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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

PHOTOVOLTAIC SYSTEM DESIGN AND ANALYSIS AT FACULTY SCALE*

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ABSTRACT

In this study, it is aimed to develop a suitable photovoltaic system design for the needs of Giresun University Faculty of Engineering. After the determination of the number of panels required for the photovoltaic system by mathematical equations, a 3-dimensional layout planning was made on the roofs of the Engineering building using the PVSol program thus the required equipment was determined for the system. After simulation of the photovoltaic system and determination of the equipment compatible with the system was done, some parameters such as cost calculations, financial analysis and self-paying of the system were determined by the PVSol simulation program and the results were analyzed.

Keywords: *Renewable Energy, Solar Energy, Power Generation, Photovoltaic.*

FAKÜLTE ÖLÇEĞİNDE FOTOVOLTAİK SİSTEM TASARIMI VE ANALİZİ

ÖZ

Bu çalışmada, Giresun Üniversitesi Mühendislik Fakültesinin ihtiyaçlarına uygun fotovoltaik sistem tasarımı geliştirilmesi amaçlanmıştır. Fotovoltaik sistem için gerekli olan panel sayısı matematiksel denklemlerle tahmini olarak belirlendikten sonra PVSol programı kullanılarak Mühendislik binası çatılarında 3 boyutlu olarak yerleşim planlaması yapılmış ve sistem için gerekli olan ekipmanlar belirlenmiştir. Fotovoltaik sistemin *simülasyonu gerçekleştirildikten ve sisteme uyumlu ekipmanlar belirlendikten sonra PVSol simülasyon programı yardımıyla maliyet hesaplamaları, finansal analizleri ve sistemin kendini amorti etmesi gibi farklı parametreler belirlenmiş olup sonuçları analiz edilmiştir.*

Anahtar Kelimeler: *Yenilenebilir Enerji, Güneş Enerjisi, Enerji Üretimi, Fotovoltaik.*

1. INTRODUCTION

A large part of the energy produced in the world is still obtained from fossil fuels such as coal, oil and natural gas. The search for new energy has gained importance since fossil energy sources are not renewable and have negative environmental effects. There are six main renewable energy sources; these are bioenergy, geothermal energy, hydroelectric energy, ocean energy, wind energy and solar energy (Ellabban et al., 2014). Renewable energy sources are clean energy sources that have much lower environmental impacts such as CO2 emissions compared to traditional energy technologies. In recent years, energy production with renewable energy sources has increased and constitutes a good alternative to fossil fuels for the future (Chiu and Chang, 2009).

Solar energy is one of the most important sources of renewable energy (International Energy Agency, 2011). Technologies developed to take advantage of solar energy not only increase the amount of solar energy use, but also reduce infrastructure costs. Solar energy, which meets its investment in a short time with its low investment cost and high efficiency, is a costless and environmentally friendly energy source (Masterson, 2021; Sulukan, 2020).

In order to meet the increasing energy demands, Turkey imports energy to a large extent and especially uses fossil fuels. It imports about three quarters of the total energy needed in our country. Therefore, expanding domestic and national renewable energy resources, reducing foreign dependency and increasing energy efficiency should be one of Turkey's energy priorities (Varlık and Yılmaz, 2017).

Our country is in an advantageous geographical position for solar energy. According to Turkey's Solar Energy Potential Atlas (General Directorate of Energy Affairs, n.d.);

- Average annual total sunshine duration = 2741.07 hours/year,
- Average daily total sunshine duration = 7.50 hours/day,
- Average annual total radiation intensity = 1527.46 kWh/m^2-year,

- Average daily total radiation intensity = 4.18 kWh/m^2-day,

calculated as (Ministry of Energy and Natural Resources of Republic of Turkey, 2020). Thanks to the solar power plants that can be established in our country, which has regions that receive sunlight during all four seasons of the year, a significant part of the energy need can be met.

As a renewable resource, solar energy provides energy without any pollutant effects and greenhouse gas emissions. Thus, it contributes to the development of sustainable energy as well as reducing the negative effects of global warming (TÜİK, 2020).

Photovoltaic systems are formed as a result of bringing together needed equipment such as photovoltaic panels and such as to provide the desired current and voltage. Depending on the system configuration, there are three main types of PV systems. These are: off grid systems, on grid systems, hybrid systems.

In this study, a hybrid PV system that both supports battery and generates electricity depending on the electricity grid is used. Hybrid systems can be thought of as an upgraded on-grid system to include a battery backup. This system has a deep-cycle battery bank that can be charged by both the electricity grid and solar panels. Thus, in the event of an outage, the backup battery can be turned on to provide backup power to the building and can be used for an alternative power source in case of photovoltaic system operation or failure, until the grid problem is resolved.

2. RESEARCH FINDINGS

2.1. Solar Energy Potential

This study on the distribution of sunshine duration for Turkey was carried out using the daily total sunshine duration data measured at the stations of the Turkish State Meteorological Service (MGM) between the years 1988-2017. Sunlight time measurements, which have been made with heliograph devices for many years within the body of MGM, have been made with sundial measurement devices mounted on Automatic Meteorology Observation Stations (OMGI) since the 2000s. According to the total daily sunshine duration for the years 1988-2017 calculated for Turkey, the lowest average annual sunshine duration was measured in 1988 with 6.37 hours, and the highest sunshine duration was measured in 1990 with 7.30 hours (MGM, n.d.).

While calculating the solar system installation, solar panel calculation is made according to factors such as the sunshine duration information, as well as the factors such as at which hours the system will be used the most, in which seasons the system will be used intensively, the exact location of the system, and the amount of designed stored energy. For example, if a system is to be used in all seasons, it should be designed for winter sundials. Designed with an average of 7 hours a day, the system will be insufficient in winter. Similarly, if a system is designed to be used only in the summer months, extreme costs will be avoided if the average duration of sunlight in the summer months of the region is considered. Figure 2.1 shows the average duration of sunlight in Turkey by months.

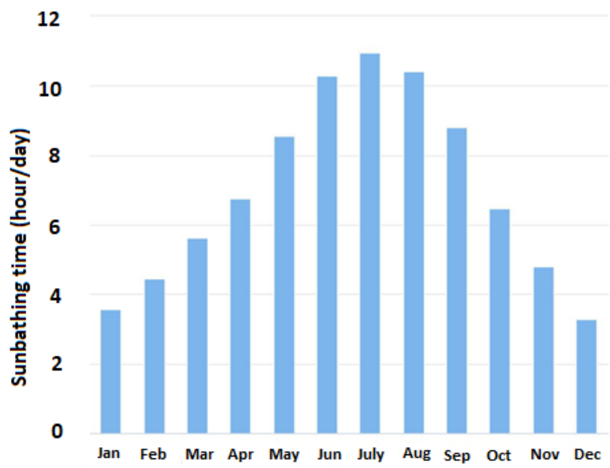

Figure 2.1. Turkey's sunshine duration by month (MGM, n.d.).

As it can be seen in Figure 2.1, the average, which rises to 11 hours in summer, decreases to 3 hours due to shorter days in winter, the sun reaching the panel with a more horizontal angle, and the weather being cloudier. In order not to interrupt off-grid solar energy systems in winter, seasonal changes should be considered, and the system should be designed according to the purpose of use.

Figure 2.2. Turkey sunshine duration distribution map (MGM, n.d.).

Obtaining the data closest to the location of the system will give more accurate results than making a calculation based on the average value of Turkey. Figure 2.2 shows the annual periods of sunlight and the average radiation intensity by region. Monthly sunshine and rainy days of the provinces are important for solar energy system design (MGM, n.d.).

Solar energy potential is an important parameter in determining the need for a solar panel for the system to be installed. The solar energy potential shows how much the sun's rays fall in which city and in which month.

Figure 2.3 shows the global solar radiation values of Giresun province and the solar energy potential according to the districts. According to this map, the districts with the highest solar energy potential are Alucra, Şebinkarahisar and Çamoluk. Figure 2.4 shows the average daily radiation values for Giresun province by month.

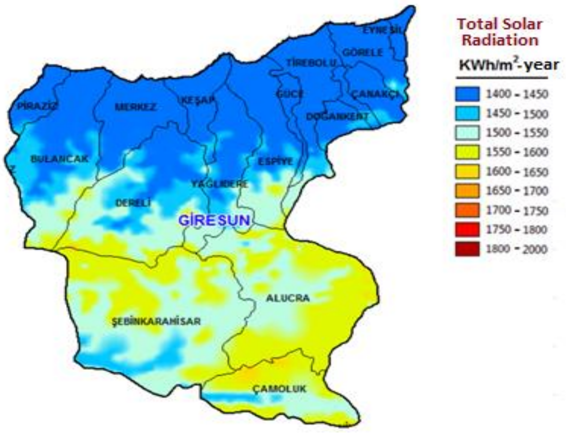

Figure 2.3. Total solar radiation values in Giresun province (General Directorate of Energy Affairs, n.d.).

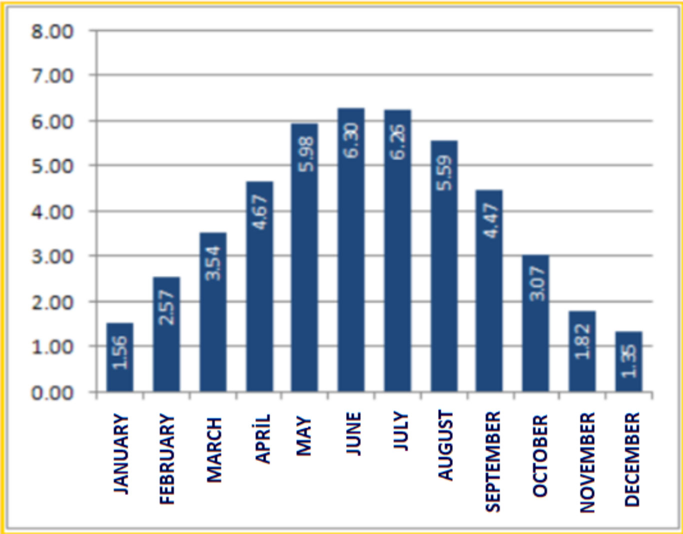

Figure 2.4. Global radiation values in Giresun province (kWh/m^2-day) (General Directorate of Energy Affairs, n.d.).

The angle of incidence of the sun's rays in the Black Sea is inefficient, moreover, due to the climate of the region, it rains constantly, the time of the sun falling on the region is less. For this reason, the potential of solar energy will be less than in the Mediterranean region, which receives more sun. Figure 2.5 shows the average monthly sunshine periods for Giresun. According to the data in Figure 2.5, in the province of Giresun, the duration of the month 9.00 average sunshine hours is the highest of June, with the lowest average sunshine duration of hours 3.05 in December.

A grid-connected PV system consists of solar panels, inverters, a power conditioning unit, and grid-connecting equipment. Since there is no loss of energy storage, it effectively uses the energy generated from solar energy. Under favorable conditions, the grid-connected PV system provides more power than the grid-connected load can consume.

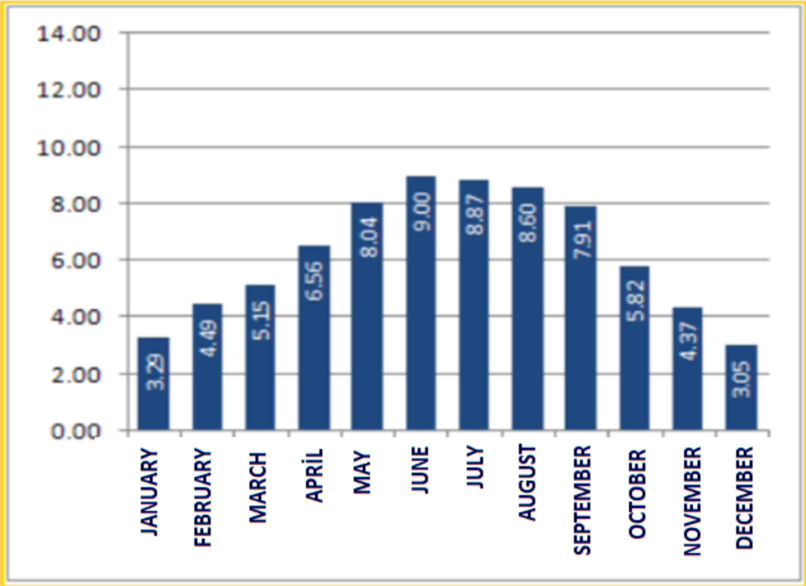

Figure 2.5. Giresun province sunshine durations (hours) (General Directorate of Energy Affairs, n.d.).

If the system to be installed is to be used only in summer, the daily average of the summer months should be found. However, if the system to be installed is to be used in summer and winter, the calculation should be made by looking at the daily production of the lowest electricity production month.

2.2. Determination of Energy Needs

As Giresun University Faculty of Engineering will be actively used at all times of the year, there will not be the same level of power consumption every month of the year due to changing sun exposure times, air conditioning loads in summer and more lighting loads in winter.

If the solar system will be used in all seasons, calculations should be made according to the winter sunshine hours. Thus, the system to be established will provide sufficient energy even in the months when electricity is produced at the lowest level. Looking at Figure 4.5, since the lowest sunshine value for Giresun province is in December, this value will be used in the calculations.

At the first stage, it should be known how much electrical energy will be needed for the solar system that we plan to install on the roof, and it should be calculated how many solar panels will be used in this context.

For this purpose, Giresun University Faculty of Engineering December 2020 electricity bill information is given in Table 4.1. The monthly incoming electricity bill showed that 22,591 kWh of energy was used during the month of December and consumed an average of 728,7419 kWh of energy per day.

Table 2.1. Giresun University Faculty of Engineering December Billing Information.

Average Daily Consumption (kWh)	728,741
Monthly Consumption (kWh)	22.591
Annual Consumption (kWh)	263.482

In Figure 2.5, it is seen that the solar panels receive 3.05 hours of sunshine in Giresun in December. Equation 2.1 given below is used to calculate the number of panels.

$$NP=\frac{DEN(Wh)\times SE}{PGM(W)\ x\ ASTD(h)} \quad \text{(piece)} \qquad \textbf{(2.1)}$$

NP = Number of Panels,
DEN = Daily Energy Need,
SE = System Efficiency,

PGM = Power Generated by a Module,
ASTD = Average Sun Time per Day.

Here the system efficiency is assumed to be approximately 1 for an account. According to this formula, when using a 300W panel, about 797 solar panel systems will meet all the energy needs of the Giresun University Faculty of Engineering when using a 300W panel.

If the 320W panel is used, the number of panels will be reduced to 747, and it can meet all the energy needs. These calculated panel values are valid for an off-grid system, and the installation cost and payback period may take many years depending on the systems connected to the grid.

If the system planned to be installed is to be used throughout the year, but the electricity consumption is not enough, a calculation should be made of the amount of energy consumption used for the entire year, considering that the electricity will be supplied from the grid. In Figure 2.1, to find the value of the average daily energy consumption from the amount of energy consumed per year,

$$\text{Daily Average Energy Consumption} = \frac{\text{Annual Consumption(W)}}{365} \qquad \textbf{(2.2)}$$

the equation will be used. With the help of this equation, the Average Daily Energy Consumption is found to be 721.86 kWh. Figure 2.5 shows the monthly sunshine periods of Giresun province. Using these data, the average duration of sunlight for Giresun can be found by equation 2.3.

$$\text{AST} = \frac{\sum_{1}^{12} \text{MST(hour)}}{12} \qquad \textbf{(2.3)}$$

AST= Average Sunshine Time,
MST=Average Monthly Sunshine time
Accordingly, the average duration of sunlight is obtained as 6.26 hours. In other words, the average monthly duration of sunlight is 6.26 hours. Using

equation 2.1, we can find the number of panels we need for a 320W panel. Accordingly, the number of panels is available in the amount of 360 pieces.

The system to be installed in this study will be used in both summer and winter months, but when solar energy is not enough; there will be a connection to the electrical network to avoid disruption in the use of electricity.

3. PHOTOVOLTAIC SYSTEM DESIGN

After determining the estimated energy needs of Giresun University Faculty of Engineering, the roof section on the southern facade, which receives the sun's rays most efficiently and has an approximate slope of 25^0, was determined for the installation of solar panels. The placement of the designated solar panels was done with the PVSol simulation program, which can design 3D buildings.

In the PVSol simulation program, in order to add Giresun University Faculty of Engineering to the system, modeling was performed using the satellite image of the building in Figure 3.1.

Figure 3.1 Satellite view of Giresun University Engineering Faculty roof.

For the design of this project, a hybrid system with mains connection and battery boost was preferred. The MeteoSyn Climate database in the PVSol program contains about 450 climate data for Germany for the years 1981-2010 and more than 8,000 climate data for the years 1986-2005 worldwide on the basis of meteonorm 7.0. Climate data can be easily selected on the map (Valentin Software, 2020).

In the simulation applied, there are climate data of Giresun province between 1991-2010. Accordingly, the annual solar radiation value of 1173 kWh/m2 and the annual average temperature of 15^{o} were obtained in real time for Giresun University Engineering Faculty. The AC data to be used in the simulation are entered into the system as in Table 3.1.

Table 3.1. AC mains.

Phase Number	3
Mains Voltage (single phase)	230 V
Displacement Power Factor (cos phi)	+/- 1

Thanks to the integration of Google Maps in the 3D modeling of the program, the roof image of the Faculty of Engineering was uploaded to the program through the program. When this image is loaded, the program automatically selects the most suitable facade for modeling - the southern facade. For Giresun province, located in the north of Turkey, the installation of photovoltaic panels facing south provides higher energy production. The annual consumption of Giresun University Faculty of Engineering is shown as 263.482 kWh in the electricity bill in Table 2.1 and these data are used in simulation calculations.

In addition to the amount of solar radiation, the most important factor in calculating the electrical energy to be generated is the characteristic of the photovoltaic module. The PVSol program has about 13,000 modules in its database. The photovoltaic module model used in this study is a model included in the database of the software. As a Solar Panel, a 327 W SunPower monocrystalline solar panel was preferred. Figure 3.2 shows the layout of 368 units of 327 W SunPower solar panels on an area of 600.1 m2 selected.

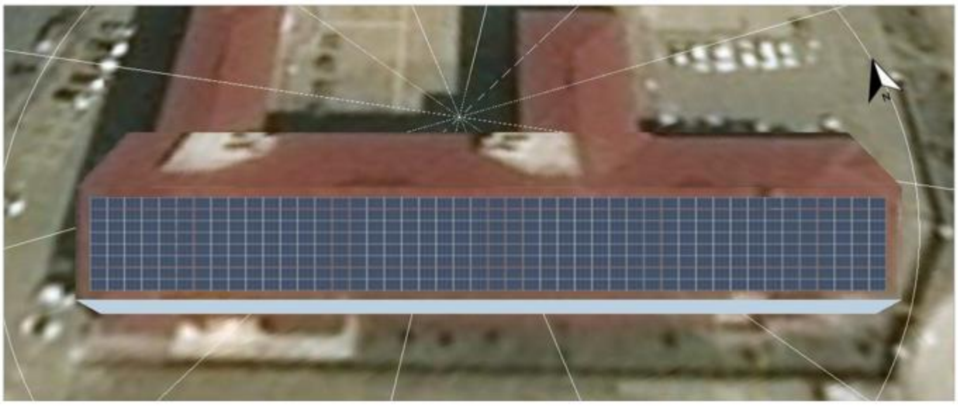

Figure 3.2. Module layout.

The dimensioning plan of the modules designed to be placed on the roof area is as in Figure 3.3.

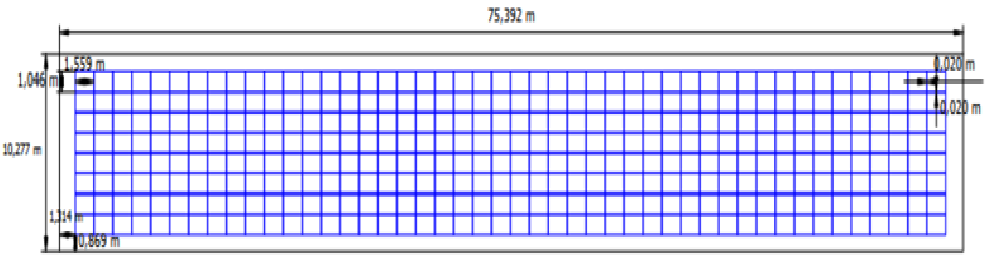

Figure 3.3. Dimensioning plan of modules.

The PVSol software with a 3D design editor draws 3D objects on the satellite map and performs the nearest realistic simulation to calculate the amount of shading. For the roof areas of the 3D buildings being drawn, the software automatically places the maximum number of modules on the roof. In addition, the selected suitable inverters are automatically configured. There are 3,100 inverter model specifications in the software database (Valentin Software, 2020).

Inverters are the most important photovoltaic system component to be considered after panels. When choosing an inverter, it should be noted that the maximum open-circuit voltage of the series-connected wire is higher than the inverter input voltage. In addition, it is necessary to choose an inverter with a power close to the power of the photovoltaic system, which is designed to be installed so that the inverters can work more efficiently. Huawei Technologies SUN2000-33KTL-A model 30kW inverter was selected for the system designed to be installed. The software program has set the required number of inverters for the system to be 4 units.

In the block diagram of the grid-connected photovoltaic system designed in Figure 3.4, there are 4 inverters in the first place, and a total of 16 MPPT is used for each inverter connected to these 4 inverters, 4 of which are connected to the grid. MPPTs connected to the first and second inverter are also divided into 2 string zones consisting of 12 modules. Further, the zones connected to the third and fourth inverter are divided into 2-string zones consisting of 11 modules.

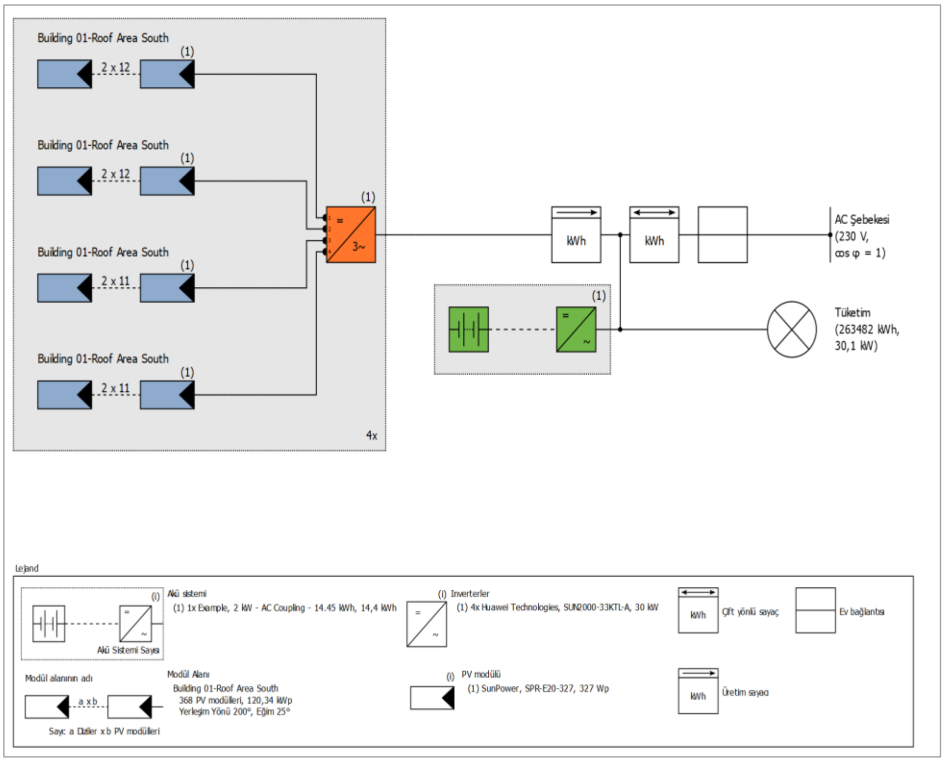

Figure 3.4. Block diagram of the designed photovoltaic system.

Batteries are used to store electrical energy on sunny days to use electrical energy on days when there is no solar energy or on days without solar energy. A battery group consisting of 12 batteries with battery energy of 14.4 kWh has been added to the system. It is generally not preferred to use it in such large-scale projects because battery groups are very costly, and their efficiency decreases after a certain number of years of use. In this study, a battery system was added to the simulation to provide energy to the system during the hours when there is no production, and the selected battery group is loaded alive for a year, and in cases where there is no production from solar energy, it is planned to provide energy to the system for about 6 hours.

The list of parts used in the system designed to be installed and the number of parts is listed in Table 3.2.

Table 3.2. Parts list.

Mat.No	Type	Manufacturer	Name	Quantity	Unit
1	PV module	Sun Power	SPR-E20-327	368	Piece
2	Inverters	Huawei Techn.	SUN2000-33KTL-A	4	Piece
3	Battery System	Example	2 Kw-AC Coupling-14,45 kWh	1	Piece
4	Counter		Production Counter	1	Piece
5	Counter		Bidirectional Counter	1	Piece

4. SIMULATION RESULTS

After the inputs of the system that is planned to be installed are added to the program and the equipment intended for use is determined, all the results of the system are taken graphically from a detailed project report and result screens. In Figure 4.1 there is a diagram of the energy flow, obtained because of the simulation of the designed solar power plant. According to this scheme, it has been calculated that the power plant installed on the roof of Giresun University Faculty of Engineering produces 138.054 kWh per year. 3,786 kWh of energy was stored in the battery groups and 3,167 kWh of energy was provided from the battery groups. According to the calculations in the simulation program, 86,681 kWh of the consumption of 263,523 kWh was obtained from the installed solar energy system, 173,682 kWh from the grid and 3,167 kWh from the battery group. In addition, according to the simulation program data, it was calculated that 47.609 kWh of energy will be sold to the grid when consumption is low.

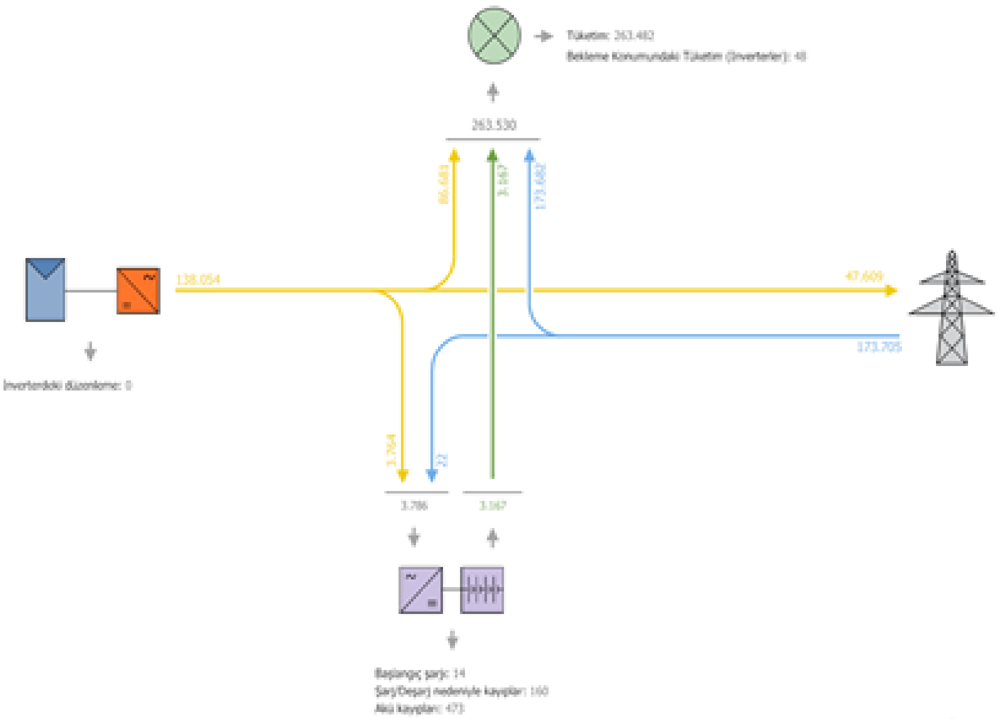

Figure 4.1. Energy flow graph.

The following input data is used to determine the evaluation dimensions:

- E_{in} = Energy radiated to the PV generator surface,
- EPV_{use} = Generated solar energy (on AC side) - own inverter consumption,
- E_{Load} = Electricity demand of devices,
- P_{nom} = Installed PV generator output,
- η_{STC} = Module efficiency under standard test conditions.

The specific annual efficiency is a measure of the number of hours that the PV system operates at full load for a year. The specific annual yield value is found with the help of the following equation.

$$\text{Annual Specific Earnings} = \frac{\mathrm{EPV_{use}}(kWh)}{\mathrm{P_{nom}}(kWp)} \quad \textbf{(4.1)}$$

The performance ratio defines the potential PV power generation efficiency in each system environment. The performance ratio is a measure of the energy losses in the system because it is compared with the energy output of the PV generator under standard test conditions (STC). The energy output under STC is determined by multiplying the modulus efficiency (ηSTC) of the energy emitted on the PV array surface (Ein) by (Equation 4.2).

$$\text{Performance Ratio} = \frac{\mathrm{EPV_{use}}(kWh)}{\mathrm{E_{in}}(kWh)} \times \eta_{STC} \quad \textbf{(4.2)}$$

It consists of PV generator efficiency and inverter efficiency, considering system efficiency, wiring and battery losses. System efficiency is a measure used to convert the total amount of energy emitted by the PV system to the array surface (Ein) (Equation 4.3).

$$\text{System efficiency} = \frac{\mathrm{EPV_{use}}(kWh)}{\mathrm{E_{in}}(kWh)} \quad \textbf{(4.3)}$$

Table 4.1 contains a summary table of the installed photovoltaic system. Here, the annual energy gain of the PV system is 1,137.06 kWh and the utilization rate of the system is 90.5%. One of the biggest harms caused by the use of fossil fuels is the release of greenhouse gases such as CO_2. It has been calculated that the amount of CO2 emissions that can be prevented by installing the system will be 65.105 kg per year. It is also calculated that the 263.482 kWh requirement of the Faculty of Engineering is met by 94.613 kWh of the PV system and 168.907 kWh of the network, so the autarky rating (self-sufficiency rating) of the system is 35.9%. The life of the battery pack installed in the system is 15 years, and it seems so.

Table 4.1. All system results.

PV System	
PV Generator Output	123 kWp
Annual Specific Earnings	1.137,26 kWh/kWp
System Usage Rate	90,5%
Loss of gain due to shadowing	0,0 % / Year
PV generator energy (AC grid)	139.8280kWh/Year
Avoided CO2 emissions	65.105 Kg/Year
Consumer	
Consumer	263.482 kWh/Year
Consumption in Standby (Inverters)	38 kWh/ Year
Total Consumption	263.520 kWh/ Year
Battery System	
Initial Charge	30 kWh
Battery Charge	9.324 kWh/ Year
Battery energy required to meet the consumption	8.046 kWh/ Year
Losses due to Charge/Discharge	563 kWh/ Year
Battery losses	744 kWh/ Year
Load Cycle	6,5 %
Lifetime	15 Year
Degree of autarky	
Total consumption	263.520 kWh/ Year
Consumption covered by the grid	168.907 kWh/ Year
Degree of autarky	35,9 %

In Figure 4.2, in the power generation table of the PV system by month, the yellow bars represent the amount of PV generator energy, the gray bars represent the amount of direct self-consumption, the blue bars represent the amount of mains supply, and the green bars represent the battery charge. yesilmaz According to this graph, almost all of the energy generated by the PV system was used. December may has the highest energy production, the highest in May and the lowest in November and December.

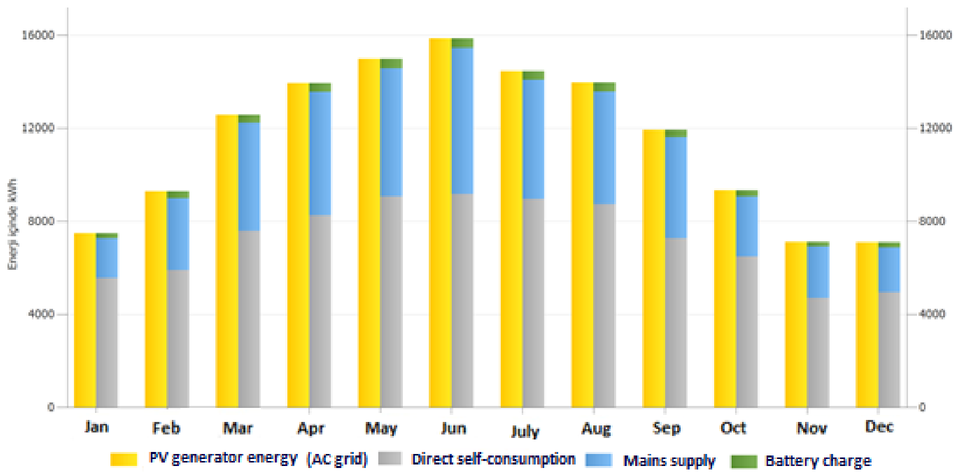

Figure 4.2 Use of the photovoltaic system.

In Figure 4.3, the gray bars represent the consumption in standby mode, the yellow bars represent the energy supplied by PV, the blue bars the energy supplied by the grid, and the green bars the energy amount met by the battery in the chart of the system to meet the consumption by months.

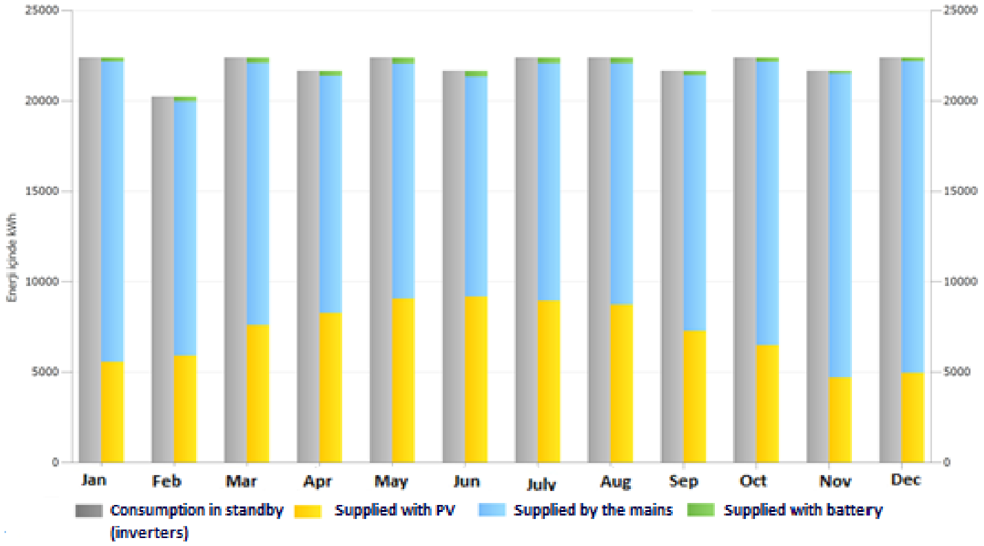

Figure 4.3. Graph of meeting the consumption of the system by months.

4.1. Financial Analysis

The calculation of economic efficiency with the PVSol program is calculated based on the capital value method using the following equations. The cash value (CV) of a price-dynamic payment sequence Z, Z*r, Z*r² ... over T years (lifetime).

$$CV = Z \times b(T,q,r) \qquad \textbf{(4.4)}$$

CV = cash value, Z = series of payments and b = net worth factors
The net worth factor is found with the help of equation 4.5 below.

$$b(T,q,r)=\begin{cases}\dfrac{1-(r/q)^T}{q-r} & r\neq q\\ \dfrac{T}{q} & r=q\end{cases} \quad \textbf{(4.5)}$$

q: Simple interest factor (e.g. 1.08 at 8 % simple interest)
r: Price change factor (e.g. 1.1 at 10 % price change)

The following applies for the net present value:

Net present value of the total investment = Σ [CV of the price-dynamic payment sequences over the lifetime] - investment + subsidies

Positive net present values indicate an investment which can be assessed as economically positive. The pay-back time is the period the system must operate for the investment to yield net present cash value of the overall investment of zero. Pay-back times of over 30 years are not supported.

Figure 4.4 shows the change in electricity bills before and after the photovoltaic system is installed and installed. In this table, the blue values indicate the values in the electricity bill before the PV system is installed, and the yellow values indicate the values in the electricity bill after the PV system is installed. According to the results of the analysis, the cash flow graph of the PV system is given in Figure 4.5. The system, which is projected to have a project life of 21 years, turns into a positive value after the first 7 years.

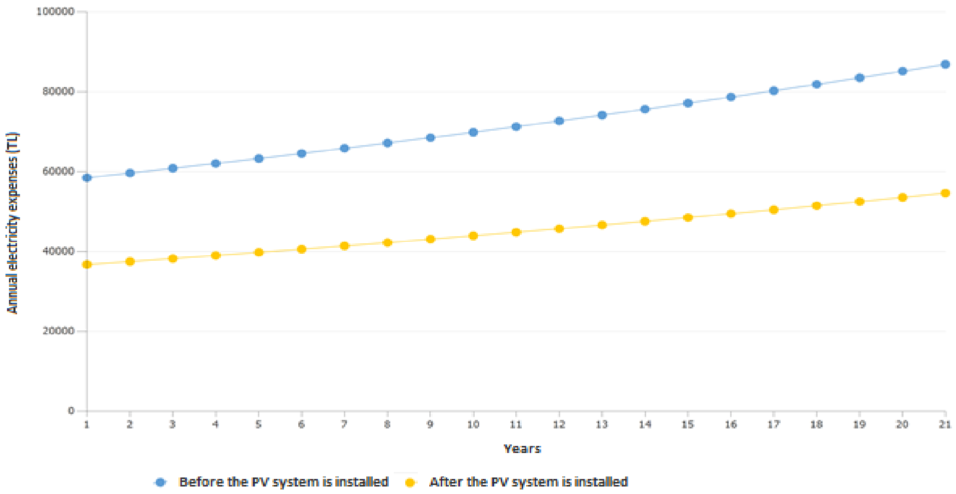

Figure 4.4. Electricity cost slope.

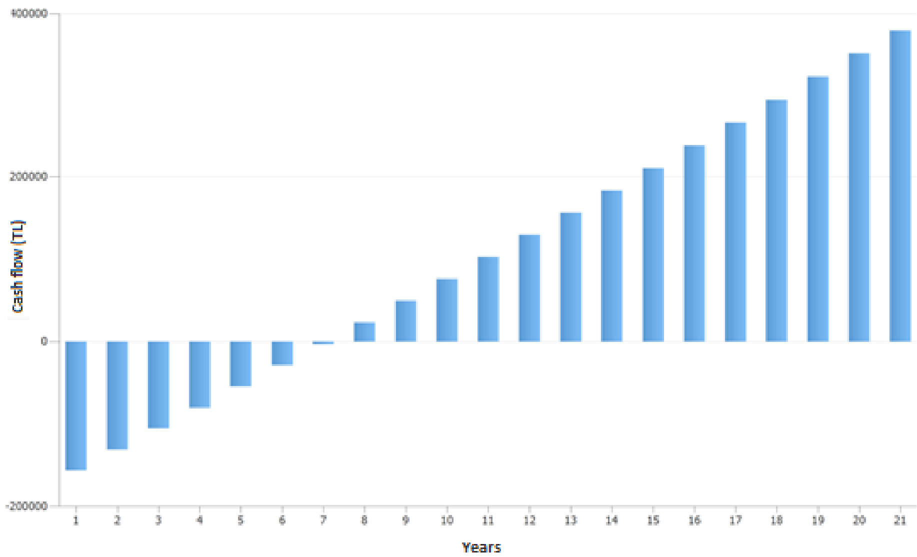

Figure 4.5. Cash flow chart.

Although solar energy systems are very costly in terms of economy, they can meet the initial investment costs in the first few years, due to their long life. The life of the simulated Giresun University Engineering Faculty Photovoltaic system is predicted to be 21 years, and after the first 7 years, there will be no extra expenses other than the maintenance costs that must be done periodically, and according to the unlicensed electricity generation law; an incentive fee is charged for each kilowatt of solar energy produced.

5. CONCLUSION

Photovoltaic system design developed for this study, solar radiation data was evaluated for the location of the system designed to be installed by the PVSol program, the appropriate roof facing south with an angle of 25^o was selected by evaluating the roofs of the buildings, the components of the photovoltaic system were selected, and finally, the PV system connected to the grid was designed and financial analyzes were made.

The number of panels required for the photovoltaic system was calculated using equation 4.1 and the estimated number of panels was determined. Then, a 3D layout was made on the roof of the engineering building using the PVSol program and the necessary equipment for the simulation of the photovoltaic system was determined and the photovoltaic module, inverter and battery were compatible with the system such as the project design was made. With the help of PVSol simulation program, various parameters of the system such as cost calculations, financial analysis and self-wear were determined, and the technical and economic suitability of the designed system was examined.

Although solar energy systems are very costly in terms of economy, they can cover the initial investment costs in the first few years due to their longevity. The life of the simulated Giresun University Faculty of Engineering Photovoltaic system will be 21 years and the system will be 7. it is predicted that he will reproach himself in his year. According to the unlicensed electricity generation law, an incentive fee is charged for every kW of solar energy produced.

Analysis of the simulation results shows that when the project is implemented, Giresun University Faculty of Engineering will provide approximately 138.054 MWh of electricity, which is about 52% of the annual electricity consumption. The system, designed to be installed, also can save about 64,588 kg of CO2 emitted by a crude oil-fired thermal power plant that produces the same amount of electricity.

According to the wage conditions prevailing in Turkey, this project may not be considered financially viable, except for the implementation of a guaranteed wage plan or other incentives such as grants/capital subsidies. However, there are other non-financial benefits, such as reducing greenhouse gas emissions.

Within the scope of this study, the solar energy system planned to be installed at Giresun University Faculty of Engineering provided an energy output of 120.34 kW with 368 photovoltaic modules of 327 W, 4 inverters and 1 battery system on an area of 600.1 m2 on the roof of the faculty. From this work we can draw the following conclusions that will justify the viability of the solar energy system:

- This system produces 138,054 kWh energy units per year.
- The rate of return on capital investment is 14.30% per annum.
- The payback period of this system is approximately 7.1 years.
- The average performance rate of the system is 91.3% and the specific annual efficiency is 1147.24 kWh.
- In the case of using conventional power, the annual CO_2 emission is 64,588 kg.
- This study has been applied to the south-facing part of the Giresun University Roof, and if desired, it may be possible to expand the scope of the project to provide more energy production.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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