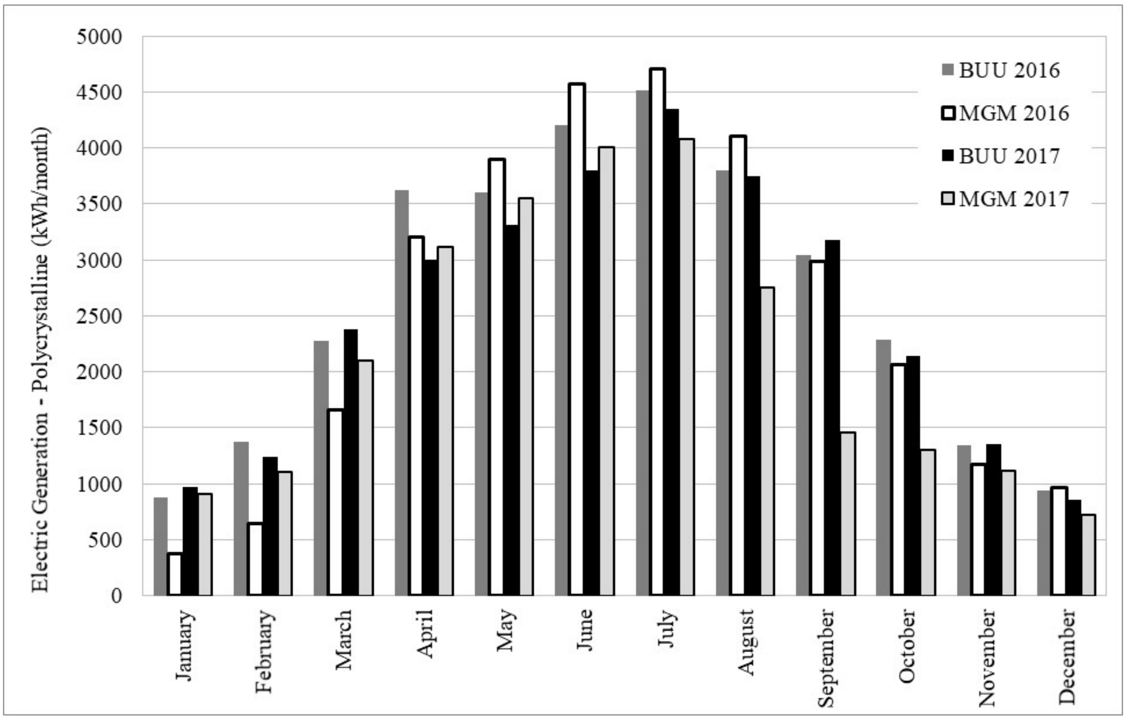

Figure 5. *Electricity generation of polycrystalline system*

When the electricity production values of the polycrystalline solar power plant were examined; MGM Osmangazi meteorological station according to the solar radiation values of 2016, the highest value was 4706 kWhmonth^{-1} and the lowest value belonged to January with 376 kWhmonth^{-1}. According to the data of BUU meteorological station, in 2016 the highest value was 4519 kWhmonth^{-1} and July, while the lowest value was 878 kWhmonth^{-1} in January. MGM Osmangazi meteorological station The highest value for 2017 data was 4081 kWhmonth^{-1} in July and the lowest value was 723 kWhmonth^{-1} in December. According to 2017 BUU meteorological station data, the highest value was obtained with 4346 kWhmonth^{-1} in July and the lowest value with 853 kWhmonth^{-1} was obtained in December.

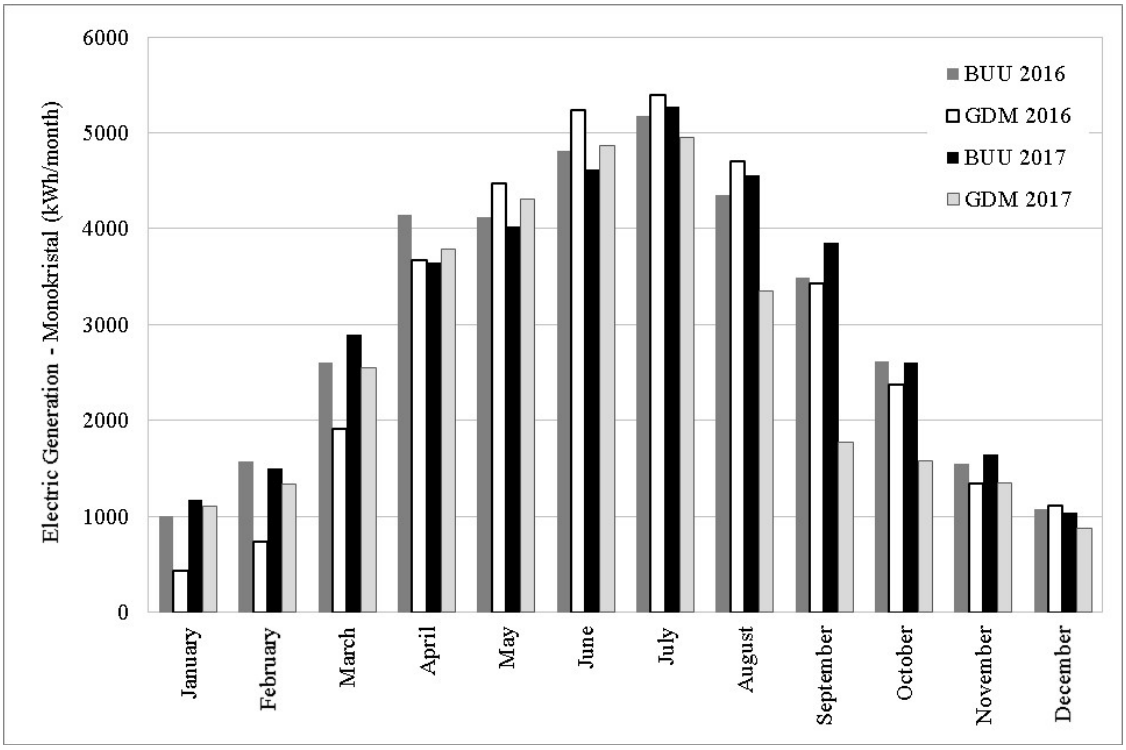

Figure 6. *Electricity generation of monocrystalline solar power plant*

When electricity production values of the monocrystalline solar power plant were examined; According to the solar radiation values of the MGM Osmangazi meteorological station in 2016, the highest value was 5392 kWhmonth^{-1} and the lowest value was 431 kWhmonth^{-1} and January. According to the data of BUU meteorological station, in 2016, the highest value was 5177 kWhmonth^{-1} and July, while the lowest value was 1066 kWhmonth^{-1} in January. MGM Osmangazi meteorological station The highest value for 2017 was 4955 kWhmonth^{-1} in July and the lowest value was 878 kWhmonth^{-1} in December. According to 2017 BUU meteorological station data, the highest value was obtained with 5278 kWhmonth^{-1} in July while the lowest value was determined with 1036 kWhmonth^{-1} in December.

Economic analysis of solar plants

The installation costs of two different solar installations in 2018 were determined as 0.99 €Wp^{-1} for the monocrystalline panel and 0.95 €Wp^{-1} for the polycrystalline panel as a result of market research. Üçgül et al. (Üçgül et al., 2014), PV equipment costs 1.25 €Wp^{-1}, supporting structures and installation costs 0.037 €Wp^{-1} and the total cost of the system was 1.29 €Wp^{-1}.

Since the total installed power of both the monocrystal and polycrystal solar power plant was 23 kW, total installation costs were 22770 € for the plant by using monocrystal panels and 21850 € for the plant by using polycrystal panels. Support mechanisms and bank loans were taken into consideration. And the actual costs for each scenario were given in Table 2.

Table 2. System setup costs (€) according to different scenarios

Scenario	Support Rate	Interest	Monocrystalline	Polycrystalline
A1	%0	%0	22770	21850
A2		%1	30390	29162
A3		%2	39303	37715
A4		%3	49365	47370
B1	%50	%0	11385	10925
B2		%1	15195	14581
B3		%2	19651	18857
B4		%3	24682	23685
C1	%75	%0	5693	5463
C2		%1	7598	7291
C3		%2	9826	9429
C4		%3	12341	11843

As shown in Table 2, in case of using bank credit only without receiving government support; As the loan interest rate increased, the cost of the power plant with monocrystalline panels increased from 22770 € to 49365 € and the cost of the power plant with polycrystalline panels increased from 21850 € to 47370 €. 50% of state support; depending on the loan interest rate, the cost of the monocrystalline power plant with a monocrystalline power plant was between 11385 € and 24682 € and the cost of the power plant with a polycrystalline panel varies between 10925 € and 23685 €. In case of 75% state support; Depending on the loan interest rate, the cost of the monocrystalline power plant was between 5693 € and 12341 € and the cost of the power plant with polycrystalline panels varies between 5463 € and 11843 €.

Considering the data of solar irradiation and hours of sunshine taken from the meteorological station of BUU and taken from MGM Osmangazi meteorological station in 2016 and 2017; The annual and total energy production results were obtained from the solar energy plant by using the monocrystalline panel and the solar power plant using the polycrystalline panel, and the total and annual revenues to be obtained from these plants were presented in Table 3.

Table 3. Annual energy production and annual revenues of facilities

		Annual Power Generation	Total Power Generation	Annual Revenue	Total Income
		kWhyear^{-1}	**kWh xyear^{-1}***	**€ xyear^{-1}**	**€year^{-1}**
BUU Monocrystalline	2016	32239	709250	3682	80996
	2017	32503	715067	3712	81661
MGM Monocrystalline	2016	30691	675206	3505	77109
	2017	28081	617838	3207	70557
BUU Polycrystalline	2016	31886	637720	3641	72828
	2017	30333	606669	3464	69282
MGM Polycrystalline	2016	30355	607110	3647	69332
	2017	26209	524179	2993	59861

* x yıl = ekonomik ömür

As can be seen in Table 3, the annual energy production in the monocrystalline energy production plant was between 28081 kWhyear^{-1} and 32239 kWhyear^{-1} and in the polycrystalline energy production plant was between 26209 kWhyear^{-1} and 31886 kWhyear^{-1}. The annual income was between 3207 € and 3682 € in the monocrystalline energy production plant and it was between 2993 € and 3641 € in the polycrystalline energy production facility. Considering total energy production; In the monocrystalline energy production plant, between 617838 kWhxyear^{-1} and 709250 kWhxyear^{-1}, it was determined between 524179 kWhxyear^{-1} and 637720 kWhyear^{-1} in the polycrystalline energy production plant. In the monocrystalline energy production facility, the total income to be obtained during the economic life was between 70557 € and 80996 €, and it was between 59861 € and 72828 € at the polycrystalline energy production plant.

Considering the data obtained from the meteorological station of the BUU and the solar irradiation and solar times taken from the MGM Osmangazi meteorological station in 2016 and 2017 with cost scenarios; The total cost of the total income from the solar power plant by using the monocrystalline panel and from the solar power plant by using the polycrystalline panel was given in Table 4 below.

Table 4. Payback periods for systems (years)

		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
BUU Monocrystalline	**2016**	6.2	8.3	10.7	13.4	3.1	4.1	5.3	6.7	1.5	2.1	2.7	3.4
	2017	6.1	8.2	10.6	13.3	3.1	4.1	5.3	6.6	1.5	2.0	2.6	3.3
MGM Monocrystalline	**2016**	6.5	8.7	11.2	14.1	3.2	4.3	5.6	7.0	1.6	2.2	2.8	3.5
	2017	7.1	9.5	12.3	15.4	3.5	4.7	6.1	6.7	1.8	2.4	3.1	3.8
BUU Polycrystalline	**2016**	6.0	8.0	10.4	13.0	3.0	4.0	5.2	6.4	1.5	2.0	2.6	3.3
	2017	6.3	8.4	10.9	13.7	3.2	4.2	5.4	6.8	1.6	2.1	2.7	3.4
MGM Polycrystalline	**2016**	6.3	8.4	10.9	13.7	3.2	4.2	5.4	7.4	1.6	2.1	2.7	3.4
	2017	7.3	9.7	12.6	15.8	3.7	4.9	6.3	6.5	1.8	2.4	3.2	4.0

For the solar power plant using the monocrystalline panel; In the scenarios where there was no state support as seen in Table 4 and as expected (scenarios A), the reimbursement periods of the facility cost were higher than the other scenarios. In these conditions, the self-repayment period of the facility varies between 6.1 years and 15.4 years. In scenarios where government support was 50% (scenarios B), the self-repayment period of the facility was between 3.1 and 7 years. In scenarios with 75% of state support (C scenarios), the self-repayment periods of the facility were between 1.5 years and 3.8 years.

For solar power plants using the polycrystalline; In scenarios where there was no governmental support (scenarios A), the self-repayment period of the facility varied between 6 years and 15.8 years. In scenarios where state support was 50% (scenarios B), it was observed that the facility's payback times were between 3 years and 7.4 years. In scenarios with 75% of state support (C scenarios), the self-repayment period of the facility was found between 1.5 and 4 years.

According to the literature surveys of the photovoltaic facility, the reimbursement period of the photovoltaic facility was determined by Nacer et al. (Nacer et al., 2014) as 23 years, by Çiftçi et al. (Çiftçi et al., 2014) as 11 years, by Üçgül et al. as 14 years, by Büyükzeren et al. (Büyükzeren et al., 2015) produced as 5.1 years for scenario, as 4.8 years for scenario 2, by Taşkın and Vardar (Taşkın and Vardar, 2018) as 10-11 years and by Bilgili (Bilgili, 2018) as 6 years. It would be correct to compare photovoltaic plants at the same installed power values. Because as the installed power value changes, the costs do not change linearly.

Conclusion

As a result of the increasing energy demand in the world, the trend towards renewable energy sources has increased. Especially in developed and developing countries, photovoltaic technology, which is one of the renewable energy sources, is being carried forward and its usage areas are aimed to be expanded.

The efforts of world states to reduce photovoltaic market prices and increase photovoltaic power plants in clean energy production continue with various policies and strategies.

Population and economically strong countries aim to contribute to their economies by trying to solve the integrated problem of grid-connected systems in public institutions and organizations.

In this study, technical and economic analysis of a 23 kW photovoltaic plant to be installed in small and medium enterprises in Bursa province, which is obtained from our country market, has been examined. From the technical point of view, the annual energy production obtained from the plant consisting of monocrystalline panels varied between 28081 kWhyear^{-1} and 32239 kWhyear^{-1} and the total energy production obtained during the economic life varied between 617838 kWhxyear^{-1} and 709250 kWhxyear^{-1}.

Annual energy generation from the plant consisting of polycrystalline panels was between 26209 kWhyear^{-1} and 31886 kWhyear^{-1} and the total energy production was between 524179 kWhxyear^{-1} and 637720 kWhyear^{-1} and less than the monocrystalline plant.

In terms of cost, polycrystalline solar energy plant was more economical than monocrystalline solar energy plant. The cost of a monocrystalline solar energy plant was 22770 €, while the cost of a polycrystalline solar power plant was 21850 €. When the self-repayment periods of the facilities were considered without government support (scenario A), the monocrystalline facility was self-repaid for at least 6.1 years because of the economic life of the facilities. Payback periods fall when it comes to government support. This is the main reason why the developed countries subsidize photovoltaic technology.

When the results obtained in the study were evaluated, it was seen that solar power plants were sustainable without an incentive mechanism. Considering the reduction of costs over time and the development of technology, incentive mechanisms may be less needed in the future. However, it was important to subsidize the photovoltaic technology, which is expected to be one of the future energy production technologies in today's conditions.

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Research and Publication Ethics were followed in this study.

NOMENCLATURE

E : Energy, kWh

I : Solar radiation (Wm^{-1})

A : Surface area (m^2)

t : Hours of sunshine (h)

η : Yield

A_i : Installment (€)

P : Debt amount (€)

i : İnterest

n : number of installments

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