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Authors: Muhammet Raşit SANCAR Ahmet Buğrahan BAYRAM

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Modeling and Economic Analysis of Greenhouse Top Solar Power Plant with Pvsyst Software

Muhammet Raşit SANCAR[1*,**], Ahmet Buğrahan BAYRAM [1,**]

[1] Isparta University of Applied Sciences, Graduate School of Education, Department of Energy Systems Engineering, Isparta, Turkey.

[*]Corresponding Author: d1840640001@isparta.edu.tr
[**] The authors are YOK 100-2000 scholarship holders.
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ABSTRACT: Due to increasing wars and global warming, the issue of providing the supply-demand balance in energy and food is becoming more important daily. When the issue of providing the electricity needed in modern greenhouses and consuming the energy where it is produced are evaluated together, rooftop applications in greenhouses become important. In this study, a photovoltaic system on a greenhouse in an area of 5031.6 m^2 was modeled three-dimensionally using PVsyst software in north-south, and east-west orientations at 10°, 20° and 35° angles, and 6 different simulation studies were performed. By determining the cost of the greenhouse and above-greenhouse photovoltaic system to be constituted, an economic analysis study was performed at the point of OG single-term and OG double-term tariffs in the Energy Market Regulatory Authority (EPDK) tariff tables. As a result, the highest electricity production of the power plant was eventuated as 1579.2 MWh at 10° east-west orientation. In the case of the sale of electricity produced in the photovoltaic system installed above the greenhouse, it has been calculated that the OG single-term tariff brings 2 162 443.087 TL, and the OG double-term tariff 2 203 707.83 TL annual income. The lowest electricity generation was at 35° north-south orientation and was 1392.3 MWh. Based on this production value, it has been calculated that in the case of electricity sales, the OG monomial tariff brings an annual income of 1 894 757.401 TL, and the OG binomial tariff brings 1 930 914.04 TL.

Keywords: Above Greenhouse SEPP, Above Greenhouse Photovoltaic System, Greenhouse SEPP

1. INTRODUCTION

With the growing world population, the demand for food is increasing rapidly. In line with this demand, sustainable agriculture gains tremendous importance in the production of high-quality products economically by environmentally friendly techniques. While environmental problems such as human activities, urbanization, climate change, and desertification threaten agricultural productivity and food security, they necessitate improving agricultural activities. Modern greenhouses are one of the areas where sustainable agriculture is applied. Control of the growth medium in light, water, temperature, relative humidity, CO_2 concentration, and ventilation provides optimal growing conditions for plants while improving crop yield and quality in greenhouse plant production. Many interrelated parameters can affect the environmental parameters in greenhouses, such as the size and location of the greenhouses, the type of cover material, the heat storage method, the amount and quality of the materials used, the type of cultivation, and the desired day and night temperature [1].

Since the sun is the essential tool for plants and photovoltaic panels, combining the two and establishing photovoltaic greenhouses has been the subject of considerable research and studies. In a study conducted in China, translucent photovoltaic panels were installed to cover 20% of the greenhouse roof area with a 30° inclination towards the south. It has been interpreted that the shading effect caused by the panels prevents overheating in summer, and the integration of shaded greenhouses may be more suitable for growing tomatoes in hot climates. It has been determined that the annual generated electrical energy of the used photovoltaic panels is 637 kWh and the payback period is 9 years [2].

It has been determined that covering 19.2% of the roof with photovoltaic panels will reduce annual natural gas consumption, electricity demand, and CO_2 emissions, respectively, by 3.57%, 45.5%, and 30.56 kg/m2, and annual electricity production of panels is approximately 42.7 kWh/m^2 [3].

The experiment was performed in Agadir, on the Atlantic coast of Morocco, using two greenhouses. On the roof of one of the equipped greenhouses, photovoltaic panels are used with 32 East-West oriented, covering 10% of the total surface area. The other greenhouse was accepted as a control and only covered with plastic cover. Tomato plants were planted in each greenhouse, and it was interpreted that the yield of tomatoes collected in the photovoltaic greenhouse was higher than in the control greenhouse and sometimes nearly the same degree as in the control greenhouse [4].

In the study performed in Izmir, Turkey, a greenhouse with an area of 150m^2 and a roof angle of 38.4° were modeled using Design Builder software. Tomato, cucumber, and lettuce cultivation in the greenhouse is examined. In order not to overshadow the plants, it is equipped with 66 photovoltaic panels covering 50% of the south face of the roof area. Annual electricity production was found as 21510.4 kWh [5].

The experiment conducted on a 1024 m^2 greenhouse in Spain was carried out with the installation of two photovoltaic panel arrays, each with a surface area of 192 m^2. It was analyzed that the shading caused by the panels placed on the greenhouse roof did not affect the yield of the tomato plant, and the plant morphology did not change, but it caused a decrease in the fruit diameter [6].

An experiment in Italy was carried out by placing photovoltaic (PV) modules on 50% of the roof area of a commercial greenhouse with an area of 960 m^2. The tomato plant was chosen as the test crop to confirm the greenhouse solar radiation distribution due to its high sensitivity to light. The existing greenhouse has a roof slope of 22°. The maximum nominal power of the photovoltaic panels used is 68 kWp, and ıt is stated that the polycrystalline silicon module covers an area of 475m^2. As a result of the experiment, it was measured that the annual average outdoor temperature was 17 °C, and the temperature inside the greenhouse was 19.8 °C. It has been determined that this temperature difference is higher in the winter and spring seasons (from November to April). A decrease was observed in the yield of the tomato plant. It was determined that the annual electricity production was 107 885 kWh, with the highest production in June and the lowest in December [7].

Based on a farm greenhouse with an area of approximately 1.50 hectares located on the northwest coast of Sicily, the study performed an economic analysis of the use of photovoltaic panels. It was stated that the white asparagus plant was cultivated because 0.5 hectares of the greenhouse would adapt well to the weak light conditions caused by the solar panels. The greenhouse is covered with polycrystalline silicon panels, and its installed power is declared to be 300 kW. Assuming that the annual electricity efficiency produced decreases by 0.8% every year, an annual average of 417 387.19 kWh of electricity production is analyzed [8].

Shading simulation was carried out using Autodesk software in a tunnel greenhouse at the University of Tuscia in Viterbo, Italy. The greenhouse is 8 m wide, 30 m long, and 3.20 m high. The photovoltaic panels used have a rectangular shape of 1.116 m × 0.165 m, 2 mm thick, and are placed on the greenhouse roof both parallel and equidistant from each other. According to the analyzed results, it was observed that from March to September, the shadows were inside the greenhouse at midday and partially inside and outside the greenhouse tunnel in the remaining months. It is interpreted that the shading depends on the distance between the panels and the slope [9].

Established in Kunming, China, the experimental greenhouse was installed on the roof of an east-west-oriented solar energy research institute building. The greenhouse is heated by a solar collector combined with a heat pump with opaque photovoltaic modules mounted on its roof with an area of 77.50 m^2. Opaque photovoltaic modules placed on the greenhouse roof with an inclination angle of 30° covered 25.9% of the total surface area of the roof. Layout was made using an order with a gap of 1.1 m between each module. The plant variety tested in the greenhouse was selected as 'Jingzangxiang' strawberry, which had a high survival rate during the trial. To compare the effects of shaded and unshaded light, thirteen pots were placed under the photovoltaic modules, and thirteen different pots were placed between the modules. In addition, twenty potted strawberry plants were used for the unshaded control samples. According to the results, it was observed that the chlorophyll content of the shaded strawberry leaves was 1.3 times higher than the unshaded strawberry leaves, the 'Jingzangxiang' strawberry plants in the shade grew better than the unshaded ones, and the strawberry fruit grown in the shade had a sweeter taste than the strawberry fruit grown without the shade [10].

"Unlicensed Electricity Generation Regulation in the Electricity Market" was published in the Official Gazette dated 12/5/2019 and numbered 30772 [11]. The purpose of this regulation is explained as "In the electricity market, consumers meet their electricity needs from their production facility closest to the point of consumption, bring small-scale generation facilities to the country's economy to ensure supply security, and reduce the number of losses in the electricity grid by ensuring effective use of small-scale generation resources". For this purpose, generating electricity where it is consumed has great importance in terms of minimizing losses.

Supporting sustainable agriculture with renewable energy will be an environmentalist approach. Applications such as supplying the electricity needed in greenhouses, operating irrigation systems, heating greenhouses, heating, cooling, ventilation, and lighting can be provided to the greenhouse in an environmentally friendly way using photovoltaic panels. If there is no suitable land near the greenhouse where the photovoltaic panel application is desired, the greenhouse roof can be considered a suitable location for the assembly and installation of this application.

In this study, a greenhouse solar power plant with two different designs and three different angles for the province of Isparta was simulated using PVsyst software. With 6 different simulation studies, electricity production values were compared with each other in 2 different designs at different angles, using identical equipment and equal installed power conditions. Obtained electricity production values were analyzed economically over electricity unit price using June tariff tables of Energy Market Regulatory Authority (EPDK). Thus, the electricity production values and economic evaluation that can be obtained from the greenhouses to be established in different designs at different angles in the province of Isparta were made and it was aimed to create a foresight for agricultural investors.

2. MATERIAL AND METHOD

This study was performed in Bozanönü village, located at 37.87° latitude and 30.58° longitude, in the central district of Isparta province. By using the PVsyst software, a greenhouse photovoltaic system simulation was made for the greenhouse designs with east-west and north-south orientation, and the income to be obtained in the case of selling all the electricity produced to the grid was examined for 2 different tariff situations in the field of "Agricultural Activities" using the EPDK tariff table.

2.1 PVsyst Simulation

In the study. 7.2.15 version of PVsyst software was used. The software is a computer software package for modeling, sizing, inspection, and data analysis of photovoltaic systems [12]. There are options for photovoltaic system designs, including pump use and off-grid and grid-connected systems in the software. In addition, there is a comprehensive climate data infrastructure with many climate data sources in the software interface. The software is widely used in the private sector and academically. The interface of the software is presented in Figure 1.

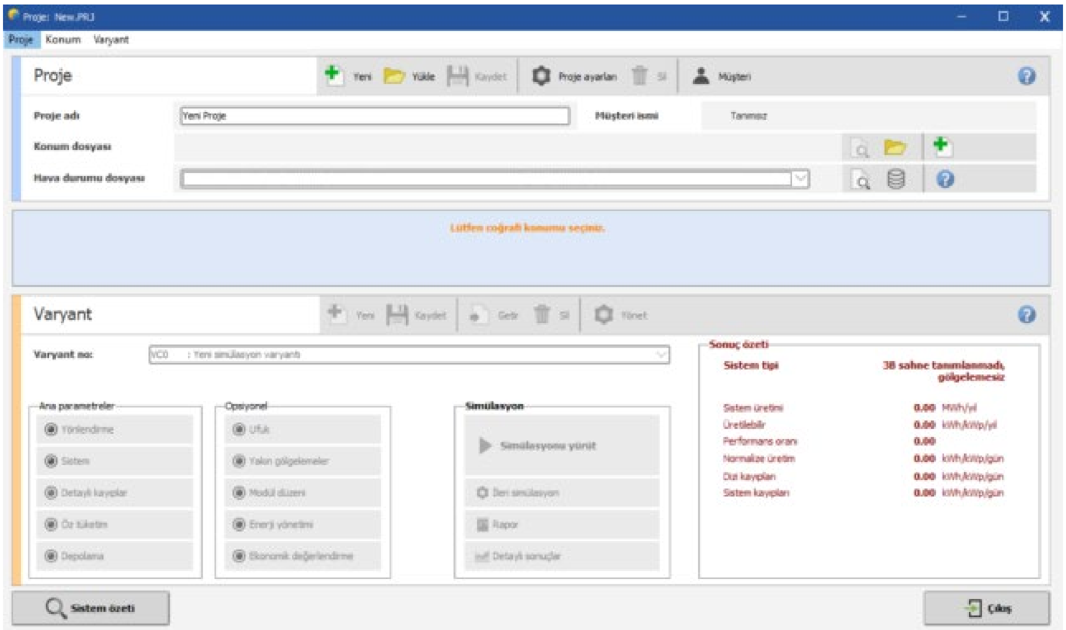

Figure 1. PVsyst software interface

The PVsyst simulation study for the greenhouse photovoltaic system was performed following the steps below.

- It will be a system connected to the grid, and the electricity generated will be supplied to the grid. For this reason, under the heading "Project design and simulation," the system was determined by checking the "Connected to the Network" system option.
- Under the steering button, the photovoltaic system's orientation angle and azimuth angle values are entered. Due to settlement, for greenhouse designs with an east-west

orientation, the azimuth angle values are entered as 70°, -110° and azimuth angle values as -20°, 160° for greenhouse designs with a north-south orientation.
- Under the "System" button, the Inverter and panel properties are entered. After these properties are entered, the serial and parallel numbers of the power plant panels are adjusted. The Inverter, panel, and other system specifications are given in Table 1.

Table 1. Photovoltaic system specifications

Photovoltaic Panel		Inverter Specifications	
Panel Model	JKM-610N-78HL4-BDV	Model	SUN2000-100KTL-M1-480Vac
Panel Power	610 Wp	Unit Power	100 kWac
Impp	13.38 A	Operating voltage	200-1000 V
Vmpp	45.6 V	Maximum AC Power	110 Kva
Voc	55.31 V	Absolute Maximum PV Voltage	1100 V
Isc	14.03 A	Mains Voltage	480 V
Photovoltaic System Properties			
Gross power	1098 kWac	Number of Sequences in the System	100
Maximum rated power (DC:AC)	1.098	Number of Panels in Array	18
Number of Panels Used	1800	Rated for total PV power (STC)	1098 kWp
Number of Inverters Used	10	Total Area	5031.6 m^2

It is modeled in three dimensions, based on the azimuth angle and plane angle properties, which were previously defined under the "orientation" button under the "close shadings" button. There are two different designs related to three-dimensional models. The first of these designs is the north-south design presented in Figure 2, and the second is the east-west design presented in Figure 3.

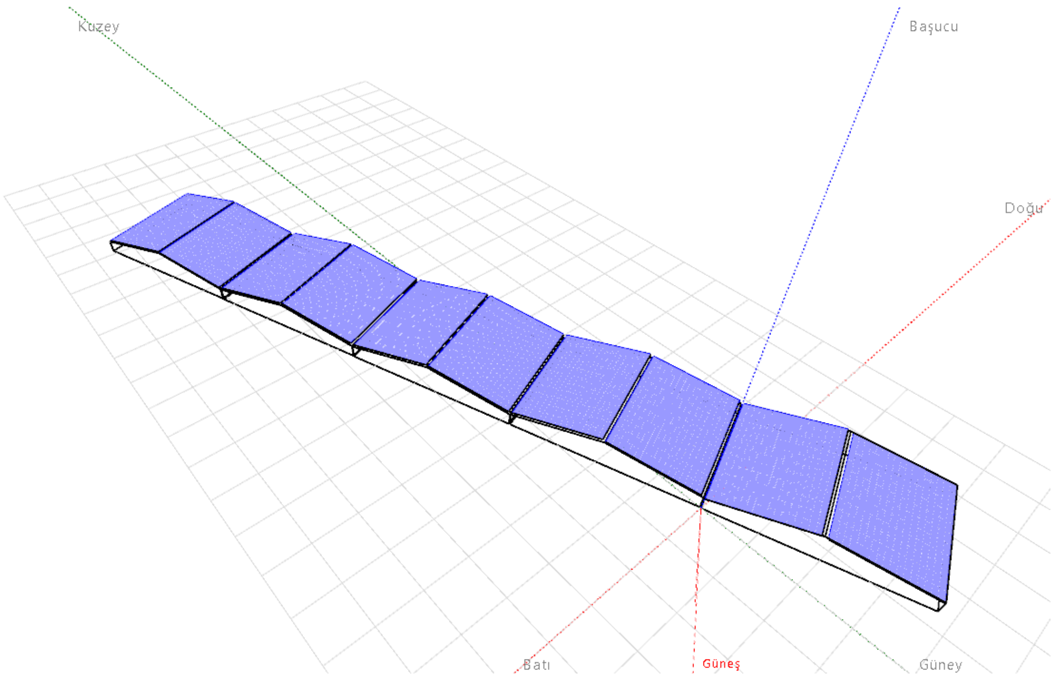

Figure 2. Design of North-South orientation [12]

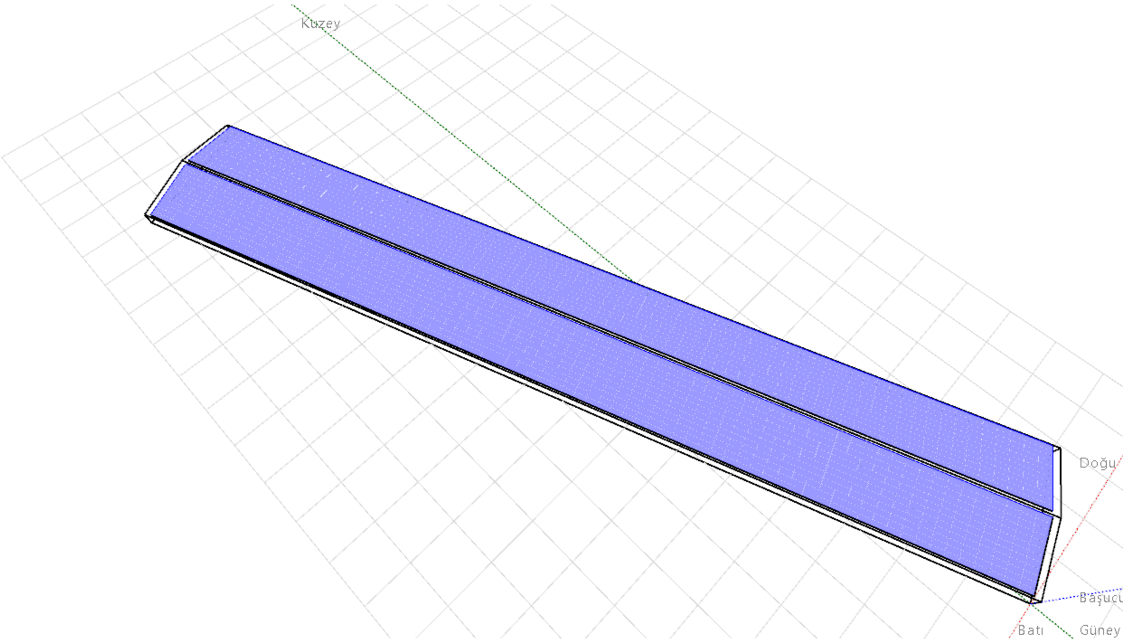

Figure 3. Design of east-west orientation [12]

The above steps were performed separately for each design at plane angles of 10°, 20°, and 35.6° different simulation studies were performed. As a result of the simulation studies, monthly and annual electricity production values were taken from the report presented by the software.

2.1 Economic Analysis

There are three main components in the greenhouse and greenhouse photovoltaic system designed in this study. These are transformer, greenhouse, and photovoltaic systems. Information on the cost of all systems is presented in Table 2.

Table 2. Greenhouse and greenhouse photovoltaic system cost

Photovoltaic System	14875000 TL
Transformer (1000 kVA)	1400000 TL
Greenhouse Installation Cost	3850000 TL
Subscription Deposit	70000 TL

In the regulation dated 12/5/2019 and numbered 30772, the expression "set-off" defines the process of "finding the net production or net consumption value in kWh as a result of deducting the production and consumption from each other within a certain period". In the "a" clause of the 24th paragraph of the same regulation, "The net electrical energy produced in the production facility or facilities located at the same place as the consumption facility and given to the grid in each billing period is ten years to be evaluated within the scope of Renewable Energy Resources Support Mechanism (YEKDEM) at a price determined by the supply company in charge as surplus electrical energy and purchased for a period of time". Within the scope of these statements, a consumption facility can produce electrical energy at the point where it consumes electrical energy and sells the excess for 10 years by offsetting. In companies that sell electricity by set-off, the selling prices of electricity are the same as the purchase prices. These prices are regularly published on EPDK's website [13].

For this study, 2 separate economic analyzes were carried out for "Agricultural Activities" users from the EPDK tariff table presented in Table 3, within the scope of "Single-term" and "binomial-term" subscription groups at medium voltage. The net income obtained as a result of the sales of electricity produced in the analysis was calculated with the help of Equation 1. The annual net income is calculated with the help of Equation 2.

$$AG = AE\text{Ü} \times (PTZEB - DB) \qquad (1)$$

$$YG = \sum_{n=12}^{n} \text{AG} \qquad (2)$$

In Equations 1 and 2, "AG" expresses the monthly net income value in TL. "AEU" represents the monthly electricity generation value. These electricity generation values are taken from the simulation results. The term "PTZEB" defines the retail one-time energy price for the applied tariff. Finally, the expression "DB" refers to the distribution price for the determined tariff. ROI value is the annual income value in TL. In Equation 3, the formula for the payback period is given.

$$G\text{Ö}S = \frac{\text{İ}YM}{YG} \qquad (3)$$

The GDS value defines the payback period in years. The expression ICE defines the initial investment cost. Acceptances made in the following items are presented.

- Electricity consumption in the greenhouse is neglected.
- When calculating the payback period, the greenhouse installation cost was not calculated since only the calculations were made for the photovoltaic system.
- All electricity produced was sold to the grid.
- Yield losses in the coming years have been neglected.
- Electricity sales prices are assumed to be constant for all years.

Table 3. Tariff Table Based on EPDK Electricity Bills [12].

	Activity Based Tariffs Approved by EPDK and Approved as of June 1 June 2022									
	1/6/2022	Activity Based Consumer Tariffs (kr/kWh)					Total Tariffs Excluding Power Fee (kr/kWh)			
Transmission System Users	Transmission System Users Receiving Energy from the Incumbent Supply Company	Retail One-Time Energy Cost	Retail Daytime Energy Fee	Retail Rush Hour Energy Cost	Retail Night Energy Fee	Distribution Fee	Single Time	Daytime	Puant	Night
	Consumer	245,3607	248,3693	392,2113	132,2746	0,0000	245,3607	248,3693	392,2113	132,2746
Distribution System Users	Distribution System Users	Retail One-Time Energy Cost	Retail Daytime Energy Fee	Retail Rush Hour Energy Cost	Retail Night Energy Fee	Distribution Fee	Single Time	Daytime	Puant	Night
	Medium Voltage						Medium Voltage			
	Double-Term						Double-Term			
	Industry	248,3714	251,3801	395,2221	135,2853	14,7972	263,1686	266,1773	410,0193	150,0825
	Public and Private Services Sector and Other	230,2455	232,5236	363,0085	128,7021	23,0611	253,3066	255,5847	386,0696	151,7632
	Residential	152,9207	155,4131	246,1925	82,8186	22,8419	175,7626	178,2550	269,0344	105,6605
	Agricultural Activities	157,6777	159,2914	251,4048	85,6839	18,9925	176,6702	178,2839	270,3973	104,6764
	Lighting	212,2218				22,1336	234,3554			
	Monomial						Monomial			
	Industry	256,6870	259,8001	408,5735	139,7250	16,3448	273,0318	276,1449	424,9183	156,0698
	Public and Private Services Sector and Other	235,0787	237,3568	367,8417	133,5347	28,7660	263,8447	266,1228	396,6077	162,3007
	Residential	154,5685	157,0611	247,8392	84,4656	28,2039	182,7724	185,2650	276,0431	112,6695
	Agricultural Activities	159,7360	161,3497	253,4633	87,7413	23,6477	183,3837	184,9974	277,1110	111,3890
	Lighting	216,7131				27,6100	244,3231			
	Low Voltage						Low Voltage			
	Monomial						Monomial			
	Industry	262,2851	265,2400	406,5304	151,2050	25,2888	287,5739	290,5288	431,8192	176,4938
	Public and Private Services Sector and Other (30 kWh/day and below)	174,6438	246,0159	376,5007	142,1943	34,2716	208,9154	280,2875	410,7723	176,4659
	Public and Private Services Sector and Other (over 30 kWh/day)	243,7383	246,0159	376,5007	142,1943	34,2716	278,0099	280,2875	410,7723	176,4659
	Residential (8 kWh/day and below)	95,5452	161,7720	252,5509	89,1764	33,5187	129,0639	195,2907	286,0696	122,6951
	Residential (over 8 kWh/day)	159,2790	161,7720	252,5509	89,1764	33,5187	192,7977	195,2907	286,0696	122,6951
	Families of Martyrs and Disabled Veterans	38,7776				22,7335	61,5111			
	Agricultural Activities	164,3828	168,6088	258,1106	92,3882	28,1603	192,5431	196,7691	286,2709	120,5485
	Lighting	224,9134				32,8247	257,7381			
	General Lighting	204,7600				32,8247	237,5847			

4. RESULTS

The electricity generation data obtained from the simulation results carried out in the study were applied using the equations 1, 2 and 3 given above. Figure 4 presents the annual gain graph at OG binomial tariff point for different designs. Since the highest electricity production values for all designs were realized in July, the gain values for this month again reached the highest value. The highest electricity generation was for the 10° east-west design, with a value of approximately 1589 MWh. The annual income amount for this design is 2 142 131.6 TL. The lowest electricity generation value was for the 35° north-south design, and the annual electricity generation value was calculated as 1392.3 MWh for this design. The annual income amount for this design is 1 879 045.77 TL.

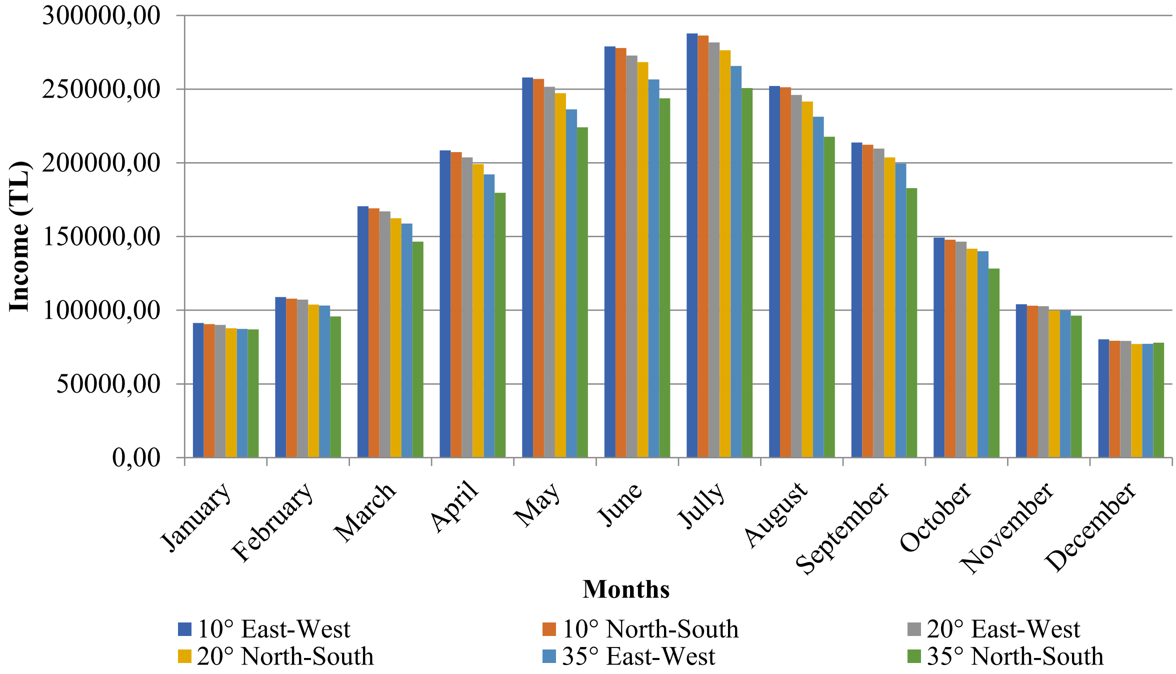

Figure 4. Monthly income values for OG binomial tariff

Figure 5 shows the annual gain graph for different designs at the OG mononomial tariff point. Since the lowest electricity production values for all designs occurred in December, the gain values for this month still seem to be at the lowest value. The lowest gain value among the designs was realized for the 35° north-south design and was calculated as 1 894 757.04 TL. The highest gain was for the 10° east-west design. The annual income amount for this design is 2 162 443.09 TL.

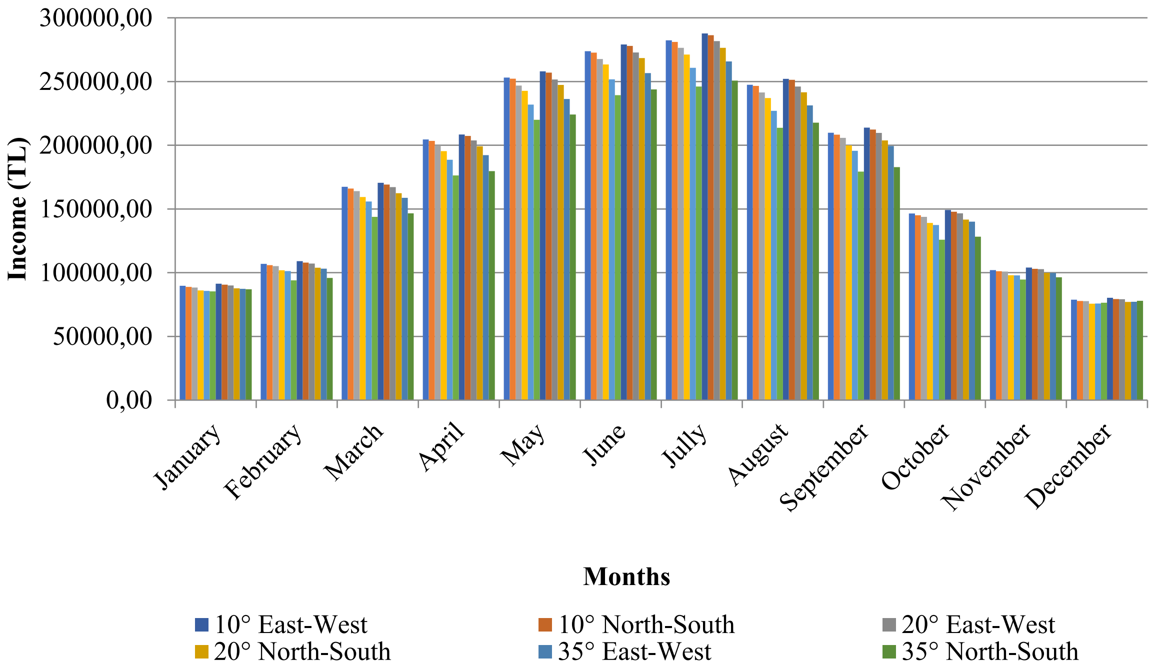

Figure 5. Monthly income values for the OG monomial tariff

Table 4 presents the payment terms for the greenhouse photovoltaic system for different greenhouse designs within the scope of the OG binary tariff. Among the calculations made for different designs within the scope of this tariff, the minimum payback period was 7.63 years, and the highest was 8.7 years.

Table 4. OG binomial payback periods.

Design	Payback Periods (Year)
10° East -West	7.63
10° North- South	7.68
20° East -West	7.79
20° North- South	7.94
35° East -West	8.21
35° North- South	8.70

Table 5 shows the payback periods for different greenhouse designs under the OG monomial tariff. For this tariff, the highest payback period is 8.63 years, while the lowest is 7.56 years.

Table 5. OG monomial payback periods

Design	Payback Periods (Year)
10° East -West	7.56
10° North- South	7.61
20° East -West	7.72
20° North- South	7.90
35° East -West	8.13
35° North- South	8.63

5. CONCLUSION

In this study, photovoltaic system designs have been performed for different types of greenhouses in order to examine the food and energy issues together, which have gained significant importance in recent years. The realized designs were simulated using PVsyst software. The electricity generation data obtained in the simulation results were analyzed economically at the point of monomial and binomial tariff groups for the "Agricultural Activities" subscription in the EPDK tariff tables. The difference between the highest electricity generation value and the lowest electricity generation value among the designs was determined as approximately 196.7 MWh. It has been calculated that the difference between the lowest annual income value and the highest annual income value within the scope of the OG binomial tariff is 272 793.79 TL. Within the OG monomial tariff scope, the difference between the lowest annual income and the highest annual income has been calculated as 267 685.69 TL. When the design and tariff parameters are evaluated together, it has been calculated that the difference between the highest and lowest values on the basis of annual income is 308 950.4271 TL. Again, when the tariffs and designs are evaluated together, it has been determined that a period of 1.14 years occurs when the highest and lowest values of the payback period are considered.

In the literature review, it has been determined that many studies have been carried out on using greenhouse photovoltaic systems. It is thought that such systems will become widespread in Turkey in the near future. Within the scope of the study, a study that will create a foresight on different designs and different subscriber groups for a greenhouse established on an area of 5031.6 m^2 has been presented, and a guideline study has been presented for investors considering agriculture and renewable energy investments together. With agricultural support mechanisms supporting such investments, payback periods can be shortened, and agricultural investors' investments in renewable energy can be encouraged. Orientation to greenhouse photovoltaic systems can be realized more quickly by directing the specialized organized industrial zones based on agriculture on these issues.

In addition, considering the increase in food prices and the supply gap, it is thought that if the following steps are taken, it can be a precaution against the food crisis that may be experienced.

- Determining the greenhouse-sourced food type and the need for these species throughout the country.
- Determining the greenhouse installation zones for the product, taking into account the climatic factors for the determined food type and need
- Designing greenhouse projects according to the standards determined for the products in the selected regions and designing greenhouse projects suitable for installing photovoltaic systems.
- Organizing the transformer capacities in the regions with the capacity to make applications to all areas where photovoltaic systems can be installed
- Opening the projects to the private sector investment in the determined regions at the point of the selected agricultural products, on the condition of continuous production.
- Encouraging investments in rural and agricultural development supports
- Purchasing the electricity production of investors who continuously produce agricultural products in the desired amount with the realization of the applications
- Fixing domestic sales prices at regular intervals by imposing a quota on the import of products.
- Increasing the electricity purchase prices and reducing the distribution costs .from the subscribers of "Agricultural Activities" presented in EPDK tariff tables.

With the realization of the above-mentioned items, energy investors, who have difficulties in finding viable photovoltaic system installation areas in the current situation, can be directed to the agricultural sector and the way of directing investments in two areas where there is a supply deficit in the world can be paved. If the condition of growing the target products determined in the greenhouse is met, the continuity of their earnings can be ensured by enabling them to sell electricity in the same place by the offsetting method. Thus, agricultural investors cannot reach sufficient income from time to time due to the fluctuations in the market. With the determination of food prices by the government, price stability can be achieved by reducing food inflation in the market. With the application of different renewable energy-based applications in agricultural areas, it can be predicted that rapid, sustainable progress can be realized in both agricultural and energy fields.

6. ACKNOWLEDGEMENTS

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Conflict of Interest

No conflict of interest was declared by the authors.

REFERENCES

[1] Koçar, G., Eryaşar A., Gödekmerdan E., Özgül S., Düzenli M. (2018). A Prospect on Integration of Solar Technology to Modern Greenhouses. Dokuz Eylul University-Faculty of Engineering Journal of Science and Engineering, 20, 58, 245-258.

[2] Hassanien, R. H. E., Li, M., Yin, F. (2018). The integration of semi-transparent photovoltaics on greenhouse roof for energy and plant production. Renewable Energy, 121, 377-388.
[3] Alinejad, T., Yaghoubi, M., Vadiee, A. (2020). Thermo-environomic assessment of an integrated greenhouse with an adjustable solar photovoltaic blind system. Renewable energy, 156, 1-13.
[4] Ezzaeri, K., Fatnassi, H., Bouharroud, R., Gourdo, L., Bazgaou, A., Wifaya, A., Bouirden, L. (2018). The effect of photovoltaic panels on the microclimate and on the tomato production under photovoltaic canarian greenhouses. Solar Energy, 173, 1126-1134.
[5] Yildirim, N., Bilir, L. (2017). Evaluation of a hybrid system for a nearly zero energy greenhouse. Energy Conversion and Management, 148, 1278-1290.
[6] Aroca-Delgado, R., Pérez-Alonso, J., Callejón-Ferre, Á. J., Díaz-Pérez, M. (2019). Morphology, yield and quality of greenhouse tomato cultivation with flexible photovoltaic rooftop panels (Almería-Spain). Scientia Horticulturae, 257, 108768.
[7] Cossu, M., Murgia, L., Ledda, L., Deligios, P. A., Sirigu, A., Chessa, F., Pazzona, A. (2014). Solar radiation distribution inside a greenhouse with south-oriented photovoltaic roofs and effects on crop productivity. Applied Energy, 133, 89-100.
[8] Sgroi, F., Tudisca, S., Di Trapani, A. M., Testa, R., Squatrito, R. (2014). Efficacy and efficiency of Italian energy policy: The case of PV systems in greenhouse farms. Energies, 7(6), 3985-4001.
[9] Marucci, A., Zambon, I., Colantoni, A., Monarca, D. (2018). A combination of agricultural and energy purposes: Evaluation of a prototype of photovoltaic greenhouse tunnel. Renewable and Sustainable Energy Reviews, 82, 1178-1186.
[10] Tang, Y., Ma, X., Li, M., Wang, Y. (2020). The effect of temperature and light on strawberry production in a solar greenhouse. Solar Energy, 195, 318-328.
[11] Official Gazette of the Republic of Turkey, 12 May 2019, number: 30772. https://www.resmigazete.gov.tr/eskiler/2019/05/20190512-1.htm [Access Date: 30.10.2022].
[12] PVsyst. (2022). Programme Interface. http://www.pvsyst.com/en/html [Access Date: 08.03.2022].
[13] EPDK, Repuclic of Turkiye Energy Market Regulatory Authority. (2022). https://www.epdk.gov.tr/Detay/Icerik/3-1327/elektrik-faturalarina-esas-tarife-tablolari.html [Access Date: 08.07.2022].