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Yozgat Bozok University Solar Power Plant, Power, Cost and Depreciation Period Calculation

Talip Çay[1a*], Mustafa Yaz[2a], Cemil Altın[2b]
[1]Yozgat Bozok University, Graduate Education Institute, Yozgat/ Turkey
talip.cay@gmail.com, ORCID: 0000-0002-5490-1651
[2]Yozgat Bozok University, Faculty Of Engineering and Architecture, Electrical and Electronics Engineering Department Yozgat/ Turkey
mustafa.yaz@bozok.edu.tr, ORCID: 0000-0001-7042-7649,
cemil.altin@bozok.edu.tr, ORCID: 0000-0001-8892-2795

Abstract: Most of the energy in our world is met by fossil fuels. It is a disadvantage for fossil fuels that rapid depletion of fossil fuel reserves and not environmentally friendly. Therefore, especially in the last 20 years, countries have directed their investments to renewable energy resources that are cheap, environmentally friendly, low maintenance costs and reduce foreign dependency. The use of RES in our country is below the world average. In this study, SPP (Solar Power Plant) power, cost and depreciation period were calculated by looking at the annual electricity consumption amount of YOBU (Yozgat Bozok University) in 2019 and the incentive charts in the law numbered 5346.

Keywords: Renewable energy, Solar power plant, YOBU, SPP cost calculation.

Yozgat Bozok Üniversitesi Güneş Enerji Santrali Güç, Maliyet ve Amortisman Süresi Hesabı

Özet: Dünyamızda enerjinin büyük bölümünün fosil yakıtlardan karşılanmaktadır. Fosil yakıt rezervlerinin hızla tükenmesi ve çevre dostu olmamaları fosil yakıtlar için dezavantajdır. Bu yüzden özellikle son 20 yılda ülkeler yatırımlarını ucuz, çevre dostu, bakım maliyeti düşük ve dışa bağımlılığı azaltan yenilenebilir enerji kaynaklarına yöneltmektedirler. Ülkemizde yenilenebilir enerji kaynaklarının kullanılması Dünya ortalamasının altındadır. Bu çalışmada 2019 yılı YOBU (Yozgat Bozok Üniversitesi) yıllık elektrik enerjisi yıllık tüketim miktarına ve 5346 sayılı kanunda bulunan teşvik cetvellerine bakılarak GES (Güneş Enerji Santrali) güç, maliyet ve amortisman süresi hesabı yapılmıştır.

Anahtar Kelimeler: Güneş Enerjisi, Şebekeden Bağımsız Fotovoltaik Sistem, Fotovoltaik Panel

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1. Introduction

Nowadays; energy costs, limited fossil fuels and increasing production needs are pushing humanity to renewable cheap energy supply. After the petroleum crisis in 1973, the importance of energy has begun to be understood by all the countries of the world. Countries have begun to look for various energy sources. After the 2000s, the search for alternative energy sources (renewable energy sources) has gained great momentum. Renewable energies; solar, wind, hydroelectric, geothermal, biomass, hydrogen energy. Renewable energy sources have advantages and disadvantages compared to other energy sources. Its main advantages are being environmentally friendly, low operating costs and being economical. Continuity and high initial investment costs are the main disadvantages of renewable energy sources.

2. Literature Review

E. Zarda et al. Presented the conceptual design of the first solar power plant using Direct Steam Generation (DSG) in a parabolic solar field. The experience and knowledge in the DSG process

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gained during the DISS project has been applied in the design of the solar energy field of this power plant. The 5-MW plant consists of a DSG parabolic corrugated solar field connected to a superheated steam power cycle. The sun area produces 410 ° C / 70 bar superheated steam. [1] Sebastijan Seme et al. Present a multi-criteria evaluation analysis of the optimum electricity price of solar power plants and small hydroelectric power plants. The aim of the study is to consider the technical and economic aspects of the investment in solar power plant and small hydro power plant construction. To achieve a 10-year payback period, a multi-criteria evaluation analysis showed that the reference price (41.94 € / kWh) for solar power plants increased 3.3 times and for small hydro plants 1.4 times. [3] Güntürk Mert, made cost analysis of the solar energy system in the Turkey Elazig province. In his study, the current value of the solar power plant was calculated as 1.156.763 USD and the annual capital cost as 1.181.875 USD. The capital cost flow of the solar power plant investment was determined at US $ 5,628 / h. The results obtained in his study were evaluated in a general framework. [4] T. Taner and A. S. Dalkılıç calculated the solar power plant and determined the profit as approximately 501.825 [$ / y]. The payback period in their studies was found to be 4.5 [y]. The aim of the study is to show that an efficient solar power plant can be built for Aksaray province. This study shows a very efficient result for establishing a solar power plant. [5] A. Carrion et al. Explain how to use the plant in the most suitable land for the location of solar power plants in accordance with legal, environmental and operational requirements for grid connected photovoltaic plants. As a result of the study, it is estimated to be 38,693 GWh / year for 164,495.37 ha of land. [6] O. Abedinia et al. Proposed a new prediction approach based on the combination of a neural network with a meta-heuristic algorithm as a hybrid prediction engine. The meta-heuristic algorithm optimizes the free parameters of the neural network. This approach also includes a 2-step feature selection filter based on knowledge-theoretical criteria of mutual knowledge and interaction gain, which filters out the ineffective input features. Test data sets are applied to show the effectiveness of the proposed estimation approach. The results show that the proposed approach is superior to other estimation methods. [7] D. Lauka et al. Predicted that the solar power plant they designed could generate 45 MWh of electricity in Lithuania in one year. It is estimated that this solar power plant will reduce the amount of CO2 emission in the atmosphere by 23.03 tons. [8] Imenes et al discussed the theory and application of a strategy based on flux mapping produced by ray tracing methods for the Multi Tower Solar Array central receiver system planned to be built in Newcastle, Australia. [9] V. Çoban discussed the application of AHP (Analytical Hierarchy Process) method in determining the most suitable project according to the criteria defined among alternative PV solar power plant projects proposed for solar energy investment. [10] Y. S. Isler and M. Salihmuhsin made a study on the choice of stand, which is one of the important factors affecting GES performance. Stand selection, one of the most important factors affecting the performance of solar power plants, was made by analyzing 5 different models. The energies produced by each model were recorded and parameters such as the variation of the produced energy per month and performance values were compared. [11th] Y. Alcan et al. Compared the electricity generation potential of Sinop with Germany in their study and the results were discussed. [12] In their study, S. Bahceci and F. Daldaban connected solar panels and energy storage system to 3 buses randomly selected in a 30-bar distribution network and investigated its effect on the distribution network. [13] F. Taktak and M. Ilı examined in detail the selection stage of the land, legal procedures, location evaluations, GES installation procedures and cost stages in the Uşak GES Project. In addition, SWOT evaluation was made during the project phase and studies were made to determine the appropriate location in the project. [16] According to the studies mentioned in the literature, how solar power plants will be more efficient, how to reduce the cost and different working techniques are mentioned. Figure 1 shows the distribution of our country's electrical energy production compared to other energy sources and Figure 2 shows the ratio of electrical energy production compared to other energy

sources. As can be seen, our country is below the world average in the use of renewable energy. In this study, solar power plant design is made according to the annual consumption data of Yozgat Bozok University central campus. Information about the land structure of the designed power plant, used panels, inverters, switch materials and additional costs will be given. In addition, an evaluation will be made about the additional income of the power plant.

3. Annual Solar Potential of Yozgat Bozok University

Figure 1 shows the distribution of our country's electrical energy production compared to other energy sources.

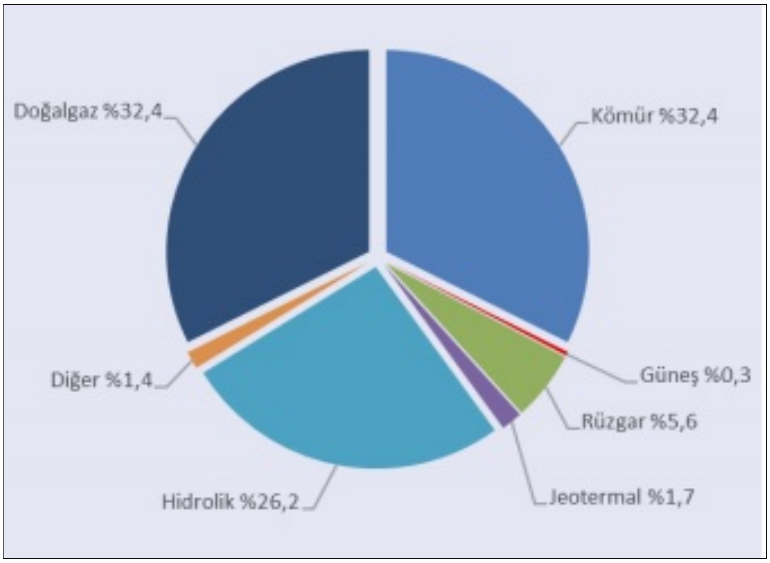

Figure 1. Power generation rates in Turkey[15]

According to Figure 1 Fossil fuel based electrical energy production is considerably higher than renewable energy sources. Figure 2 shows the ratio of electrical energy production compared to other energy sources.

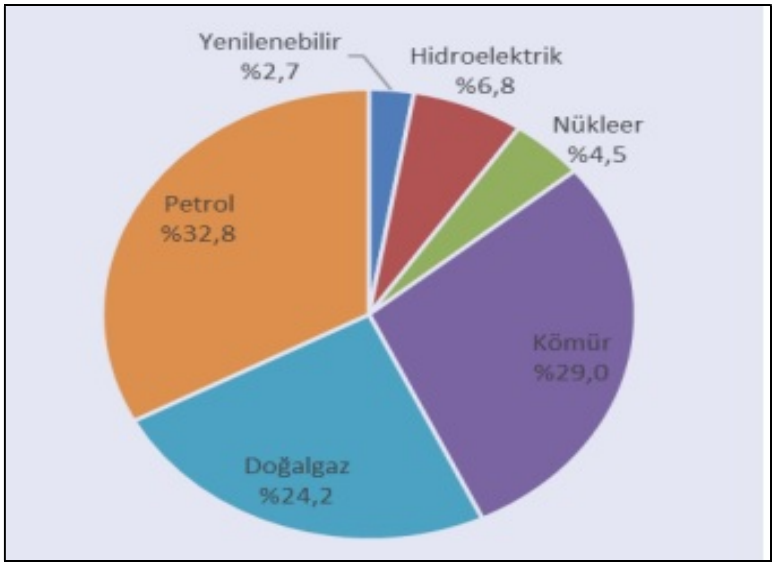

Figure 2. Power generation rates in the World[15]

As can be seen Figure 1 and Figure 2, our country is below the world average in the use of renewable energy. In this study, solar power plant design is made according to the annual consumption data of Yozgat Bozok University central campus. Information about the land structure of the designed power plant, used panels, inverters, switchgear and additional costs will be given. In addition, an evaluation will be made about the power plant return.

It is seen that our country is very advantageous compared to other countries in terms of solar energy due to its geographical location. According to the Solar Energy Potential Atlas, the annual sunshine in our country is 2.740 hours (7.5 hours a day on average), and the annual average solar energy is 1.530 kWh / m². [14] Our country is a productive country in terms of solar energy and the southern regions receive more solar energy. Location and climate differences are important points to consider in solar energy investment. In Figure 3, the annual solar energy potential of our country and in Figure 4, the annual solar energy potential belonging to the province of Yozgat are seen in terms of kWh / m2.

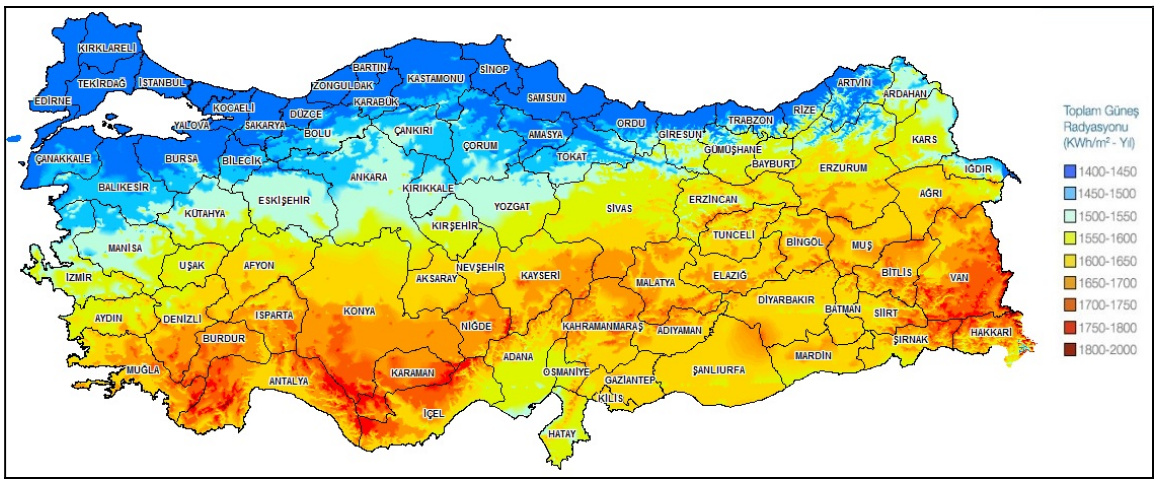

Figure 3. Annual Solar Energy potential of Turkey[2]

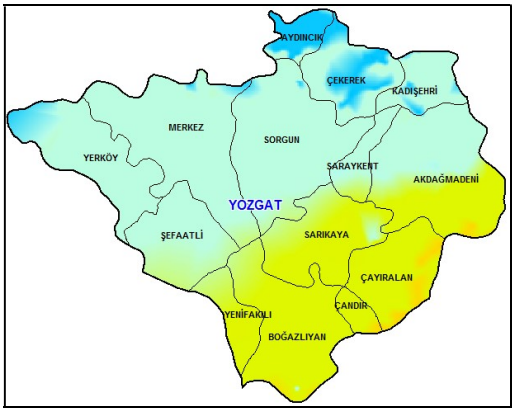

Figure 4. Annual Solar Energy potential of Yozgat[2]

Table 1. Solar Power Plants(SPP) active and under construction in Yozgat province

Active SPP's				
1)	Emrel Energy SPP	Boğazlıyan	Emrel Enerji	0,75 MW
2)	Practica Energy SPP	Boğazlıyan	Practica Enerji	0,75 MW
3)	Yenipazar SPP Irrigation Sys.	Boğazlıyan	Yenipazar Beld.	0,11 MW
Under construction SPP's				
1)	Yozgat SPP	Yozgat, Merkez		4,99 MW
2)	Doğankent Mun. SPP	Sorgun	Doğankent Mun.	1,00 MW
3)	Şefaatli Mun. SPP	Şefaatli	Şefaatli Mun.	1,00 MW
4)	Bahadın Mun. SPP	Sorgun	Bahadın Mun.	0,50 MW
5)	Çekerek Mun SPP	Çekerek	Çekerek Mun.	0,14 MW

According to the Photovoltaic Geographic Information System on the official website of the European Union, the energy information to be produced by a 1 KWh SPP in an area of 1 m2 in the main campus location of YOBU is given in Figure 5 and Table 2, monthly and annually.

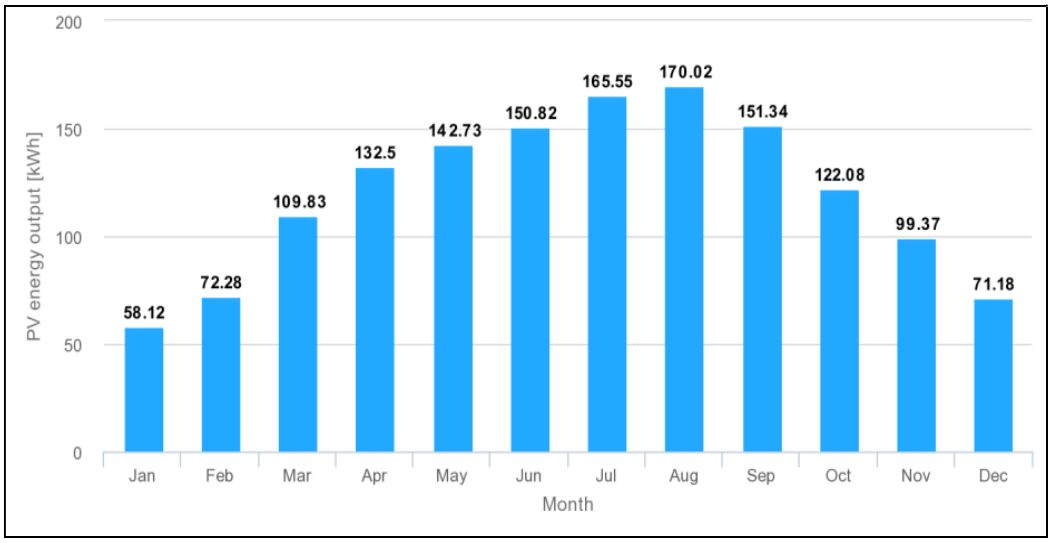

Figure 5. SPP monthly electricity energy generation belonging to YOBU location (kWh/m^2) [14]

As seen in Figure 5, the monthly generation amounts of SPPs are given in kWh / m2. There was a generation of 58.12 kWh / m2 in January, the lowest production, and 170.02 kWh / m2 in August, when the highest production was.

Table 2. SPP monthly electricity energy generation information belonging to YOBU location [14]

Location [lat/long]:	39.777, 34.797
PV technology:	Cristal Slicon
PV installed [kWp]:	1
Angle of inclination	35
Annual production [kWh]:	1445.83
Annual irradiation [kWh/m^2]:	1821.25

Year-to-year variability [kWh]:	50.27
Angle of incidence [%]:	-2.75
Spectral effects [%]:	0.39
Total loss [%]:	-20.61

Here, the point to be considered while calculating SPP; It is the calculation of a power plant that will meet all energy needs without the need for any external energy supply. While doing this, the calculation should be made by taking into account the month in which energy production is the lowest. If the calculation is made according to the lowest month, the consumption need will be met more in the other months. The excess energy produced can be included in the interconnected system thanks to a bidirectional counter.

4. SPP Power Calculation

According to the data of 2019, the annual electrical energy consumption in YOBU central campus is approximately 4,050,000 kWh. The monthly electrical energy consumption of YOBU central campus in January 2019 is approximately 390,000 kWh. While calculating the power plant, it is aimed to meet the entire consumption through the SPP to be installed without the need for an external electrical energy supplier. For this, the calculation should be based on the month (January) when the solar energy is the lowest. If the consumption need is met by SPP in January, the installed power of the power plant will meet the total annual consumption need. The data in Figure 6 and Table 3 emerges when a re-calculation process is performed with the YOBU location in the European Union Photovoltaic Geographical Information System.

Table 3. SPP installed power data [14]

location [lat / long] :	39.776, 34.797
PV technology :	Cristal silicon
PV installed [kWh]:	**6750**
Inclination angle	35
Approx. energy prod. [kWh]:	**9759485,1**
Annual irradiation [kWh/m^2]:	1821.36
İncidence angle [%]:	-2.75
Spectral effects [%]:	0.39
Total loss [%]:	-20.62

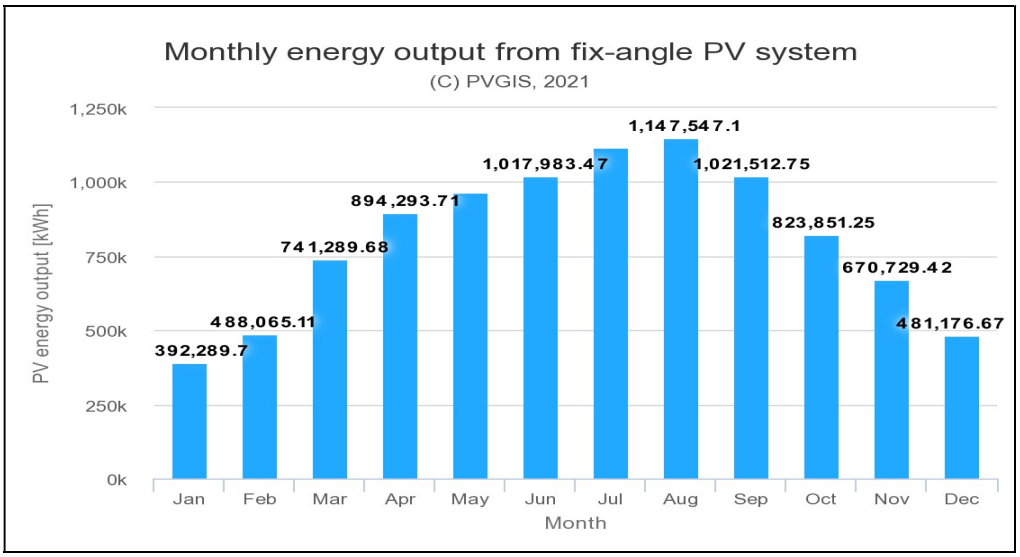

Figure 6. Monthly electrical energy production data of the last SPP with an installed capacity of 6750 MW [14]

Figure 6 shows the monthly generation data of a power plant with an installed power of 6750 kW (6.75 MW). As can be seen here, the January electrical energy generation data of the power plant with an installed power of 6750 kW is 392,289.7 kWh. This energy production data also corresponds to YOBU 2019 January consumption data. Therefore, the minimum installed power of the power plant designed for YOBU must be 6750 kW, which must meet the entire energy need from the GES to be installed without the need for an external energy supplier. Again, as can be seen in Table 3, the total energy that the plant will generate annually is approximately 9,759,485.1 kWh. It is seen that this energy expected to be produced is more than the amount of YOBU consumption in 2019 (4,050,000 kWh). Excess energy (kWh 5709485.1), will be sold to the Turkey Government at the price indicated in the State of Law No. 5346.

5. SPP Installation Cost

For SPPs with an installed power of 1 MW, an area of approximately 20000 m2 is required. The land conditions of the required area should be taken into consideration. In addition, as can be seen in Table 4, the list of materials to be needed in the power plant with an installed power of 6750 kW (6.75 MW) has been determined approximately.

Table 4. Cost and product list for the 6750 kW SPP

N.	Product	unit	Amount (~)
1	Photovoltaic Panel (270W, 38,3V, insurance 10 years)	unit	25000
2	50 KW (İnverters): (insurance 10 years)	unit	135
3	two-way electricity meter (3 phase)	unit	1
4	Pan system (with cover)	ton	5
5	1×6 mm^2 PVİ1-F cable (solar red-blue)	m	40500
6	5×16 mm^2 underground cable NYY MV+LV electrical panel (1 unit. 36 KV, transformer 10 KVA, 1 unit. Inverter	m	2700
7	15 KW, 1 un. separator 36 KV, 1 ad. residual current protection relay 4X63 A (300 mA), 1 un. automat 3×25 A)	unit	473

8	3×35 mm^2 XLPE (36 KV)	m	20250
9	35 mm XLPE head	unit	2875
10	16mm XLPE head	unit	958
11	100×10 mm^2 modular cell (copper busbar)	unit	5
12	1250 A voltage/current meas. cell (with load breaker)	unit	5
13	1250 A Transformer cell (with breaker)	unit	5
14	1250 A input/output cell	unit	5
15	Kiosk (concrete5 m)	unit	5
16	1×95mm^2 XLPE cable	m	7500
17	10 KVA transformer (dry type)	unit	350
18	one-way electricity meter (3 phase)	unit	1
19	residual current protection relay 4x63A (300 mA)	unit	750
20	3×63A NH fuse	unit	500
21	0,28 kV, 100 kA surge arrester (LV) (B+C)	unit	500
22	MV surge arrester	set	5
23	Grounding bracket (65x65x7) 1,5 m	unit	1500
24	Grounding strip (30×3,5 mm)	m	4000
25	1×16 mm2 NYAF grounding cable	m	3375
26	1×50 mm2 NYY	m	3375
27	PV panel construction (1 MW)	system	1
28	lightning rod set	set	6
29	wire fence price	m	4500
30	CCTV (Camera system)	set	3
31	Field lighting	set	3

Considering the factors such as the excavation cost of the SPP to be established and its proximity to the transformer center, there will be a cost of $ 1,200,000 per MW. This cost will vary according to the quality, type and properties of the material to be used. For example, if the panel to be used is determined as 270 W, if a panel above 270 W is used, the cost will increase, but the number of panels will decrease.

6. Incentives and Amortization Period

In the establishment of SPP, some incentives are given by the government according to the Renewable Energy Law No. 5346. These incentives are the fact that the energy produced in excess by the SPP is taken by the state and the materials to be used in the SPP are supported for 5 periods in case of domestic production. Table 6 shows the unit prices of energy produced by SPP in cent / kWh. If the energy cost spent for YOBU 2019 consumption (4.050.000 kWh) is calculated over EPDK (Energy Market Regulatory Authority) current prices (price tariff published on 1 October 2020); 4.050.000 x 0.803861 = 3.255.637 TL As can be seen, YOBU consumed 3,255,637 TL of electricity at current prices, excluding VAT, in 2019. According to Table 3, it is seen that the annual average electricity energy generated by the GES with an installed power of 6.75 MW is 9,759,485.1 kWh. If the amount of electricity consumption of YOBU in 2019 is subtracted from the amount to be produced; 9,759,485.1 - 4,050,000 = 5,709,485.1 kWh. If the excess production is calculated at the current exchange rate with the 10-year state procurement guarantee in the schedule I of 5346 numbered law; 5.709.485,1 x 0.133 = 759.361,5 $, 759.361.5 x 7.37 = 5.596.494,4 TL Considering the annual return of the SPP to be

established in consumption; It has a total annual return of 5,596,494.4 + 3,255,637 = 8,852,131.4 TL. In Chapter 4 we said that the installation cost per MW is approximately $ 1,200,200. When calculated with the current exchange rate, the cost of the GES with an installed power of 6.75 MW is approximately 60 million TL. We calculated the annual return as 8,852,131.4 TL at current prices, as it can be understood from here, GES will pay for itself in 6.77 years. Considering the domestic product incentive for 5 years in the table number II of the law numbered 5436 in Table 7, the depreciation period will be further reduced.

Table 6. 5346 numbered law's number 1 schedule [15]

Number 1 schedule	
Renewable production type	Price Tariff
a. Hydroelectric power plant	0,073 (dollar/kWh)
b. Wind power plant	0,073 dollar/kWh)
c. Geothermal power plant	0,105 (dollar/kWh)
d. Biyomass power plant	0,133 (dollar/kWh)
d. Solar power plant	0,133 (dollar/kWh)

Table 7. 5346 numbered law's number 2 schedule [15]

Number 2 schedule		
Plant	Domestic Product Manufacturation	Domestic Contribution Prices (dolar/kWh)
C- SPP	1- PV Panel production (including structural mechanics)	0,008
	2- PV modules	0,013
	3- Module cells	0,035
	4- İnverter	0,006
	5- PV module sun focusing material	0,005
D- İntensived SPP	1- Collection tubes	0,024
	2- Surface plates	0,006
	3- Tracking systems	0,006
	4- Heat energy storage system mechanical parts	0,013
	5- Mechanical parts of the tower steam generation system	0,024
	6- Stirling engine	0,013
	7- Panel integrated materials and panel structural mechanical manufacturing	0,006

7. Results and Recommendations

In this study, GES (Solar Power Plant) power, cost and depreciation period calculated based on renewable energy according to Yozgat Bozok University central campus 2019 annual consumption data. When a calculation is made according to the geographical location of the central campus of Yozgat Bozok University, the installed power of the Solar Power Plant, which will meet the entire annual energy need at all times of the year, is seen as 6.75 MWh. In the

summer months when production is high, excess energy will be transferred to the network thanks to the bidirectional meter. The cost of this power plant with installed power according to the calculation in Chapter 4 is calculated as approximately 60 million TL based on the exchange rate as of October 1, 2020. When an assessment is made based on 2019 consumption data, the power plant to be established in a period of 6.77 years will pay for itself. In addition, if the 10-year energy purchase guarantee and the products used in the manufacturing phase are domestic products, this period will be further reduced when incentives to use domestic products are included. The development of solar panels to be used in this study, increasing their efficiency and reducing losses will make a great contribution to energy production. Meeting the energy needs of institutions with complex structures such as Yozgat Bozok University from renewable energy will make a great contribution to the country's economy in the long term and reduce foreign dependency in energy. As can be seen in the study, it is seen that renewable energy sources are more advantageous than other alternative energy sources because they are both economical and environmentally friendly.

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