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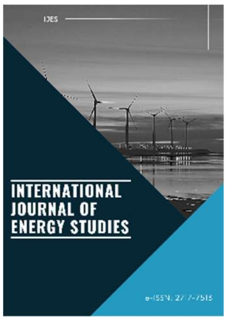

Research Article

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Grid connected photovoltaic system design an example application for İstanbul province

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Highlights

- The aim of this study is to estimate the amount of energy to be produced by simulating and modeling the performance of PV (Photovoltaic) systems using PVsyst and PV*SOL programs before the photovoltaic systems are installed in the region.
- It is predicted that 17.1 kW of energy will be obtained when the whole system is used.
- In the system design, the avoided CO_2 emission is calculated as 8,856 kg/year and the amortization period is calculated as 7.2 years.

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ABSTRACT

It is seen that the damage to the environment has increased with the use of fossil fuels around the world. It is known that studies continue to minimize the damage to the environment with alternative energy generation methods. Recently, it is seen that generating electrical energy using solar energy, known as clean energy, has an important place. With the developing semiconductor technologies, the use of photovoltaic systems is increasing day by day. The aim of this study is to estimate the amount of energy that will be produced by simulating and modeling the performance of PV (Photovoltaic) systems using PVsyst and PV*SOL programs before the Photovoltaic systems are installed in the region. In the study, grid-connected roof system modeling was made in Bakırköy district of Istanbul province. In the modeling of the system, a total of 90 solar panels were placed on an area of 114.9 m^2 , in East and West directions. In total, it is predicted that 17.1 kW of energy will be obtained when the system is used. In the system design, the avoided CO_2 emission is calculated as 8,856 kg/year and the amortization period is calculated as 7.2 years. When the programs are used, the analysis of the system is made before the implementation and it is seen that time and cost savings are achieved.

Keywords: Photovoltaic systems, Solar panels, PVsyst, PV*SOL

1. INTRODUCTION

It is known that the concept of energy is important in the world, contributing to the basic needs of life and its sustainability [1]. There are many methods of obtaining energy, and one of the most used in these methods is to obtain it from fossil fuels. Considering that the energy obtained from fossil fuels is not sustainable, exhaustible and the damage it causes to the environment, it is seen that energy production should be increased in other ways [2]. In order to increase the basic energy resources and to minimize foreign dependency, the tendency towards renewable energy resources is increasing in our country as in other countries and it is predicted that it continue to increase [3,4]. The decrease or increase in the prices of production and resource input costs of traditional fossil-sourced electrical energy production methods over the years makes the reliability of production methods questionable [5]. Some legal regulations and decisions are taken by countries on a global scale to reduce fossil fuel production methods and to produce electrical energy with renewable energy sources [6, 7].

When it comes to energy generation methods around the world, solar, wind, biomass, geothermal and other sources come. The use of resources varies according to the potential and needs of countries. Recently, electricity production from solar energy is seen to be ahead of other sources [8]. The reason why it is preferred to produce electrical energy from solar energy is shown as real-like analyses in simulation programs and the increase in the efficiency obtained from the panels with the advancement of technology. The difficulties in obtaining energy in the world also increase the use of renewable energy. According to the International Energy Agency, it is predicted that renewable energy will be used more in the coming years and that the share of solar energy will be approximately 11% of electrical energy production in 2050 [9].

When Türkiye is evaluated in terms of renewable energy, solar energy is seen as an important resource. When Figure 1 is examined, it is understood that it will be possible for Türkiye to benefit from solar energy. It is observed that the total solar radiation is high in some parts of the Southeast, Central Anatolia, Mediterranean, and Aegean regions.

Figure 1. Türkiye Solar Energy Potential Atlas [10,11]

It is known that the share of renewable energy plants in total electrical energy production in 2022 is 36% on average. In 2021, total electrical energy production is 334,723.1 GWh, and renewable resource-based production is 118,567.5 GWh. Renewable resource-based production is constituted 35.42% of total electrical energy production. Dam-type hydroelectric power plants are constituted 12.17% of the total production. The electrical energy produced from solar power plants by utilizing solar energy constitutes 4.16% of the total production during 2021. Renewable resource-based production for 2021 is given in Figure 2.

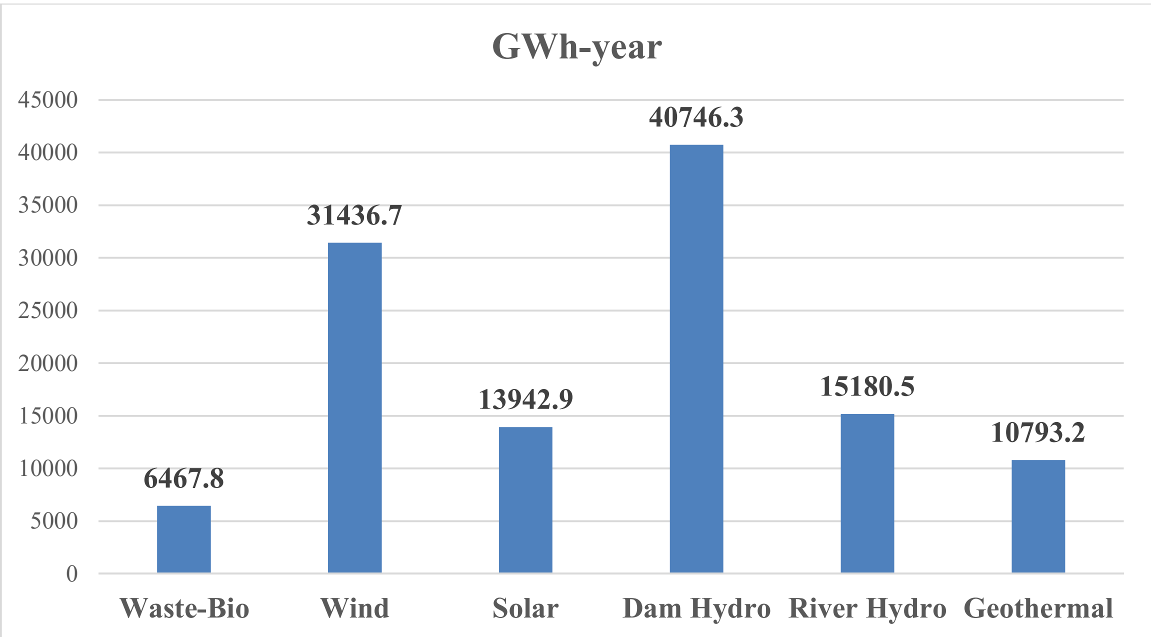


Figure 2. Renewable Resource-Based Generation at Power Plants in Türkiye during 2021 [12]

Solar energy systems are separated by thermal solar power plants and photovoltaic systems. The photovoltaic system is the most used method to generate electrical energy from the sun. The photovoltaic effect is based on the photon phenomenon in sun rays. Photovoltaic panels are made of silicon cells. When the p-type and n-type silicones are combined, the free electrons from the n-type rush toward the positively charged section to fill the voids created [13]. However, not all the electrons manage to fill the voids, at the barrier between p and n-type silicone, the electrons are clumped; making it difficult for electrons to get to the other side because of the repulsion forces. At equilibrium, this phenomenon creates an electric field between the different types of silicone [14]. A diode is composed allowing the electrons to flow from the positive region to the negative region only, given the difficulty of electrons to flow to the positive reason because of the repulsion at the junction. The electric field causes voltage; since there is a difference in electric potential [15].

It is known that the use of solar energy has increased and will increase with the advancement of technology in European countries and other countries. It is important that the energy obtained from solar panels is connected to the grid and that no batteries are used.

When we look at the previous studies, simulations were made to meet the electrical energy in some centers with the PV*SOL program [16]. Energy system design simulation was carried out in the PV*SOL program with a rooftop PV solar power plant with an installed power of 1202.4 kWp in Bursa, with different solar panels [17]. In the same way, 8 different systems were studied on Uludag University's campus, and the most efficient one was selected and implemented. In addition to these, a solar power plant system has been designed in different programs connected to the 1 MW grid in Isparta province, and studies have been initiated to put it into practice by considering the differences between the programs [18].

The analysis of the 5.1 kWp rooftop PV system installed in the Faculty of Technology building at Kocaeli University was made using the PV*SOL program, and it was stated that there was a 97.97% similarity rate when it was actually applied [19]. 3 units of 320 Wp Gazioğlu GSE 320 MP model solar panels independent of the grid were designed and simulated in the Vize district of Kırklareli province. After the analyzes were made, the application was also made. It has been seen that the results are compatible with simulation programs and give approximate results [10].

In this study, a PV generator surface was simulated using 90 panels and 2 inverters on an area of 114.9 m^2 in order to obtain 17.1 kW of electrical energy by using the rooftop PV system in Bakırköy district of Istanbul, and cost analysis was made before the application. has been made.

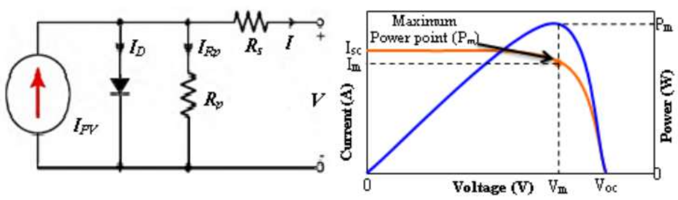
2. ABOUT PV*SOL PROGRAM

With PV*SOL, which is used as a photovoltaic design program, analysis can be performed with simulation before implementation. All common system types can be visualized in 3D and cost analysis can be calculated with up to 7,500 mounted modules or up to 10,000 roof-parallel modules in roof-integrated, roof-mounted, or open areas. The program includes many products such as more than 21,900 PV modules, 5,500 inverters, and 2,600 battery systems. PV*SOL consists of 6 parts; terrain view, object view, module coverage, module assembly, module configuration, and wiring plan. The climate database used is MeteoSyn and it automatically adds data about the region.

3. MATERIAL AND METHOD

In this study, the temperature data of the Bakırköy district of Istanbul province was used and the area where the panels will be placed was determined as 114.9 m^2. It is aimed to meet the electrical energy of an institution or building by generating electricity from renewable energy solar panels. There are multiple parameters that affect the efficiency of solar panels. Some of these are known as the orientation of the panels, the angle of inclination, and the shading. Before the panels were placed, the most efficient states of the panels were evaluated using the PV*SOL program.

The equivalent circuit model, current-voltage (IV), and power-voltage (PV) curves for a typical photovoltaic cell are shown in Figure 3. These equivalent models and curves provide guidance for interpreting the dynamic electrical behavior of solar cells in the design. In the cell model, there is a current source and a diode connected in reverse parallel to it. However, there are series and parallel resistors that represent the losses in the cell.



a) b)

Figure 3. Photovoltaic cell a) equivalent circuit model b) IV and PV curves

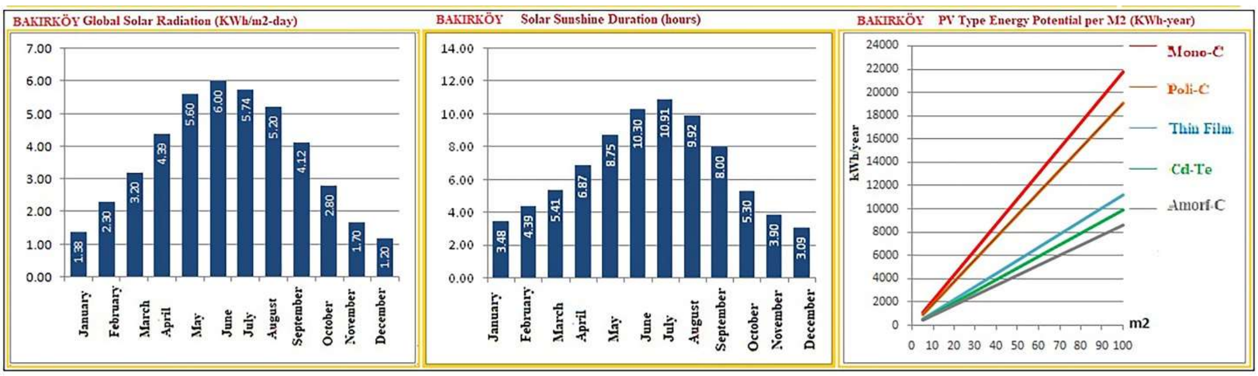
In general, when the efficiency calculation is made as below,
The power output of the solar panel (kWp) / the area of the panel (m^2) = the efficiency of the solar panel.
The efficiency of a 270 Wp PV module on a solar panel with an area of 1.6 m² is 16.8%.

$$(270/1000 \times 1.6) \times 100 = 16.8\% \quad (1)$$

This nominal rate is given for standard test conditions (STC): Radiation = 1000 W/m², Panel temperature = 25 °C, Wind speed = 1 m/s

4. RESULTS AND DISCUSSION

Before the inputs of the system are designed using the PV*SOL program, it is necessary to know the sunshine duration of the region where the system will be installed, the global radiation values, and the amount of energy that can produce a PV-type area. It is seen that the energy obtained from the panels in the summer months will increase with the increase of the sunshine duration, and the energy obtained from the panels in the winter months will decrease due to the shortness of the sunshine duration. This is the main reason why the On-Grid (grid-connected) system is preferred in the study. When the sunshine time is low, it should continue to be fed from the mains. Figure 4 According to the information from the PVsyst program, the global radiation values of the Bakırköy district of Istanbul province represent the electrical equivalent of the solar radiation values per 1 meter for 1 month in kWh. In Figure 4b, monthly sunshine durations are given in hours. In Figure 4c, it is expressed how much energy is produced in kWh per square meter per year according to the PV type.



a) Global Solar Radiation b) Sunshine Duration c) Producible Energy by PVs

Figure 4. Solar energy data of Bakırköy district [11]

When designing a photovoltaic system, it is first necessary to specify the input data, that is, exactly what is required. First of all, it should be known how much area you have and what type of this area (roof type or field type). When Table 1 is examined, it is seen that the numerical data to be used in the photovoltaic system connected to the grid is related to the area used.

Table 1. Grid Connect Photovoltaic Data

PV generator output	17.1 kW
PV generator surface	114.9 m^2
Quantities of PV modules	90
Quantities of Inverters	2

According to the values given in Table 1, the roof should be divided into two parts and placed. Placing the panels in the East and West was seen as the most suitable option to make the most of the panels. Figure 5 shows the layout of the panels.

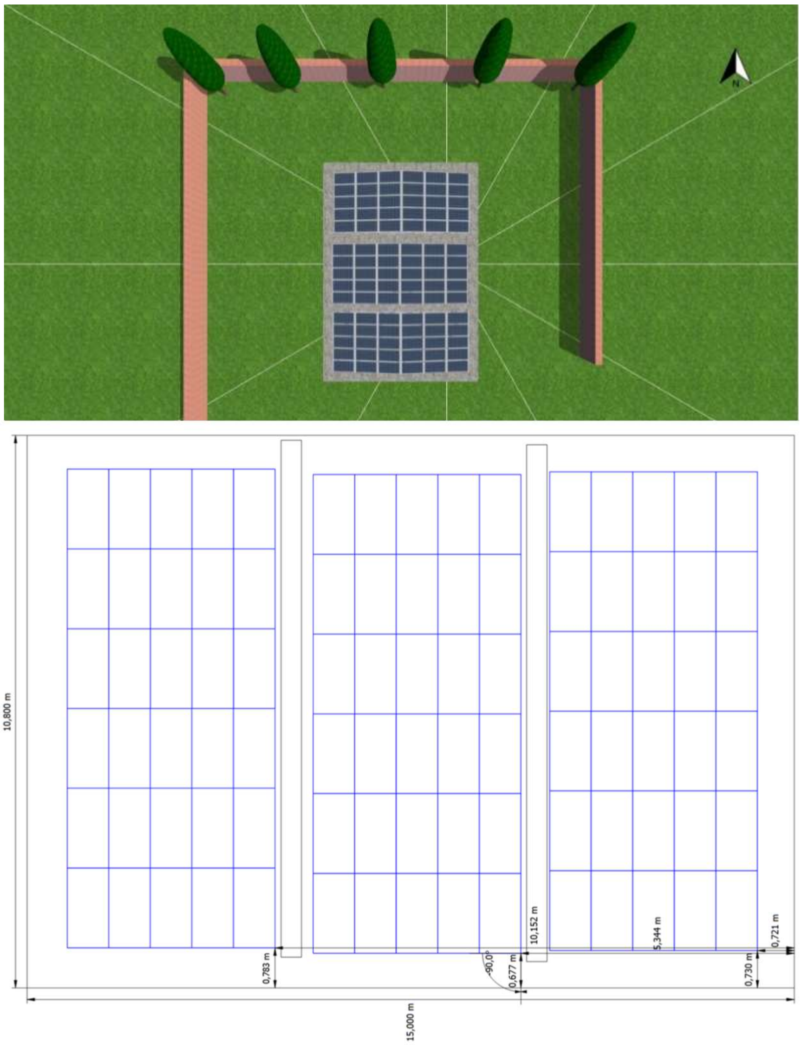


Figure 5. Illustration of grid-connected roof system

The electrical wiring diagram indicating the number of panels and showing the inverter connections is given in Figure 6.

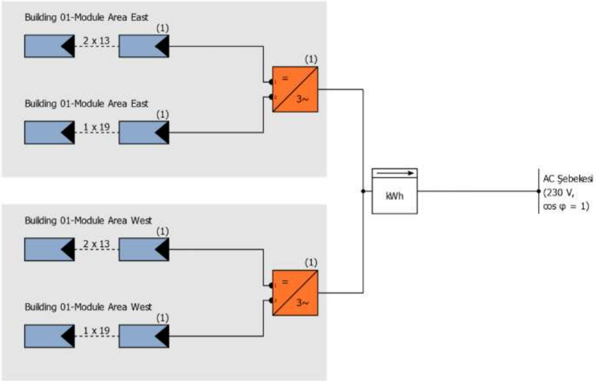


Figure 6. Circuit diagram representation of the grid-connected photovoltaic system

In the system design, solar panels are placed on the roof in the East and West directions. There are 45 solar panels placed in the east direction. However, the slope between the panels and the roof is 10 degrees. The settlement direction is 90 degrees and covers an area of 57.4 m^2. There are 45 solar panels placed in the western direction. However, the slope between the panels and the roof is 10 degrees. The settlement direction is 270 degrees and covers an area of 57.4 m^2. In both panel layouts, 45 x JYSP-190 Wp (v1) was chosen as photovoltaic panel modules. JoySolar was chosen as the brand. The values taken per module as East and West are given in Table 2.

Table 2. Output Values of East and West Solar Panels in Grid Connected System

a) Roof East side settlement data

PV generator output	8.55 kWp
PV generator surface	57.4 m²
Total Radiation Falling on the Module	1335.3 kWh/m²
PV generator energy (AC mains)	9434.5 kWh/Year
Annual Specific Earnings	1103.5 kWh/kWp
System utilization rate (PR)	82.7%

b) Roof West side settlement data

PV generator output	8.55 kWp
PV generator surface	57.4 m²
Total Radiation Falling on the Module	1334.9 kWh/m²
PV generator energy (AC mains)	9408.3 kWh/Year
Annual Specific Earnings	1100.4 kWh/kWp
System utilization rate (PR)	82.5%

The electrical and mechanical data, I/V parameter values, and load parameter values of the panels used are given in Table 3.

Table 3. Values of panels used in the grid-connected system

ELECTRICAL DATA	MECHANICAL DATA	I/V PARAMETERS AVAİLABLE IN STC	I/V PART LOAD PARAMETERS (CALCULATED)
CELL TYPE: MONOCRYSTALLINE Sİ	Width: 808mm	MPP voltage: 36.8 V	Radiation: 200 W/m²
NUMBER OF CELLS: 49	Height: 1580mm	MPP Current: 5.16 A	MPP Voltage at Partial Load: 34.78 V
NUMBER OF BYPASS DIODES: 7	Depth: 35mm	Rated Output: 190 W	MPP current at partial load: 1.03 A
HALF-CELL MODULATED: NO	Weight: 16 kg	Efficiency: 14.87%	Open Circuit Voltage (Partial Load): 39.79 V

Data of inverters used, DC rated output 8 kW, AC rated power 8 kW, maximum DC power 9.6 kW, maximum AC power 8.8 kVA, standby consumption 0.4 W, night consumption 1 W, minimum input power 2 W, the maximum input current is 22 A, the maximum input voltage is 1000 V, the nominal DC voltage is 600 V. When the financial analysis is evaluated; When the grid supply in the first year is evaluated (including the performance decrease), it is 18,743 kWh/year, and the photovoltaic generator output is 17.1 kWp.

4. CONCLUSION

Within the scope of this study, the issue of electricity generation by utilizing solar potential has been examined. As a result of the study, the effects of geographical conditions on production and the measurements of the produced energy data were examined in the simulation environment. In previous studies, the efficiency of photovoltaic panels was compared in terms of inverter brand, models, and current/voltage values, and the differences between them were also seen. Systems are designed as independent and independent from the network. The system considered in this study is grid-connected. Some previous studies given in the introduction are not connected to the grid and use batteries. This also increases the cost. In this study, a roof area of 114.9 m^2 was determined for the Istanbul Bakırköy district and a grid-connected system was designed using the PV*SOL program. Considering the developing technologies, the installation cost for 1,000 kWp rooftop solar power plants is around 650,000 USD. Solar power plant installation costs vary depending on whether the solar plant to be installed is roof or land, the type and angle of the construction system to be used, and the power of the solar panels. When the amortization period is considered, it is seen that it is 7.2 years on average. It has been taken into account that the efficiency of solar panels will decrease by 20% at the end of 20 years.

Simulation programs are important when designing photovoltaic energy systems. The designers of the system can use different components (effect of the geographical region, reliability of the system, energy demand, etc.) to reduce the cost by using different components beforehand.

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

CONTRIBUTION OF THE AUTHORS

Taner Dindar: Performed the experiments and analyse the results.
Ali Samet Sarkın: Performed the experiments and analyse the results.
Vedat Esen: Wrote, and organized the manuscript. Finally, he made a technical analysis of the article.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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