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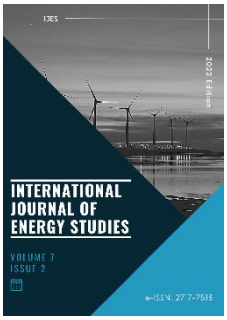

Research Article
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Software-based solar energy potential assessment for an industrial facility: a case study from Aegean Region of Turkey

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Highlights

- Potential utilization of a rooftop solar energy system in an industrial facility has been simulated.
- PvSOL software has been used in the simulation process.
- Payback period of the proposed system was found as 3.4 years.

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ABSTRACT

Solar energy is considered as one of the clean and sustainable energy sources. As known, big portion of the energy demand in industrial processes are generally met by fossil energy sources. Utilizing renewable and sustainable energy technologies in industrial facilities can decrease negative environmental effects. In this study, applicability of a rooftop solar energy generation system in an industrial building has been analyzed. In the simulation process, PvSOL software has been employed. Considering available areas on the roof of the facility, solar electrical energy generation system with installed power of 573.75 kWp was planned and simulated. Moreover, economic analysis results of the proposed rooftop solar energy system were presented within the scope of this research. According to the economic analysis outcomes, payback period of the proposed rooftop energy system was achieved less than 4 years.

Keywords: Solar energy, energy potential, photovoltaics, software, PvSOL.

1. INTRODUCTION

Industrial facilities have high electrical energy demand and it is known that these loads are generally met by using fossil fuels. Utilization of fossil energy sources has some negative impacts on the environment such as greenhouse gas emissions and global warming [1]. Sustainable energy sources can be utilized in industrial facilities to decrease these mentioned negative effects [2]. Solar energy is of great importance in renewable energy sources, both because it is simple and clean source of energy. Electrical energy generation utilizing solar radiation in industrial buildings became popular in the last decades. Also, this technique can be utilized in different types of domestic and commercial buildings considering available installation area. Before the installation phase of solar energy systems, the solar energy potential of the relevant region/location should be investigated. Preliminary information on this subject can be obtained by using simulation techniques.

There are many surveys available in the academic literature that utilized simulation methods for photovoltaic (PV) systems in buildings [3,4,5,6]. Behura et al. designed a new type of roof PV system [7]. In the study, annual environmental data has been utilized and simulation study has been performed using PVsyst software. Results showed that 40MWh more energy was achieved and performance had increased as the new design decreased shading space. Kumar et al. conducted a study on the design and installation of an independent solar PV system, and used PVsyst software for simulation, according to the requirement of the charge in a university building in India [8]. Yearly energy demand was found as 1086.24 kWh. In addition, it has been calculated that 1143.6 kWh of energy can be produced with the system to be installed. The average performance rate was obtained as 72.8%. Anang et al. investigated the performance of a grid-connected, rooftop solar system in Malaysia [9]. PVsyst software was used to determine parameters such as tilt angle to achiee maximum efficiency from the system, and two-year parameters were evaluated for 2018-2019. The highest performance value was found as 75.72% and the payback time was estimated as 5-7 years. In another academic research, van Vuuren et al. simulated a photovoltaic system of a 5000 KVA power-consuming mall in Gauteng, Johannesburg [10]. PVsyst software was used for the simulation. Also, the system has been designed as rooftop PV power generation system. Owing to the region's electricity tariff structure, system efficiency will increase with the tariff structure, while the amount of energy available during the winter will be considerably higher than the losses that may occur in the summer. Ali and Khan studied on the techno-economic performance of 2 solar panels in Pakistan [11]. The study focused on 42 kWp polycrystal-Si and

BDT thin film-based solar panels and evaluated over 1-year operation results. The study found that CIS thin film solar panels are more efficient in terms of energy production, but polycrystal-Si panels are more positive in both space utilization and unit cost. Dehwah et al. conducted a study on solar energy potential on building roofs in Saudi Arabia [12]. A study of 33,000 buildings was also examined by identifying parameters such as the shading effect with PVsol software. Consequently, it is estimated that 796 GWh of electric power can be generated and the generate increased by 22.5% with policy support. Odou et al. studied on a grid circuit-independent hybrid system for a village in Fouay, Benin [13]. Cost analysis of this hybrid system has been performed that it would be made with solar panels, diesel generators and batteries, and the system simulation process was done with HOMER software. As a result, the system's payback time was found less than 3.45 years. Dahmoun et al. conducted a study in Algeria on the performance investigation of a small-scale PV system [14]. They analyzed the Scada data for a 36-month period of time between March 2017 and February 2020 for the performance assessment of the system. The analysis was compared with the SolarGIS and PVsyst. The output from the Scada analysis was found to be 43261.4 MWh and was found to be satisfactory for the region's electricity generation. Redweik et al. analyzed solar energy potential of façades and roof in an urban landscape [15]. In the study, LiDAR data has been utilized to develop digital elevation model. According to their results, façades showed significant impact on the solar energy potential of the investigated area. In another research, Ahmed et al. analyzed the solar energy utilization potential on university buildings by using PvSOL software [16]. It was obtained that university buildings have the potential to produce 5389.2 MWh/year with a yearly specific yield of 1336.6 kWh/kWp.

In addition to the given surveys about investigation of solar energy potential of specific regions, studies to improve the performance of solar energy systems are also available in the literature. Nisar et al. conducted an experimental study to analyze the performance variations between solar energy systems floating and solar energy systems positioned on land [17]. Experimental systems have been installed and studied on water and ground for this system. It is emphasized that the designed floating system can generate 20-28% more electricity at 0° than the system on land with optimal tilt angle. Agrawal et al. conducted a study of floating solar panels for an area located in India [18]. The study was evaluated for Rajghat dam in India and simulated with PVsyst software. It has been stated that 10623501 MWh of electric power can be produced annually, and that it may prevent the vaporization of the large percentage of water in the dam. Kechiche and Hamza studied the performance of a low-concentrated commercial PV system [19]. The study examined

variations in the parameters of electricity generation by adding the standard then cooling system under a low concentrated light first. Simulation using Matlab/Simulink software was performed with the aid of a numerical model. With the use concentrated system, the yield decreased from 8% to 1% due to a rise in temperature, and with the addition of a cooling system, the efficiency reached 13.79% in the concentrated system. Belhaouas et al. studied on a new system structure to increase the efficiency of the solar generator [20]. In the study, they performed an analysis to eliminate the problem of partial shading effects, and they mentioned that the analysis was based on a system of traditional MPPT structure and physical PV editing. As a result, it is stated that this structure reduces both malfunction and increases efficiency.

This study examined the solar energy potential for an industrial plant in the Aegean Region of Turkey. PvSOL Premium 2022 R4 software has been used to obtain in the simulation study. The main purpose of the study is to investigate the applicability of a photovoltaic system to an industrial building employing a software-based technique.

2. MATERIAL & METHOD

It can be said that the solar energy potential of İzmir is suitable for the use of solar energy systems. Annual solar energy distribution in Turkey is 1100-1600 kWh/m^2, while İzmir receives 1680 kWh/m^2 solar radiation per year [21]. In this direction, it is possible to say that the solar energy coming to İzmir is above the Turkey average. Solar energy distribution of İzmir is given in Fig. 1.

In this work, software-based solar energy potential analysis has been performed. PvSOL Premium 2022 R4 has been utilized in solar energy potential investigation process. Investigated industrial facility is located in İzmir province of Turkey. Location of the investigated factory can be seen in Fig. 2 in detail.

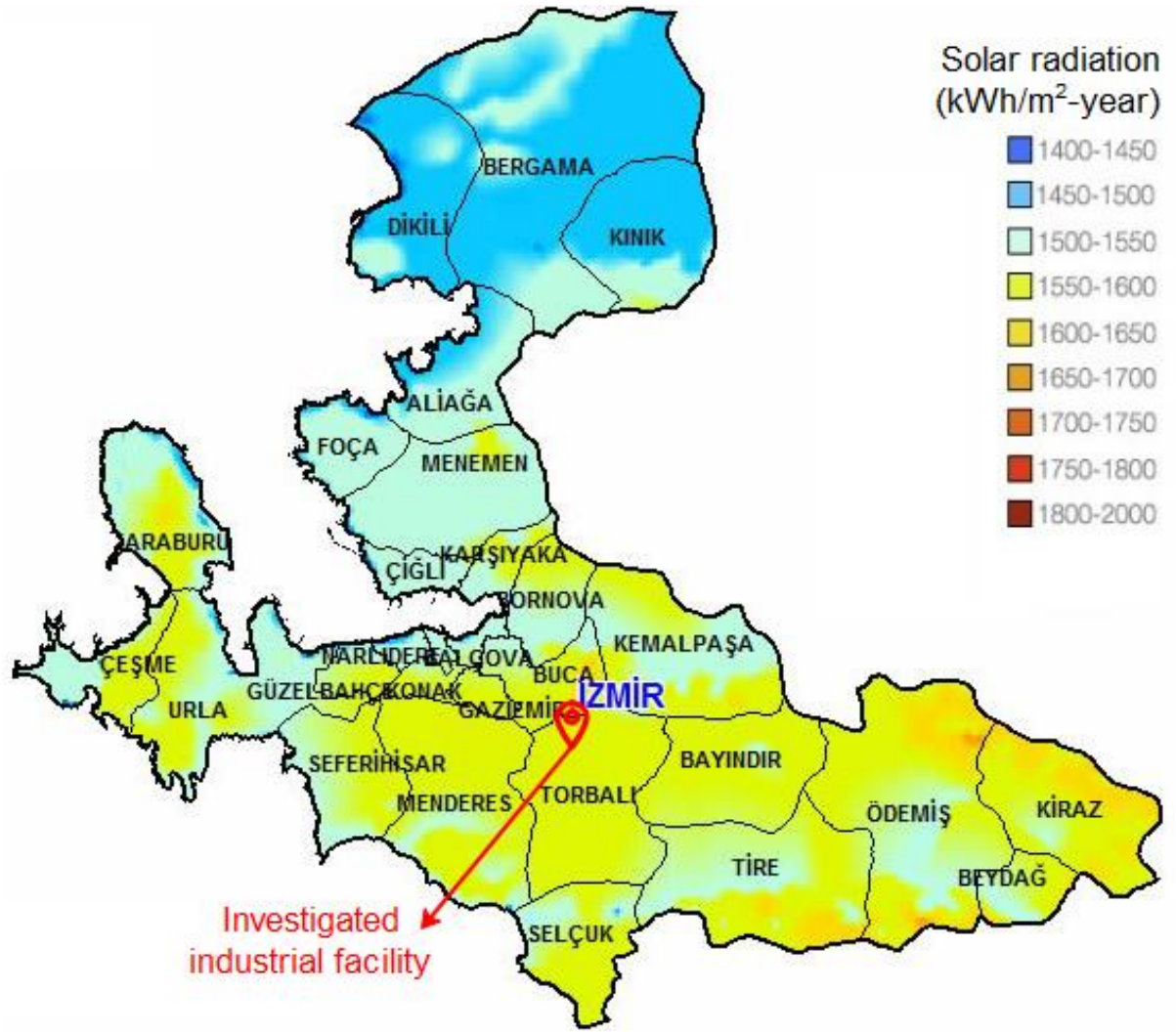

Fig. 1. Solar energy distribution of İzmir province of Turkey [21]

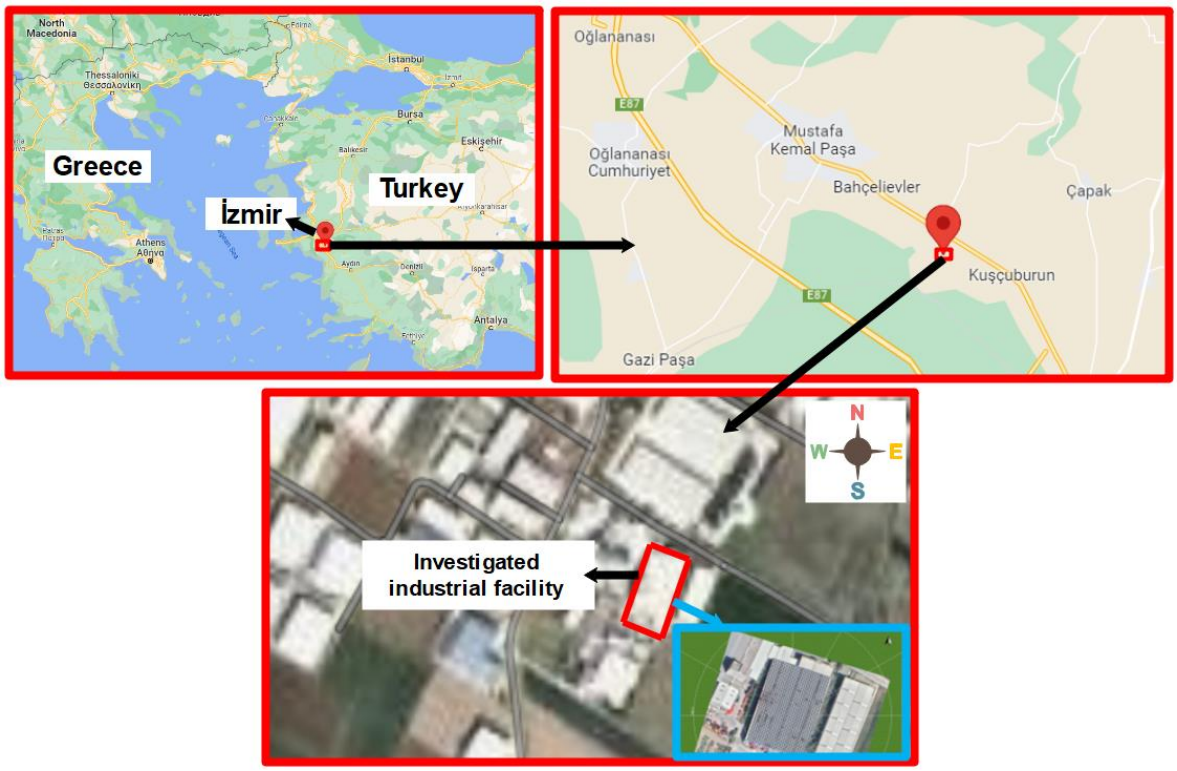

Fig. 2. Location of the investigated industrial facility

In the simulation study, the physical conditions of the location where the system is to be installed, the surface area where the panels will be placed, the survey of the area to be installed against shading were analyzed. Moreover, low voltage patch panels were taken into consideration in the economical evaluation.

1530 photovoltaic panels (Suntech Power) with 375 Wp power were selected in the simulation study. Utilized panel is monocrystalline. MPP current and MPP voltage values of the PV panel are 10.87 A and 34.5 V, respectively. Moreover, short circuit current and open circuit voltage values are 11.57 A and 41.1 V, respectively. Characteristic curves of the utilized PV panel type are given in Figure 3. Slope angle and placement angles were determined as 3° and 289°, respectively. 4 on-grid inverters were selected for the simulation process.

In the analysis process, annual power dissipation value was taken as %2.5 for the first year. This value was taken as %0.07 for other years of operation. Also, annual electricity price increase was taken as %30. A total of 1300 $ has been assumed for the general maintenance costs after the first two years.

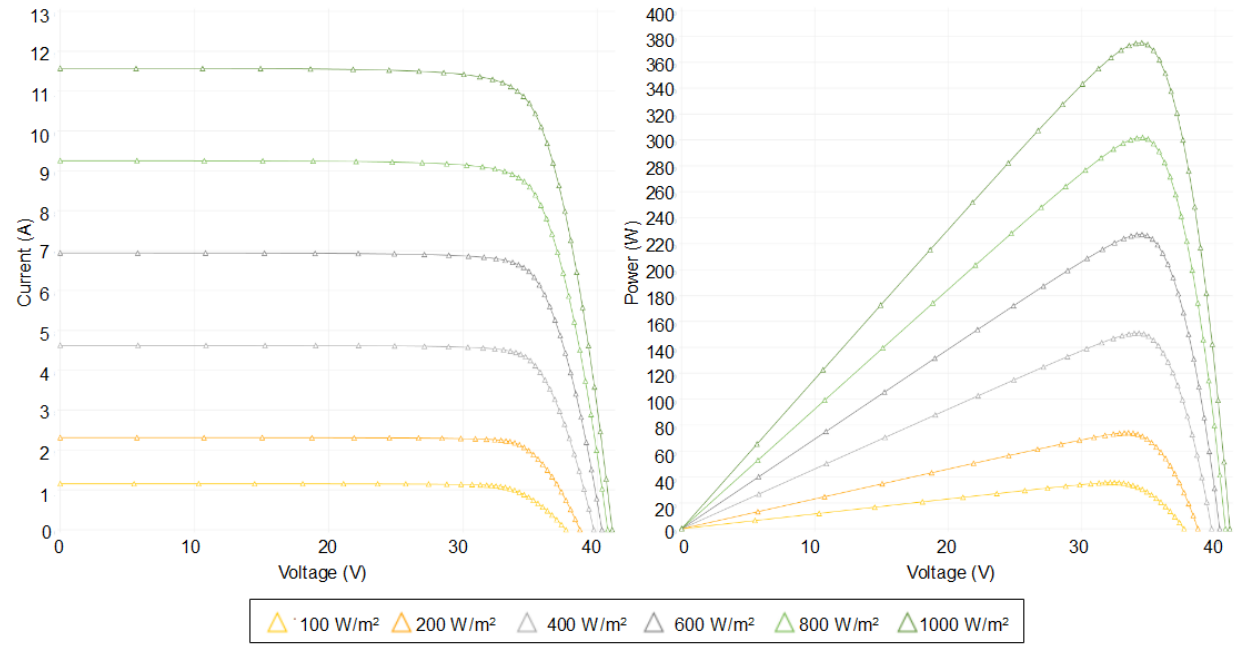

Fig. 3. Characteristic curves of the utilized PV panel

3. RESULTS & DISCUSSION

As mentioned before, an industrial building in Izmir is discussed in the study. The environmental conditions of the region are important considerations for the installation of solar energy systems. Figure 4 shows the change in environmental conditions depending on the months. As expected, both solar radiation and ambient temperature values are highest in June, July and August.

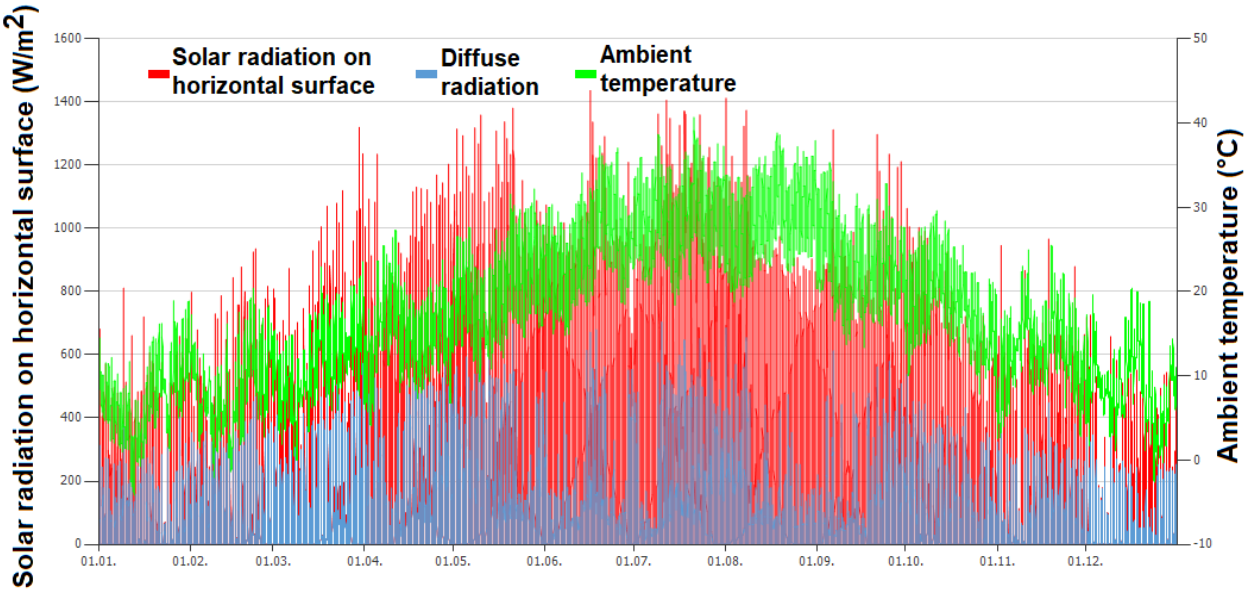

Fig. 4. Annual environmental conditions for the investigated industrial facility

Monthly electricity consumption and expected production values are given in Fig. 5. The monthly average electricity consumption of the examined industrial facility is 298362 kWh. Therefore, this value is taken as constant for all months of year. In addition, annual average energy consumption was calculated as 3580344 kWh for the investigated industrial facility. The expected annual energy production of the solar power plant to be established is 874183 kWh. With the system planned to be established, the highest monthly electricity production was calculated as 115891 kWh in July. Besides, the lowest monthly electricity production of the proposed rooftop photovoltaic system was found as 30901 kWh in December.

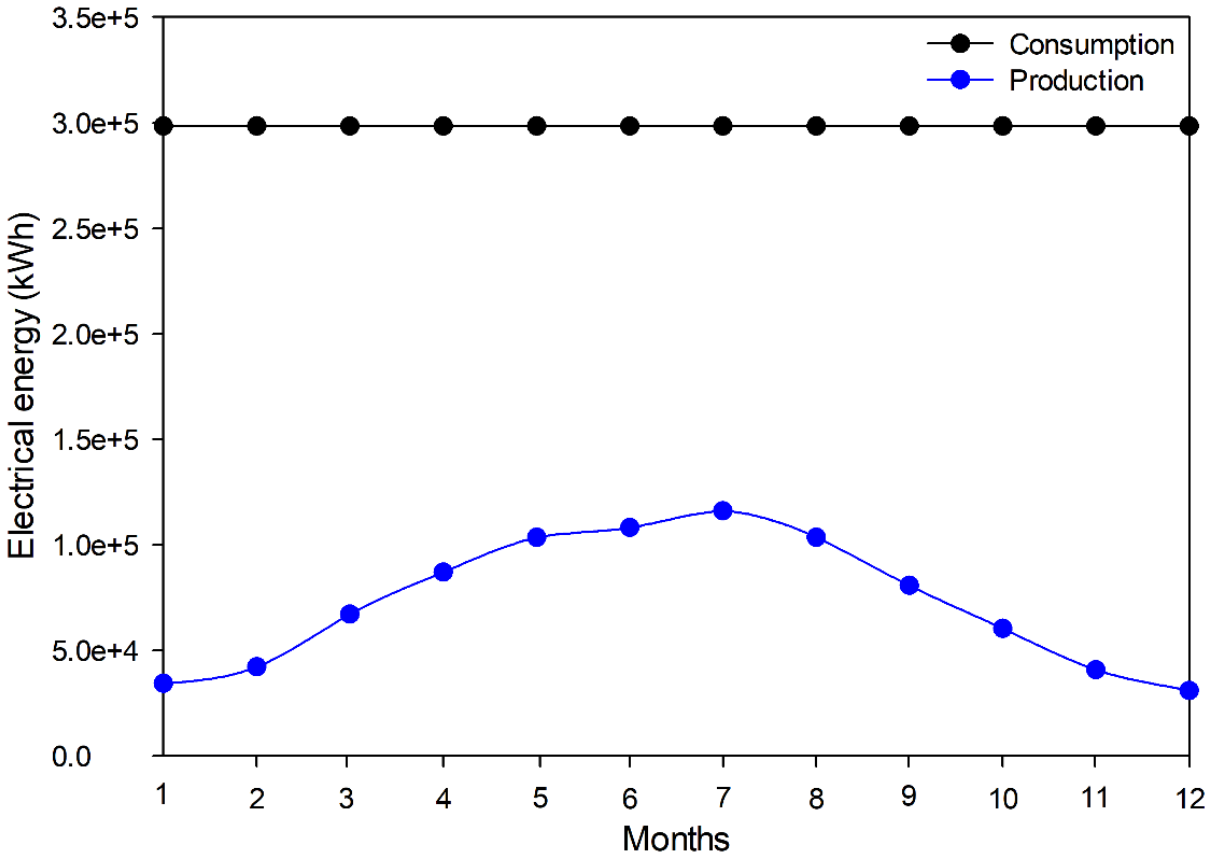

Fig. 5. Monthly electricity consumption and expected production values

Current monthly consumption and expected monthly production amounts are presented in Fig. 6. The annual electrical energy expense over the average amount of the industrial enterprise has been determined as 3381692 TRY (Turkish Lira) including taxes. According to the obtained findings, monthly production amount is between 29186-109461 TRY. It is expected that the one-year electricity cost will decrease by 22.34% after the system installation.

Variation of monthly coverage ratio is presented in Fig. 7. As expected, the coverage ratio of the electrical energy values to be produced in the summer months was found to be higher than the other months. Monthly coverage ratio values was found between the range of 10.36-38.84%. The annual energy coverage rate of the system to be established is calculated to be around 24.42%.

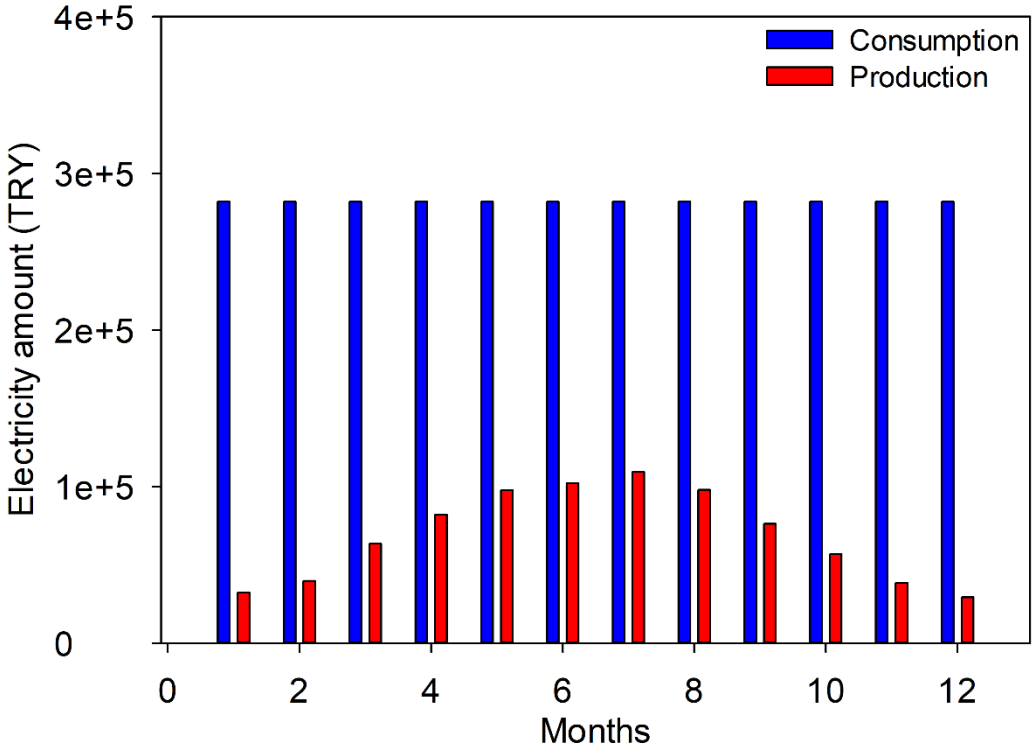

Fig. 6. Current monthly consumption and expected monthly production amounts

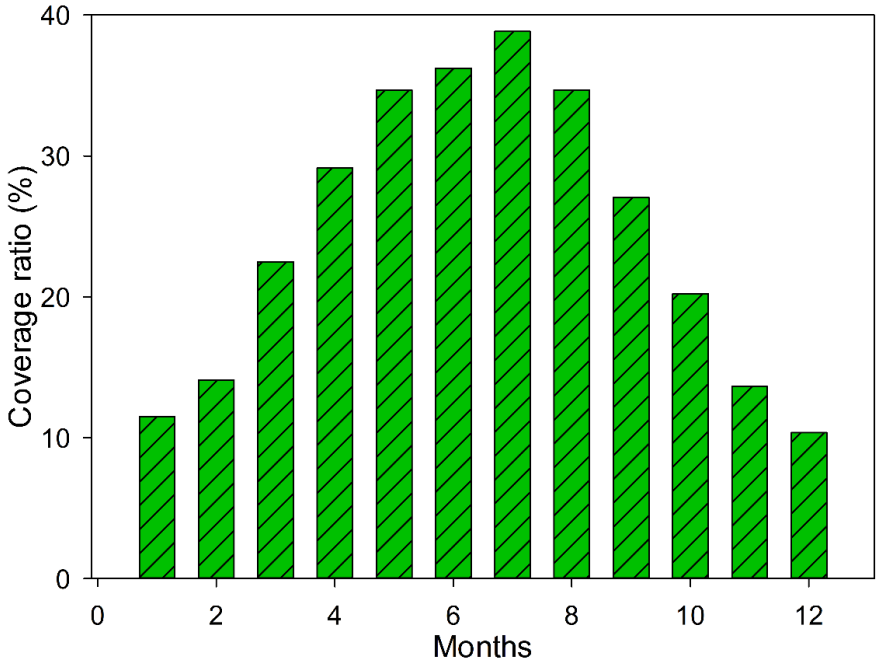

Fig. 7. Variation of monthly coverage ratio

Annual savings for 15 years-period of the proposed rooftop photovoltaic system are shown in Fig. 8. In the economic evaluation process, 15 years has been considered for the proposed photovoltaic system. It was found that payback period of the system is 3.4 years. It can be said that payback of the proposed system is acceptable. As stated before, yearly energy coverage of the system is almost 25%. In order to increase the coverage ratio, the planned facility can be increased in capacity. Installed power can be increased by using suitable areas. In addition, new designs can be made to place photovoltaic panels on the appropriate south-facing walls of the industrial facility.

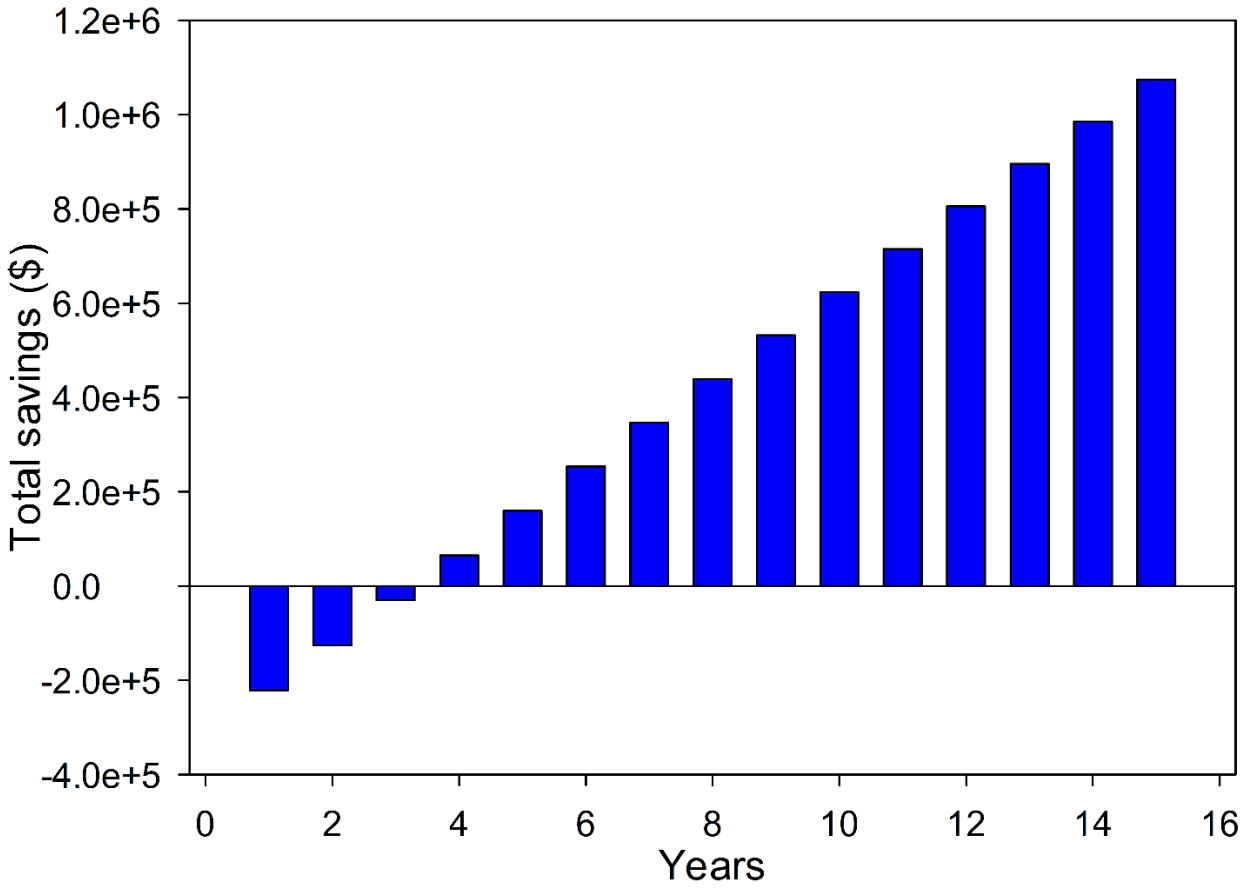

Fig. 8. Annual savings for 15 years-period

3. CONCLUSION

In this study, the solar energy potential of an industrial facility was investigated. In this context, the suitable roof area was determined using the simulation technique and the results to be obtained in the case of using a solar energy system were examined. The general outcomes of this study can be listed as follows:

- It is planned to install a solar energy system with an installed power of 573.75 kWp on the roof of the industrial building. The system is expected to produce 874183 kWh of energy annually.
- One-year electricity cost is expected to decrease by 22.34% after system installation.
- It has been determined that the payback period of the system is 3.4 years.

When the results of the study are examined, it can be said that the planned solar energy system can meet some part of the electrical energy demand of the facility. In future studies, the case of placing additional PV panels on suitable areas such as parking lots within the facility can be examined. The higher part of electricity demand can be met through capacity expansion. Besides, different types of PV panels can be examined for further studies and the results can be compared.

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