Use Of Photovoltaic Systems in Buildings – Sample Design on the Office Building Roof in Dörtöyol District of Hatay

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ABSTRACT

In this study, the use of solar energy, which is the most abundant renewable energy resource in the world, in the production of electricity and meeting the need for electricity by applying this technology on buildings is discussed. Examined the solar energy potential in Turkey within the scope of the study, the structure of photovoltaic panels, working principle, by considering the types, design principles of photovoltaic systems were examined. In addition, applications on buildings, design criteria and system dimensions of these applications are examined. The current standards and regulations regarding the use of photovoltaic systems in buildings are examined, and the problems and recommendations regarding the use of these systems are discussed. As a result of the research, a sample PV system was designed for an office building roof in Dörtöyol district of Hatay. When the sample application is examined in terms of cost, it is still possible to perceive PV systems as an expensive electricity generation method today, but when the return percentage is calculated, it turned out that there is a prospective investment. Considering the increase in electricity needs in the world, possible electricity prices in the future and the decrease in PV system costs, it has emerged that PV systems will be economically usable in the near future.

KEY WORDS: RENEWABLE; ENERGY; SOLAR ENERGY; PHOTOVOLTAIC (PV); BUILDING INDUSTRY.

INTRODUCTION

Most of the energies we use today are fossil-based energy systems, and they are rapidly depleted sources that, due to their use, harm the environment to a great extent. The most important of these energy sources are coal, oil and natural gas. The CO₂ released by the burning of fossil sources leads to the warming of the atmosphere,

increasing the greenhouse gas, and thus climate change. In addition, it has impacts such as Global warming, pollution of water and soil, damage of vegetation, acid rains, desertification and biological diversity. Accordingly, human health is negatively affected. It is an inevitable fact that these energies are not endlessly sourced, but they will be consumed in the near future. Industrial systems based on fossil-based technologies will also become inoperable. The results of this may be big enough to affect the whole world economy.

Water, wind, solar, liquid fuels and hydrogen technologies, which we can count among renewable energy sources, have become more important day by day. Solar energy is considered to be extremely important among these energy sources. In the past two decades, solar technology has developed rapidly, both the thermal applications of solar energy and the applications for obtaining electricity have

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accelerated promising for the future. Turkey's used in a very high level, domestic, renewable "Clean Energy" has potential. When this energy potential is used correctly, foreign dependency in energy and the use of energy types that pollute the air and produce emissions will cease. Considering the current environmental and energy problems, an effective way to utilize natural energy sources other than fossil sources is to use renewable

Figure 1: Solar Energy Potential of Turkey

Table 1. Breakdown of Turkey's Total Solar Energy Potential of the Moon

Months	Sunbathing Time (hours / month)	Monthly Total Solar Energy	
		(KWh / m2 month)	(Kcal / cm2 month)
January	103,0	51,75	4,45
February	115,0	63,27	5,44
March	165,0	96,65	8,31
April	197,0	122,23	10,51
May	273,0	153,86	13,23
June	325,0	168,75	14,51
July	365,0	175,38	15,08
August	343,0	158,40	13,62
September	280,0	123,28	10,60
October	214,0	89,90	7,73
November	157,0	60,82	5,23
December	103,0	46,87	4,03
Total	2640,0	1311	112,74
Average	7,2 hour / day	3,6 KWh / m ² day	308,0 cal / cm ² day

Photovoltaic (PV) systems that utilize solar energy are among the most promising renewable energy sources in the world. We need to make maximum use of solar energy, which we can call continuous energy. In this work, the integration of solar and solar energy, solar cell structure, photovoltaic systems and their features, photovoltaic systems, which we can also use as a design tool in architecture, to architectural elements (roof, facade and building elements) are examined. A sample design has been made for roof application in Dörtöyl district of Hatay. Standards, regulations and regulations related to the subject have been researched. With this study, it was aimed to draw attention to the possibilities

energy sources. Solar energy is the first source that comes to mind as a renewable energy source.

Table 2. Total Annual Turkey's Regional Distribution of Solar Energy Potential

Turkey's Total Annual Regional Distribution of Solar Energy Potential		
REGION	TOTAL SOLAR ENERGY (kWh/m ² -year)	SOLAR TIME (H / year)
SOUTH-EAST ANATOLIA	1460	2993
MEDITERRANEAN	1390	2956
EASTERN ANATOLIA	1365	2664
CENTRAL ANATOLIA	1314	2628
AEGEAN	1304	2738
MARMARA	1168	2409
BLACK SEA	1120	1971

Figure 2: Cell, Module, Panel and Array Used in PV Systems

Figure 3: Structure of Photovoltaic Cell

of using solar energy in our country, especially in the field of architecture, and to make a contribution not to ignore this information in the new building designs to be made. It is aimed to develop suggestions on the subject.

2- Turkey's Solar Energy Potential: Turkey, the opportunity to use depending on the angle of incidence of solar radiation on Earth is quite high, is located on the

sun belt. Our country, which provides a significant part of its energy need by import, needs to utilize the solar energy that is inexhaustible, free, has no transportation problems, does not create environmental problems and air pollution. For this, there is a need for economic systems that will convert the radiation from the sun into the most efficient type of energy available. Turkey location as solar intensity and duration of sunshine is among the highest countries. Especially Southeast, Central Anatolia, Aegean and Mediterranean regions are rich in solar energy potential. Turkey's solar map in Figure 1 shows. Orange colors show the provinces with the highest solar energy density. The Black Sea region is the weakest settlements in terms of solar yield.

According to the study conducted by EIE; Turkey's average annual sunshine time of 2640 hours (7.2 hours per day total) average total solar radiation is 1311 kWh / m²-year (daily total of 3.6 kWh / m²) has determined that it is. Solar energy potential of Turkey and sunshine duration values by months is given in Table 1.

Turkey's biggest area of solar energy is the South East Anatolia Region, followed by the Mediterranean Coast. The distribution of solar potential and sunshine duration values by region is also given in Table 2.

Accordingly, Turkey as well as the overall most and the least solar energy will be produced in the months of June and December is. Southeastern Anatolia and Mediterranean coasts are among the regions. Except for the Black Sea region, where solar energy production is almost non-existent, 1,100 kWh of energy can be produced per square meter per year and the total amount of sunny hours is 2,640 hours. Accordingly, while the total annual amount of energy taken in Turkey is about 1015 kW hours.

Photovoltaic System and its Characteristics

a- Solar Cells: Photovoltaic is the name given to technology that can generate electrical energy directly from special semiconductor assemblies illuminated by photons. The devices designed to obtain direct electricity from solar energy with photovoltaic technology are called solar cells. Today, solar cells have wide usage areas. The trend towards renewable energy sources is increasing day by day. One of the most important reasons for this is the ability to generate electrical energy without harming the environment. Solar energy is also a renewable energy source and has been used in most applications recently. The main element that forms solar energy systems are solar cells, also called photovoltaic (PV) batteries. PV batteries are highly preferred for their longevity, easy electrical power generation and environmental protection. Solar cells are the most basic unit of PV systems. These cells are connected in series and in parallel, forming PV modules, modules joining panels and panels joining sequences. Figure 2 shows schematically PV cell, module, panel and array.

Solar cells (photovoltaic cells) are semiconductor materials that directly convert the sunlight (photon) coming to their surface into electricity. The solar cells, whose surfaces are shaped as square, rectangular, and circle, are generally around 1m² and their thickness is between 0.20-0.4mm. Solar cells operate on the basis of photovoltaic principle, that is, when the light falls on them, electric voltage is created at the ends. Depending on the structure of the solar cell, solar energy can be converted into electrical energy in an efficiency of 5% to 20%. Solar cells are electronic devices that convert sunlight directly into electricity. It consists of materials of electrical nature between a metal such as semiconductor copper and insulating material such as glass. Those working on these semiconductor materials; crystalline silicon is CuInSe₂ (CIS) (copper indium diselenide), CdTe, GaAs and Amorphous silicon oxygen. Effectively converting solar energy into electrical energy requires quality semi-permeable layers and a perfect structure in crystal. Crystal surface defects are passivated with high quality coating layers.

Solar cells, or solar cells, are a structure made of silicon and semiconductor materials. The upper layer of the solar cell is covered with a layer called ARC that minimizes reflection and absorbs incoming light. After that, there is a protective front contact part. Below that is the n-type layer. This layer was added with a small amount of phosphorus. In this way, a displacement occurs between silicon atoms and phosphorus atoms. This creates negative charges, which is why it is called the n-type. The lower layer contains a p-type silicone layer added with a small amount of boron. The displacement of the silicon and boron atoms also creates positive charges in this layer. The last layer is the back contact made of metal, which increases the cell's durability and closes its back.

Solar cells operate on the basis of photovoltaic principle, that is, when light falls on them, electric voltage is generated at their ends. The source of the electrical energy supplied by the batteries is the solar energy coming to its surface. The radiation intensity at sea level on a bright cloudless day is around 1000 W / M² maximum. Depending on the region, the amount of solar energy per 1m² varies between 800-2600 KWh per year. This energy can be converted into electrical energy with an efficiency of 5% -70% depending on the structure of the solar cell.

Solar cells consist of two layers, positive and negative. These layers consist of N type and P type semiconductor materials. Of these substances, the P-type semiconductor material has one more electron and the N-type semiconductor material has one less electron. The atom of the top layer, which has an excess of electrons in its atomic structure, is stimulated by photons of the sun rays, and the atomic structure in the lower layer tends to advance to an electron-missing layer. When electrons flowing from this upper layer to the lower layer are collected with appropriate circuits, an electric current is

created. The properties of PV panels change according to the material they are made of. Although the efficiency of PV panels varies according to the material used in laboratory conditions, PV panels made of crystalline silicon are preferred in our country. PV panel types are given below.

Figure 4: Basic Working Principle of Photovoltaic Systems

- Crystal Silicon Solar Cell
- Thin Film Solar Cells
- Other Cell Technologies Under Development

b- Photovoltaic Systems and Components: Photovoltaic modules are manufactured for outdoor use and are resistant to conditions such as sea conditions, tropical conditions, desert conditions. A photovoltaic module system is created by combining PV panels and complementary equipment to provide the desired current and voltage. The diagram showing the basic working principle of photovoltaic systems is shown in Figure 4.

Components that make up the photovoltaic system;

1. Solar Panels
2. Batteries
3. Charge Control Units (Regulator)
4. Inverters (Inverters)
5. Other System Components

The solar panel converts the solar energy falling on it into electrical energy as DC. There are batteries that store electricity to be used in situations where the user wants a constant voltage electrical energy or for use in sunless moments. Charge controllers are available to balance the input-output voltage values in order to prolong the life of the batteries. These prevent the battery from overcharging or discharging. If the user needs electrical energy with AC characteristics, the inverter must use the inverter. If DC electrical energy is required, there is no need for an inverter.

c- Photovoltaic System Types: Photovoltaic systems can be constructed independently from the local electricity grid to feed the electrical loads located at distant locations from the residential area, and photovoltaic systems located near the local power grid can also be designed to transfer energy to the grid. Solar cells can be used in any application that requires electricity. For this reason, they are used away from residential areas, where

there is no electricity grid, or if a renewable energy source is preferred, even though it is a grid. Basically, grid-connected systems are divided into three main groups: grid-independent systems and hybrid systems.

Grid Connected Systems (On-Grid): In solar cell systems connected to the grid, the solar energy is converted into electricity with the help of panels, it is given to the city grid with the help of converters. In these systems, PV plants are divided into two as domestic systems

Grid Connected PV Power Plants: These systems produce electricity by themselves and sell it to the network (Figure 3.10). The powers produced by these power generation centers vary between 100 kW and 10 MW. It is generally established for places that cannot reach electricity and its cost is quite high. The plant, which produces 1 MW of energy, costs about 4 million €.

Figure 5: Grid Connected PV Power Plant

Figure 6: Grid Connected Domestic PV Systems

Figure 7: Off-Grid PV System

Domestic PV Systems: These systems, whose main purpose is to meet the electrical needs of a dwelling, can sell the excess electricity they produce to the city grid. In cases where sufficient energy is not produced, they receive energy from the grid. DC electricity produced from panels is converted to AC electricity. There is no need for energy storage because it can send the excess energy directly to the city grid. The power of these systems varies between 150 kW. The structures forming the domestic PV power systems are as follows;

- Solar panels arranged according to the required power,
- Converter (DC / AC conversion),
- Electronic control devices,
- Counter

Meters are two for measuring the electricity drawn from the network and the electricity supplied to the network. Electronic devices, on the other hand, stop the system in case of any malfunction of the system and thus ensure that other subscribers connected to the network are not affected.

Off Grid Systems: Grid-independent systems are often used in areas with high energy requirements away from the city grid. The energy range produced by the systems is very wide and can reach from 1 W to 100 kW. Independent PV systems seen in Figure 7 generally consist of solar panels, charge control unit, battery and converter if necessary. The electricity produced in the system is stored in the battery to be used when the sunlight is insufficient. There is a charge control unit to prevent the battery from being overcharged or discharged. The inverters convert the DC electricity produced by the panels into AC for use where necessary. Thus, both direct current and alternating current can be used.

Mixed Systems: These systems, also called Hybrid Connected Systems, have other systems that generate electricity outside of the panels (Figure 8). Primary electricity generators are panels, in addition, they can be a system that uses a renewable energy source such as a wind turbine or a diesel generator that generates secondary energy to the system.

In addition to the storage system, in mixed systems, there are conventional electricity generation systems with solid fuel or natural gas that will supply energy to the system and fill the storage devices (batteries) in case of extra power requirement. Mixed systems require more complex control systems, but are more reliable than other systems.

4- Usage Of Photovoltaic Systems In Buildings: The most common solar energy systems used in buildings are thermal and photovoltaic systems. Thermal systems can be used independently for space heating and domestic hot water or in combination with other fossil fuel-operated boilers. These systems can only meet the needs of the building they are established in and it is not always possible to use them efficiently throughout the year due to the seasonal change of the building need.

Photovoltaic systems are composed of modules used in solar power generation and are in the category of distributed electricity generation system. This means that these systems used in buildings work in parallel with the electricity grid to load the function of a small scale power plant and supply electricity to the nearest demand point. If there is a need for electricity in the building where they are installed, they can meet this, and if there is more than this need, they can meet the needs of other buildings by giving the energy they produce to the network. Such distributed electricity generation systems not only work with zero CO₂ emissions, but also prevent losses of 40% caused by central production and transmission.

a- Factors Affecting Energy Inputs of Photovoltaic Systems: The power that can be obtained from photovoltaic generators in photovoltaic systems installed in buildings is not a fixed value. We can list the main factors that affect the power we can obtain from generators as follows.

- The position of the world relative to the sun
- Solar radiation intensity received by the neighborhood
- Location of panels
- Tilt of panels relative to the floor (Tilt angle)
- Panels orientation to the south (Azimuth angle)
- Shading factor
- Temperature

b- Design Criteria of Photovoltaic Systems Used in Buildings: The design of the PV systems on the building depends on many parameters such as the area where the building is located, its location, the area it occupies, the architectural plan and for what purpose it is built. While designing my site, the most suitable project is prepared by considering the design of the architect and the functionality of the engineer. One of the most important advantages of using photovoltaic systems in buildings is that there is no need for an additional space to place the system. PV panels can be combined with the building envelope vertically (on the facade) or horizontally (on the roof). Module sizes, forms and colors are features that affect the design when using PV panels

in buildings. Factors such as location, orientation and angle of inclination, shading, panel type, maintenance and cleaning, and temperature occurring behind the modules affect the performance / efficiency to be provided from PV panels.

- External Climate Conditions
- Location
- External Barriers and Building Ranges (Shading)
- Direction and Surface Slope Angle
- Temperature Occurring Behind the Modules
- Converters (Inverters)
- Landscape
- Glare
- Color
- Form

c- Forms of Use of Photovoltaic Systems in Buildings:

The application of photovoltaic systems to buildings can be in two different ways. The first of these; designing and installing a photovoltaic system for a built building; The second is to consider the photovoltaic system from the beginning of the project when designing the building and to use the photovoltaic panels as an integral building element of the building. The design of the PV systems on the building depends on many parameters such as the area where the building is located, its orientation, the area it occupies, the architectural plan and for what purpose it is built. While designing my site, the most suitable project is prepared by considering the design of the architect and the functionality of the engineer. One of the most important advantages of using photovoltaic systems in buildings is that there is no need for an additional space to place the system. Systems can be applied to the roof or the facade in two ways.

PV modules are often used in building envelope. The building envelope is composed of elements that separate the internal and external environment. Building envelope users control the changing physical environmental conditions outside and provide comfort conditions for users inside.

Table 3. Use of PV Systems in Buildings

Usage on Roofs	Use on Facades	Usage in Different Building Sections
Flat roof	Curtain PV wall	Patio
Inclined roof	Rain-screen facade PV	Sun shutter
Set roof (saw tooth)	Shading element	Entrance fringe
Curved roof Atrium		Balcony railing

The use of PV systems in buildings is examined under 3 main headings.

1. Use on roofs
2. Use on facades
3. Use in different building sections

5- A Sample Bapv Application: As a case study; The two-storey office building of Filitoglu Petrol located in Dörtöl District of Hatay Province has been selected. In the image below, the yellow area indicates the oil office. Below is the Google Earth image of the example building. The sample house is shown in Figure 9. In the 2 floor building chosen as an example building; There are 4 rooms and a market on the ground floor and 6 rooms on the 1st floor. The second floor is used as a storage. Total building construction area is 756 m². The roffice area of the building is 340 m². In this building, where there is no elevator, the roof is triangular.

Figure 9: Google Earth Image of The Sample Building

Figure 10: Floor Plans of the Sample Building

Figure 11: Site Plan of the Sample Building

a- Building Analysis

Climate Data Analysis: Although Dörtöl's annual total solar energy varies depending on the aspect, it varies

between 1450-1750 kWh / m². (Figure 12). Annual total sunshine duration is 2997 hours and annual total radiation amount is 1536 kWh / m².year (daily average 4.21 kWh / m².day). The reason why the amount of radiation is partially low compared to the duration of sunbathing is related to topography features and climatic conditions. In Dörtöyl, where the Mediterranean climate is dominant, the high amount of humidity and the number of foggy days and the higher altitude in terms of topography reduce the amount of radiation partially. Considering the time and the sun radiation values are above the average of Turkey is seen as a high solar energy potential. Average radiation values and sunshine times by months are given in Figure 13.

Figure 12: Hatay- Dörtöyl Solar Energy Potential

Figure 13: Radiation Amount and Sunbathing Times by Month in Hatay-Dörtöyl

Dörtöyl has a typical Mediterranean climate. 70 m altitude in the district, most rainfall in Rize province after centers in Turkey. The average humidity is 48.3 %. It receives the most precipitation in December, January, February and March, and the least in August. As of the end of 2013, the temperature was the highest 43.2 ° C and the lowest 2.00 ° C. The surface area of the district is 342 Km².

This diagram shows the current season compared to the average climate for Dörtöyl. The diagram is labeled with temperature and months.

- The black line shows the mean temperature for every

month of the last 12 months (current).

- The thick red line shows the calculated mean temperature of the last 30 years for every month (climate). This line denotes the exact mean of the temperatures but does not reveal fluctuations of the temperature from year to year.
- The orange buffer around the red line makes the fluctuations between the last 30 years more visible. It shows in what range the temperatures of the last 30 years are distributed. It shows the maximum monthly mean and the minimum monthly mean of the last 30 years.
- The monthly precipitation diagram for Dörtöyl shows the precipitation for every month of the last 12 months based on the precipitation of the last 30 years. The chart is labeled in millimeters and months.
- The black bars show the recorded precipitation for each current month.
- The dark blue bars show the maximum amount of precipitation during the last 30 years for each month. The light blue bars show the minimum amount of precipitation during the last 30 years.
- The boundary between dark blue and light blue is the monthly mean precipitation calculated from the last 30 years.

Figure 14: Monthly Average Temperature Graph of 2019

Location and Direction Selection: Dörtöyl, located between 36.925 0 - 36.805 0 North parallels and 36.075 0 - 36.300 0 East meridians. In the east of the Mediterranean Region; There are Amanos mountains and Hassa in the east, Payas in the south, Kskenderun Bay in the west and Erzincan district in the north. The roof of the existing building is the pitched roof. The south, south-west and south-east facades are suitable for use. We will use the south facade to get high performance from the panels. The degree of azimuth (angle to the south) of the southern facade is 0 °, and the slope of the roof is 32°. The usable area value of the roof for the solar panel is about 340 m².

Shading Analysis: The location of the chimneys on the roof and the absence of other obstacles keep shadow losses at low values. As seen in Figure 17, the stairs and

other equipment of the existing building are located on the north facade. The possibility of shading of the panels is very low.

Figure 15: Average Monthly Precipitation Graph for 2019

Figure 16: South View of Existing Building

Another important issue is the change of the angle that the sun makes to the earth every day. Radiations that are perpendicular to the summer fall to the earth at a narrower angle in winter. When we calculate hourly production for the longest day, July 21 and the shortest night, December 21, we see the production values for the longest day of the western part and the shortest day of the year. This analysis gives us more detailed and concrete information about the production profile of the system. In addition, although we say that solar panels are negatively affected by temperature, we see the effect of clouding by examining hot and cold days.

Consumption Analysis: When the consumption profile is examined, energy consumption in winter is higher than in summer. This situation shows us that a special care must be taken in production analysis. Because sunbathing hours differ in winter and summer. Studies should proceed based on winter consumption. The annual electricity consumption value of the building is explained below.

b- Standards And Regulations: In Turkey, 50 kW (50 kW included) features a rooftop legislation. The photovoltaic system we have established takes advantage of this legislation. All equipment used in the design and installation of the PV system under this legislation will comply with the latest editions of the Turkish Standards

(TS), International Electrotechnical Commission (IEC, EN, HD, ISO) Standards and other standards.

Figure 17: East View of Existing Building

Table 4. Annual Electricity Consumption Chart of The Sample Building on a Monthly Basis

Months	The Amount of Electricity Consumed	Energy Consumption
January	5.921 tL	6,713 KWh
February	7.512 tL	8.493 KWh
March	7.347 tL	7.903 KWh
April	5.187 tL	5.660 KWh
May	5.913 tL	6.162 KWh
June	4.513 tL	4.715 KWh
July	4.963 tL	6.985 KWh
August	6.686 tL	8.506 KWh
September	8.296 tL	10.542 KWh
October	7.488 tL	9.365 KWh
November	6.062 tL	6.873 KWh
December	4.833 tL	5.479 KWh
Total	74.721TL	87.396 KWh
Average	6.226 TL	7.283 KWh

c- PV Design Analysis

Technology And Product Selection: The selection criteria of solar panels and inverters, which are two important products that enable us to produce electricity and transmit it to the network, differ in each application. The points that we should be careful about in this application will be as follows for these two product groups.

Choosing of Solar panel: Since low air gaps in roof applications increase the temperature of the panels rapidly, temperature resistant solar panels should be chosen. This leads us to panel groups where the current temperature coefficient is low. Another issue is the use of solar panels consisting of efficient cells. In this way, a production facility with more capacity will be installed. The most efficient solar panel among PV panel types in this project, whose system size is designed as 50 kWp; monocrystal panel selected. This solar panel type generates great energy in a small space. The usage and electricity production life of these solar panels are longer. Monocrystalline solar panels can work more efficiently

in hot climates and the efficiency rate is around 24%. This rate is much higher than other solar panels on the market. Some of its advantages are as follows;

- High Conversion Efficiency
- Excellent Strength Capacity
- High Efficiency In Low Beam
- Self-Cleaning Glass That Reduces Reflection
- Easy Setup

Figure 18: Expected Monthly Energy Production Data

Figure 19: Monthly Solar Radiation Data

Figure 20: Expected Annual Earning Gain Curve

Choosing of invertör: The inverter selected in this project is ABB On-Grid inverter Uno-Dm 50. A single 3-phase inverter will be used.

Appropriate Electrical Design

This design; It was created by considering that the building has a consumption counter of 50 kW. 157 pieces of 320w monocrystalline solar panel will be used. Shades will be calculated and placed in the required places on

the roof. The inverter can be placed below if there is no space on the roof.

d- Production Analysis: The power generation capacity of the power plant per kW per year is estimated to be 1,422.4 kWh on average. Filitoglu Petrol GES will contribute to the evaluation of domestic and renewable resources of our country. It is planned to meet 82% of the electricity to be taken from the network thanks to the on-site production in this amount to be realized at the consumption point. Approximately 71.118 kWh of energy will be prevented from polluting the environment annually and approximately 73.000 kg of CO₂ emission will be prevented annually. The values given in the figures below are obtained from the numerical values SOLMART veri base.

Table 5. System Production Data

Location of Building	Dortyol / Hatay
Annual Irradiation	1845.4 kWh / m ²
Annual Average Temperature Value	18.3 ° C
Azimuth Angle of the Roof	0 °
Suitable Space on the Roof	340 m ²
Slope Angle of Roof	32 °
Annual Electricity Consumption Value	87.396 kWh
Production Facility Installed Capacity	50 kWp
Number of Panels	157
Panel Power	320 Watt
Panel Technology Used	Monocrystalline Solar Panel
Inverter Technology Used	3 phase
Annual PV Electricity Production Value (P50)	71.118 kWh
Arrival Angle Reflection Rate	-2.67%
Temperature And Low Irradiation Rate	-8.25%
Spectral Effect Rate	0.36% by
Total loss rate	-22.92%
Project Cost	\$ 38,460
25-Year Energy Gain	\$ 223,025.40

As seen in Figure 18, the most efficient months of photovoltaic batteries are May and September. Dörtyol is located in terms of location and climate; photovoltaic efficiency decreases in the summer months. Altitude and temperature affect the performance of the batteries.

CONCLUSION

In the architecture, areas that are not used with photovoltaic systems applied on roofs are evaluated and energy production is provided. Photovoltaic systems used on the building facade are applied as curtain walls. On the facades where translucent and opaque photovoltaic glasses are used, the amount of R energy consumed by reducing the comfort conditions of the space is reduced and energy is also produced. The first P50 production

value of the BAPV system, which is planned to be installed as 50 kWp, was analyzed as 71.118 MWh per year. It is predicted that 223.025 MWh electricity will be produced by the end of 25 years. The daily electricity consumption of the building, whose daily electricity usage is 1.777.95 kWh, is calculated as 194.8 kWh. It is expected to provide 25% return in 4 years. Project information is given in Table 5.

The cost of the sample project is approximately \$ 38.460.000. In order to keep the return time of an investment with such a high cost to a minimum, much attention should be paid to the analysis work to be carried out during the design phase. In the approach developed in this project, the whole process from location selection to income chart has been explained. The method in the study; It is applicable to all consumers who want to produce their own electricity from the roof.

As a result, designs should be realized by integrating photovoltaic systems with the projects from the first design stages of the buildings, considering the most efficient orientation and surface slopes for these systems. When these developments are achieved, architects should be informed about the structural design of photovoltaics, and they should be able to design well-integrated systems compatible with the building. Since the model presented in the study was created by examining the detection systems used today, new systems may be designed in the future by making use of the alternatives and design inputs in the model. The model can be updated depending on the developments in photovoltaic technology.

Solar power plants are distributed facilities and generate electricity only during the daytime. As the number of these facilities increases, these plants, which exhibit variable production during the day, do not work at full capacity at noon, and in the evening will cause voltage changes in the network. For this reason, in future studies, an answer should be sought to the question of how distributed plants can sustain their assets without harming the network by researching the impact of distributed generation facilities on distributed networks. Thus, with the increase in the number of samples in this study, a damage to the network will be prevented.

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