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Performance Analysis and Investment Cost Account Calculation of Building Integrated Photovoltaic Systems

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Abstract

Population growth in developing countries, industrialization and rapid advancement of technology cause the increase of energy demand day by day. Fossil energy sources, which are frequently used to produce energy, are also rapidly depleting with this demand. In addition, the trend towards renewable energy sources is increasing in the context of the damage caused by the usage of fossil resources and the strategies developed by countries to supply their own energy demands. Buildings have a big role in total energy consumption and are among the important elements of environmental pollution caused by energy consumption. Solar energy is one of the important energy sources with its clean, local and renewable features. It can be used with today's photovoltaic system technologies, for building energy needs. The aim of the study is to determine the efficiency and cost analysis of a photovoltaic system which was integrated into an existing building. For this purpose, a glass factory building in Afyonkarahisar / Turkey was used. By integrating the photovoltaic system on the roof of this building, the system's energy analysis, initial investment cost and payback period were calculated. The performance analysis of the system was performed with PVsyst V6.7.8 simulation. On the roof, 5184 piece 265 V si-mono PV modules with a total area of 7014 m^2 and inverter with a total power of 1025 kWac were used. According to the results, it is concluded that the grid-connected photovoltaic system can generate 1723 MWh of energy annually, thus 64% of the annual energy need can be supply from the system and the efficiency of the system is 84.49%. It can repay the initial investment cost in about 7 years. It is appropriate to perform the study according to the net present value calculation.

Keywords: Solar energy, Photovoltaic system, PVsyst, Building integrated photovoltaics.

Introduction

Due to the technological, climatic and demographic changes, energy consumption increased rapidly in all over the world. Fossil energy sources are used widely for energy demand and they have significant impacts on the environment. Buildings have a big role in total energy consumption and are among the important elements of environmental pollution caused by fossil energy sources. This situation has brought to the agenda the concept of environment-friendly architecture. This concept is reflected in applications of the use of solar energy, which is one of the most important renewable energy sources and basis of our lives as heat, light and energy sources [1]. Solar energy can be used with today's photovoltaic system technologies, for building energy needs. Solar energy is more advantageous than other renewable energy sources with its clean energy, potential and ease of use [2]. Although, Turkey is in the sun belt, this solar energy potential is not efficiently and widely used.

There are many methods for generating usable energy from the sun. The widely used photovoltaic (PV) cell technology converts the energy carried by the Sun to the Earth through radiation into electrical energy [3]. Photovoltaic systems are beneficial in long-term use thanks to both environmentally friendly and easily accessible sources.

In the study, the photovoltaic system design of a factory in Afyonkarahisar/ TURKEY was carried out and the performance of the system was analysed PVsyst V6.7.8 simulation tool.

Photovoltaic Systems

Photovoltaic systems are mechanisms that directly generate electrical energy from solar radiation. It consists of many components including PV modules, inverters, batteries, charge control units, and other system components. PV modules are the most important part of the system. PV cells are made of semiconductor materials that generate electricity with solar energy.

There are many factors that need to be calculated and considered to learn the feasibility and performance of a PV system. These factors are; geographical location and solar radiation values of the location, the properties of the panels and inverters to be used, the shadowing of the radiation falling on the panels, the energy losses of the system, etc. For this reason, it is much more efficient and easy to make these calculations with simulation programs such as PVsyst.

Material and Method

In this study, a grid-connected photovoltaic system was designed with panel layouts which is added to the roof of a glass factory building in Afyonkarahisar/TURKEY. The study was carried out using the PVsyst V6.7.8 simulation tool and the performance evaluation of the system was made according to the simulation outputs of this tool. While calculating the cost, market research was conducted for the system requirements, net present value and payback and depreciation period were determined according to prices.

PVsyst Simulation Tool Method:

PVsyst program is used effectively in dimensioning, simulation and analysis of PV systems. With the help of this program, the daily or monthly total solar radiation data of the regions can be converted into hourly solar radiation data, and energy simulations can be performed by making system designs [5].

Afyonkarahisar is located on 37° 45° and 39° 17° north latitude, 29° 40° and 31° 43° east longitude and its altitude is 1034 meters. Afyonkarahisar's annual average temperature is 11.2 °C, the average temperature of the coldest month is 0.3 °C and the average temperature of the hottest month is 22.1 °C [6]. In Figure 1, the solar energy map of Afyonkarahisar with annual solar energy radiation of 1550-1650 kWh/m^2-year is given.

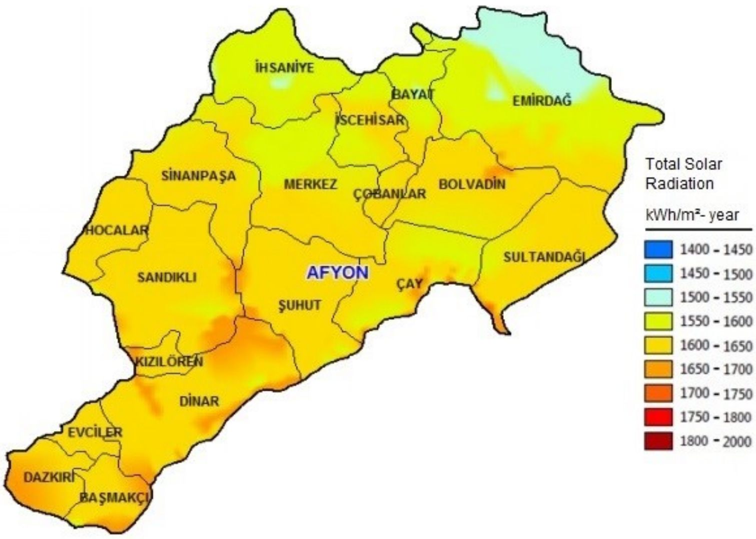

Figure 1: Afyonkarahisar solar energy map [8].

Afyonkarahisar monthly global radiation values and sunshine duration are shown in Table 1. Turkey average sunshine duration is 7.2 hours/day. When the chart is examined, sunbathing periods in May, June, July, August and September in Afyonkarahisar are higher than this value [10].

Table 1: Global radiation values and sunshine duration for Afyonkarahisar [8].

Month	Global Radiation Value (KWh/m^2-day)	Sunshine Duration (Hour)	Month	Global Radiation Value (KWh/m^2-day)	Sunshine Duration (Hour)
January	1.85	3.91	July	6.72	11,36
February	2.47	5.17	August	8.94	10.73
March	4.00	5.64	September	4.92	9.39
April	5.10	7.05	October	3.53	6.82
May	6.21	9.27	November	2.19	5.12
June	6.63	10.71	December	1.66	3.74

Average Sunshine Duration = 5,80

The factory located in Afyonkarahisar, are shown in Figure 2 and 3, and selected for system design has a short side of 65.5 meters, a long side of 120 meters, a height of 9.5 meters and a roof area of 7.860 square meters. The azimuth angle of the building is -17°. The slope of the roof, which is solved as a split gable roof, is 10%, the slope angle is 6 ° and the slope is in the east-west direction. Roof surface azimuth angles are -107° and 73°. Data such as the location of the building and its azimuth angle were obtained using Google Earth Pro program.

Figure 2: Location of glass factory.

Figure 3: Facade of glass factory.

Cost Calculation Method:

Average values method was used while calculating the investment cost. Market research has been made according to the properties of the selected system elements and the average prices of the products have been determined. With reference to other PV panel applications, installation, transportation, maintenance-repair and cabling costs were calculated on average as a result of interviews with a local PV panel practitioner.

Then, it was evaluated whether the investment is suitable or not according to the Net Present Value (NPV) calculation method. The net present value of a project is the sum of the net cash flows during its economic life, reduced to present value at a predetermined discount rate [7]. The net present value method is used to evaluate existing or potential investments.

Results and Discussion

In this section, the PV system simulation is realized with the methods which are explained in Section 3. The results of the simulation are presented in addition with the cost calculations and they are discussed.

System design realization with PVsyst simulation tool:

A grid-connected system design is simulated in the PVsyst program. The area of the building was determined and the photovoltaic panel and inverter were selected according to optimum values depending on factors such as climate, cost, profit, payback and installed power. In this study, a monocrystalline silicon cell photovoltaic panel of 1638 x 826 x 40 mm with a unit norm power of 265 W was chosen. A circuit with a power output of 2.5 kWac, made by Canadian Solar brand, was selected as the inverter. Since the panels are integrated into a pitched roof, the current roof inclination angle of 6 ° has been entered into the program.

Roof dimensions and angles determined in the PVsyst simulation tool, modelled as shown in Figure 4.

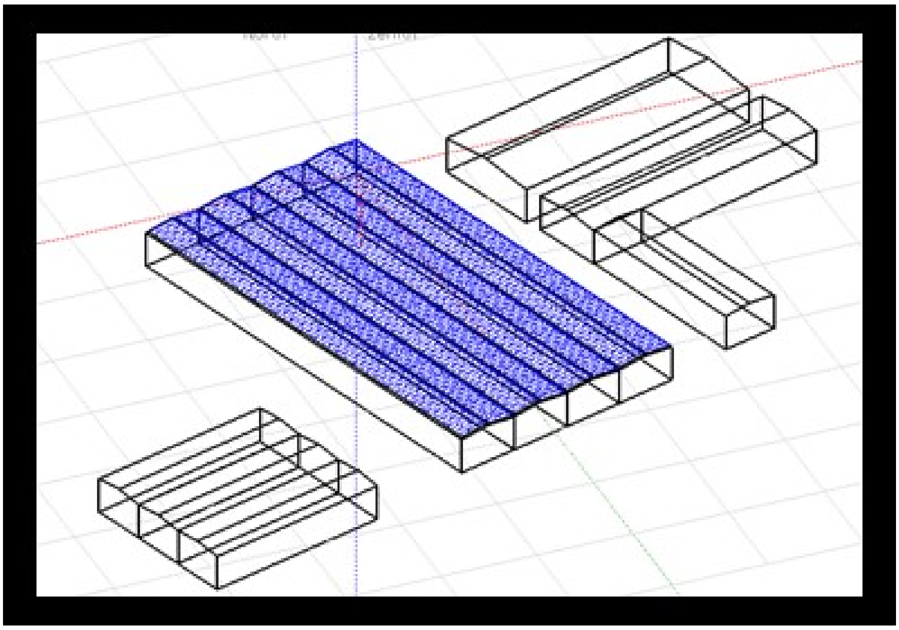

Figure 4: 3D Modelling done in PVsyst simulation tool.

According to the design, 5184 panels in total were placed on the roof (Table 2).

Table 2: Calculation of PV panels.

Total Area = 7860 m^2
Usable Area = 7014 m^2
1 PV Module Area= 1.35 m^2 (1638 x 0.826)
7014/1.35=5184 Panels

The installed power of the planned mechanism is 1374 kWp. The inverters have a total power of 1025 kWac, 513 kWac for each direction. The annual amount of energy supplied to the grid by the system has some energy losses due to shadow factor, panel efficiency, temperature and inverter lose. The annual energy production decrease to 1723 MWh/year, although the amount of energy produced is 1972 MWh/year. Figure 5 shows the annual loss and gain diagram obtained from the PVsyst program, showing where all the losses are coming from.

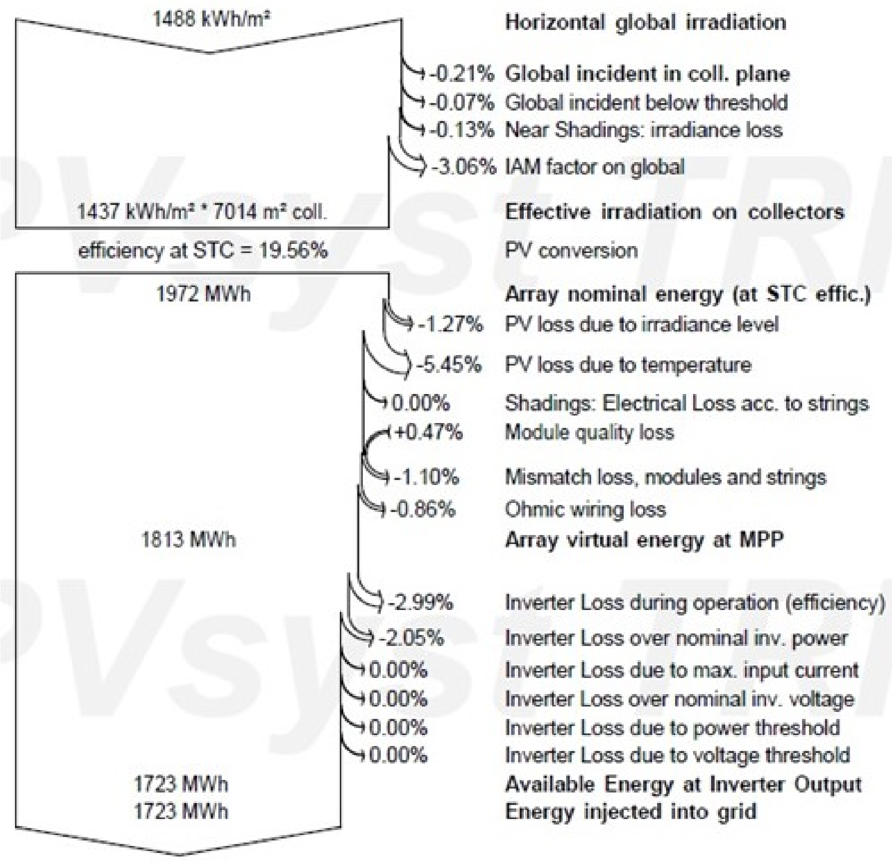

Figure 5: System loss diagram derived from PVsyst tool.

Due to the temperature increase, the energy efficiency of the PV modules decreases over a certain value. As seen in the Figure 6, system performance decreases from May to September. However, energy production is higher during the warmer months than the colder months. According to the simulation result report, the average performance rate of the system is 84.49%.

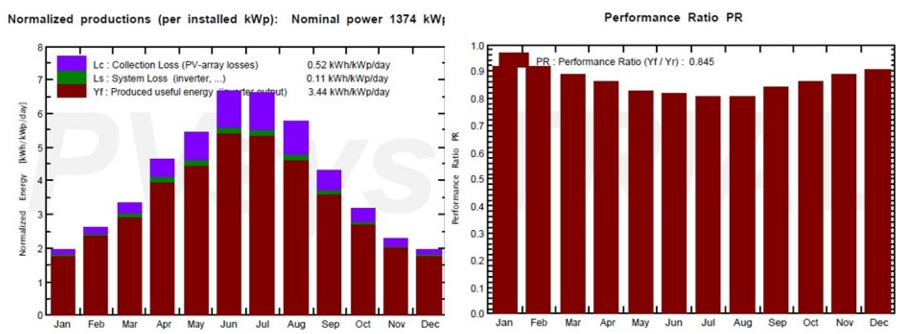

Figure 6: System performance / performance ratios by months obtained from the PVsyst tool.

Cost Calculation:

According to the calculation method mentioned in section 3, the costs shown in the Table 3 have emerged.

Table 3: System Cost. Table is derived from Guven, Kilic's (2018) study [5].

System Cost	
One Solar Panel Price	125$
Total Panel Price	648 000$
Invertor Price	5150$
Construction	200$
Setup-Transport	250$
Wiring	290$
Other (Repair-Maintenance)	1100$
Total	654 950$

Total Cost according to the table 3 is $654,950. In this case, payback period account is calculated with the ratio of the total cost to the annual earnings (Equation 1). The exchange rate has been accepted as 6.85 TL according to its value on 04.07.2020. The unit price of electricity was taken as 0.36 TL based on the invoice information obtained from the owner of the factory. Canadian Solar panel and inverter prices are taken from "Sunwatt" solar panel manufacturer [10].

1 year energy production= 1723 MWh. 1 MWh=1000 kWh, 1kWh=0,36 TL
1 723 000 x 0,36 = 620.280 TL. (The gain of the system in 1 year) (1)
654.950 x 6,85 = 4.486.408 TL. (Cost in TL)
Payback Period = 4.486.408 / 620.280 =7.23 year (Total cost/ Annual gain)

According to the payback period calculation, the initial investment cost of the PV panel system pays back approximately within 7 years. 2019 electricity consumption of the amount of electricity consumed by the factory in one year is 2,668,103 kWh. After calculating the investment cost and payback period of the system, it has been evaluated whether it is suitable for application according to NPV calculation (Equation 2). NPV account formula is shown below. In the formula, the economic life of the system is 25 years and the interest rate is 10%.

NPV=R1/(1+i)1+R2/(1+i)2+R3/(1+i)3...Rn/(1+i)n-C (2)
NPV=620.280/(1+0.1)+ 620.280/(1+0.1)2+...620.280/(1+0.1)25 - 4.486.408 >0
R=Cash flow, C=Cost of capital n=Economic life, i=Interest rate
According to the NPV method is positive, the system is considered applicable.

Conclusion

In this study, the situation of meeting the electricity need of a factory in Afyonkarahisar with photovoltaic systems was discussed. It is aimed to calculate the amount of energy that can be produced from the system and the system performance in the simulation tool. For this purpose, the PVsyst V6.7.8 simulation tool was chosen and the performance analysis of the designed photovoltaic system was made.

It was observed that the global irradiation amount at the location reached the lowest effective irradiance value on the panel surface in January, and the highest effective irradiance value in July.

It is predicted that the annual total energy amount that can be transferred to the network after deducting the system losses will be 1723 MWh. In this case, 64% of the annual energy consumed can be met from the PV system.

According to the electricity bill, it has been calculated that the electricity consumption unit price is 0.36 TL / kWh and the system will gain approximately 620,280 TL in the annual electricity bill.

By taking the methods used in this study as an example, energy generation estimates of a PV system to be designed can be made. Evaluations of the system can be made as described in this study and the most appropriate and profitable designs can be created before the system is implemented. If the efforts are increased in order to benefit from the renewable energy source, the sun, and if photovoltaic systems become widespread for electricity generation, the damages caused by fossil fuels will be reduced.

References

[1] Knowles, R. L. (2003). The solar envelope: its meaning for energy and buildings. Energy and Buildings, 35(1), 15–25. https://doi.org/10.1016/s0378-7788(02)00076-2

[2] Freitas, S., Catita, C., Redweik, P., & Brito, M. C. (2015). Modelling solar potential in the urban environment: State-of-the-art review. Renewable and Sustainable Energy Reviews, 41, 915–931. https://doi.org/10.1016/j.rser.2014.08.060

[3] Aksangor, N. N., Martin, K., & Boran, K. (2019, April). PVsyst Simulasyon Araci Kullanarak Ankara'da Fotovoltaik Gunes Sistemlerin Performans Analizi. SETSCI Conference Proceedings, 217–220.

[4] Sayın, S. (2006). Yenilenebilir Enerjinin Ulkemiz Yapi Sektorunde Kullaniminin Onemi ve Yapilarda Gunes Enerjisinden Yararlanma Olanaklari, Selcuk University, Konya, Turkey.

[5] Guven, F., Kilic, S. (2018). Armutlu Devlet Hastanesinin Enerji Ihtiyacinin Gunes Enerjisiyle Karsilanmasi ve Maliyet Analizi. 3th International Conference on Multidisciplinary Sciences, 131-140.

[6] Cunkas, M., Demirkol, Z. (2014). Afyonkarahisar Ili Yenilenebilir Enerji Potansiyeli, Selcuk Universitesi Muhendislik, Bilim ve Teknoloji Dergisi.

[7] Demirbugan, A. (2008). Yatirim Projelerinin Degerlendirilmesinde Net Bugunku Deger(Nbd) ve Ic Karlilik Orani(Iko) Yontemlerinin Karsilastirilmasi. Afyon Kocatepe Universitesi, I.I.B.F. Dergisi.

[8] http://www.yegm.gov.tr/anasayfa.aspx [Access date: 09 June 2020]

[9] http://www.yegm.gov.tr/MyCalculator/ [Access date: 09 June 2020]

[10] https://sunwatts.com/2-5kw-solar-kit-canadian-320-enphase-micro-inverter/ [Access date: 03 July 2020]