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A Study on the Potential of Photovoltaic Panels in Existing Buildings: Housing Example in the Mediterranean

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ABSTRACT

It is an accepted reality that it is necessary to turn to the use of clean energy resources in the fight against climate change and the environmental problems it brings with it, which has become the common agenda of all countries of the world. In this context, it is one of the prominent research topics that the buildings, which cover a large percentage of the built environment and where life-related activities are carried out, can obtain the energy they need with their own clean energy sources. In this study, which considers the sun-facing surfaces of the components in the outer shell of the building as potential areas of use for photovoltaic (PV) systems, three different scenarios were developed in which PV systems are placed on the south-facing wall and roof surfaces of an existing building in Antalya. First of all, the energy needs of the existing building were determined by using the 'Design Builder' simulation tool. In order to measure the potential of the building to obtain some of the energy it needs with PV systems, three scenarios with different usage location, shape and angle of inclination were analyzed with the same simulation tool for the dates of December 15 and July 15, when the daylight level differed. By keeping their numbers, sizes and technical features constant, the different results obtained in terms of the efficiency of energy production of PV systems with varying usage, shape and angle of inclination were examined and evaluated comparatively. As a result, it has been determined that PV system applications, which can be found in the building envelope components of existing buildings with the correct position, shape and inclination angle, have a high potential to provide the energy needed by the buildings from solar energy.

Keywords: Renewable Energy, PV System, Existing Building Envelope, Design Builder

1. INTRODUCTION

Today, where energy has become a great need, 70% of energy consumption takes place in cities. The construction sector is responsible for approximately 40% of total energy consumption and approximately 36% of CO_2 emissions. (Skandalos and Tywoniak, 2019; Duran et al., 2022) With industrial developments, urbanization, rapid population growth and increase in living standards in recent years, energy consumption has also increased. Countries are carrying out many studies to reduce the increasing energy consumption and to use clean, zero-emission renewable energy sources in buildings (EPBD; Paris Agreement, 2015). Especially the European Union (EU) countries have set many targets for increasing energy performance in buildings and producing energy (Zero energy building targets).

Approximately 75% of the buildings fail to meet minimum energy performance in Europe, and an average of 1.2% of the building stock is renewed every year in order to increase energy conservation and reduce CO_2 emissions (Martin et al., 2018). In order to make the buildings that need to be renovated comply with the sustainability criteria, it is necessary to reduce the energy used by increasing the energy performance of the building and to use suitable renewable energy systems in the building.

The integrated architectural design approach, which envisages the use of solar energy, is seen by many architects as one of the most important parts of all sustainability areas (Kanters and Horvat, 2012). Photovoltaic (PV) systems are the most suitable systems that can be applied to the building envelope in order to benefit from renewable solar energy in the building sector (Akbari, 2020). In recent years, accelerated development has been observed in energy production thanks to PV systems (Thebault et al., 2020). Especially as a result of the increase in the efficiency of PV systems and the decrease in prices with the developing technology, energy production by using these systems has become widespread in many areas.

According to a study on PV system, it has been determined that 40% of the EU electricity demand will be met if suitable roofs and facades are covered with PV panels (Sanchez and Izard, 2015). PV panels; it has many important features such as converting direct sunlight to electrical energy, easy integration into the building envelope (roofs, facade, atrium, etc.), reducing CO_2 emissions (Sanchez and Izard, 2015; Basnet, 2012; SUPSI, 2017). PV systems; It consists of PV modules, inverters, batteries, charge control units and other system components (Sayın and Koc, 2011). In order to obtain high energy efficiency from PV systems, the appropriate cell type must be used fist. PV cell types are generally divided into two. Cell in silicon structure are divided into two as monocrystalline silicon cells with high efficiency (%22) and polycrystalline silicon cells (%17). Thin-film cells are the cell types with the lowest efficiency (%10) (Dabbagh, 2015). Since these cells have a flexible and formable structure, they can be applied to amorphous structure shells. The use of cells of different colors also affects PV efficiency (Van Sark et al., 2017). One of the parameters affecting the PV efficiency is the application of the appropriate orientation and inclination angle to the sun. The occurrence of any shading situation on PV systems caused by external factors causes their efficiency to decrease. At the same time, high temperature greatly affects the efficiency of PV systems, so the temperature must be kept at an optimum level. In these systems, which are applied to the building envelope, the energy can be produced and consumed in the field (off grid), but the excess of the generated energy can be transferred to the grid (on grid). However, power losses occur due to the transport of energy in grid-connected system (on-grid) (Ofualagba, 2008).

PV systems can be applied both in new buildings and in existing buildings by adding them to the building envelope. Since these systems, called BAPV, are added to the building later, it should not be overlooked that they create an additional static load (Kaya and Beyhan, 2021). With the development of technology, solutions have been produced in which PV systems are used as building materials or components. In these systems, known as BIPV systems, PV systems, which are included in the construction as an element of the building envelope, are also used with an integrated design approach (Figure 1).


(a) (b) (c)

Figure 1 (a) BAPV system Indira Paryavaran Bhawan, (b) translucent BIPV application (Singh et al., 2019), (c) BP Solar Showcase inclined BIPV application (Qadourah, 2020)

Systems applied as BIPV; it performs many functions in the building at the same time, such as providing an aesthetic appearance, protection against weather conditions, use as a sunshade, providing heat insulation, protection from noise, use as a covering element, and on-site energy generation (SUPSI, 2017; Heinstein et al., 2013; Kumar et al., 2018). Regarding the application rate to the building typology, Tabakovic et al., in a study conducted on 162 existing buildings in 2016, determined that BIPV systems were mostly used in the housing typology with a rate of 19% (Tabakovic et al., 2016).

Application forms of PV systems to the building envelope are realized with different design forms. It is necessary to know the application forms of different systems in order to provide high visual comfort in the building and to perform many functions together in an appropriate way. These applications are; vertical PV facade, vertical and horizontal saw tooth PV facade, accordion PV facade and sloped / stepped PV facade systems (Dabbagh, 2015).

In the vertical PV facade system, PV panels are applied vertically on the facade surface. This application can be applied more easily than other façade systems and has a lower cost. However, it provides less energy production, and cleaning and maintenance operations are more difficult (Dabbagh, 2015). Horizontal saw tooth PV facade systems can be placed at the most suitable angle of inclination to the sun, so maximum energy production can be achieved and because of its function as a shading element, it provides solar control indoors (Kiss, 1993) (Figure 2).

Figure 2 (a) Vertical PV facade, (b) horizontal saw tooth PV facade, (Kaya, 2022) (c) vertical saw tooth PV facade Nursery+E In Marburg/ Germany (Archdaily, 2015)

Accordion PV facade system shows high performance both in terms of aesthetics and in terms of energy production. However, in some cases, the positioning of the panels can create an obstacle to the visual relationship between the interior and the exterior. As with vertical saw tooth PV facades, cleaning and maintenance are difficult. Sloped PV facade systems produce high energy when they are positioned with a suitable orientation and inclination angle to the sun. However, this may cause the interior to be exposed to direct sunlight. For this reason, these systems are preferred in cold climates where sunlight is less intense. Slopped PV facade systems are similar to stepped PV facade systems, but the difference between them is that the slope continues in a gradual shape on the facade. High energy efficiency can be achieved in these systems, as in slopped PV facade systems (Figure 3).

Figure 3 (a) Blauhaus building Germany accordion PV facade (Kaya, 2022), (b) Monte Rosa Hut Switzerland slopped PV façade (Archdaily, 2016), (c) stepped PV facade (Kuby, 2020)

When the location, shape, angle of inclination, application type and connection type of BAPV and BIPV systems are designed correctly, their effectiveness and efficiency is an accepted reality. In this context, their use should be foreseen in order to obtain the energy needed in both newly designed buildings and existing structures with their own potential. BIPV systems find more use in newly designed buildings. BAPV systems are suitable for use in all new or existing buildings. Considering the benefits of reducing energy problems and existing building stocks, it is inevitable to consider the use of these systems in existing buildings. In this context, the main objective of the study is to reveal the potential of use of the relevant systems in an existing building and to examine the effects of system design on efficiency and productivity.

2. METHODOLOGY

Reducing the energy needed in buildings (energy conservation) without compromising the comfort conditions in the processes of sustaining life is an extremely important issue in architectural designs. Despite the performance expectations foreseen in the building envelope, there is still an amount of energy needed in the building usage processes. The use of PV systems, which are widely used in order to obtain the required energy from renewable energy sources, increases their potential for use in architectural design processes with an integrated design approach. However, the potential to improve existing building stocks in order to obtain the energy they need from renewable energy sources is an issue that should not be neglected.

The building envelope surfaces of the existing buildings prepare a suitable ground for the application of energy recovery oriented PV systems. In this context, in the design processes to be carried out, the place of use, the shape and the angle of inclination of the PV systems create different results in terms of the effectiveness and efficiency of the systems. In this study, which was carried out to examine the relevant results, an existing residential building in the province of Antalya, which has a hot humid climate, where cooling loads are prominent, is discussed. Three different scenarios were planned for the design of PV panels on the south façade, which provides the best confrontation with the solar orbit, and energy calculations were made using the Energy Plus 8.9 energy simulation tool, which works with the Design Builder simulation program. The application steps specified in Figure 4 were used to obtain the results by making data entries for the current situation and for each scenario.

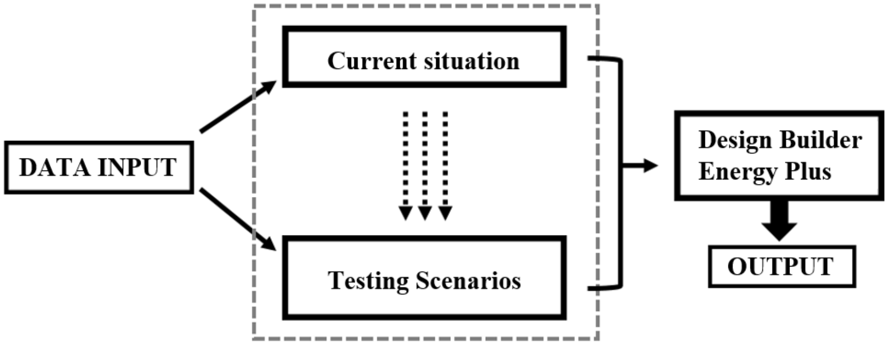


Figure 4 Implementation steps for Design Builder simulation

This study, which aims to reveal the potential of residential buildings, which are found in large numbers in the existing building stock, to produce their own energy, was carried out in two stages. First of all, the energy load calculation of the existing building was made and since no improvement in the construction (building materials and facade transparency ratios were kept constant) in the building envelope, energy consumption was considered constant in all scenarios. In the second stage, the energy production calculations of the PV panels used in the planned scenarios were made.

In the planning of the scenarios, a systematic literature study was conducted on active solar systems, architectural design approach and application examples, and vertical PV, vertical saw tooth PV and horizontal saw tooth PV facade types, which are suitable for design in the existing building envelope, were selected from different application types that are widely used. Accordion PV façade system and sloped and stepped PV façade systems are not included in the improvement scenarios since they are more suitable for application to the building while they are in the design phase and their application to the building requires high cost. In addition, in all three scenarios, the same number of PVs was placed on the south-facing surface of the hipped roof of the existing building with the current inclination angle.

The panel dimensions and high cell efficiency of the panel were taken into consideration in order to provide design diversity and ease in the selection of PV. In this context, 36-cell monocrystalline PV panels with the dimensions of 1505X685X35 mm and a cell efficiency of 19.36%, which are included in the product catalog of a company that serves widely in the building sector, were preferred. Attention was paid to ensure that the number of PV panels used in different design types in the scenarios was equal.

The methodology of the study, which aims to measure the differing efficiency level in PV system applications in an existing building in terms of design concept, application type, application method, location, inclination angle and connection type, is summarized in Figure 5.

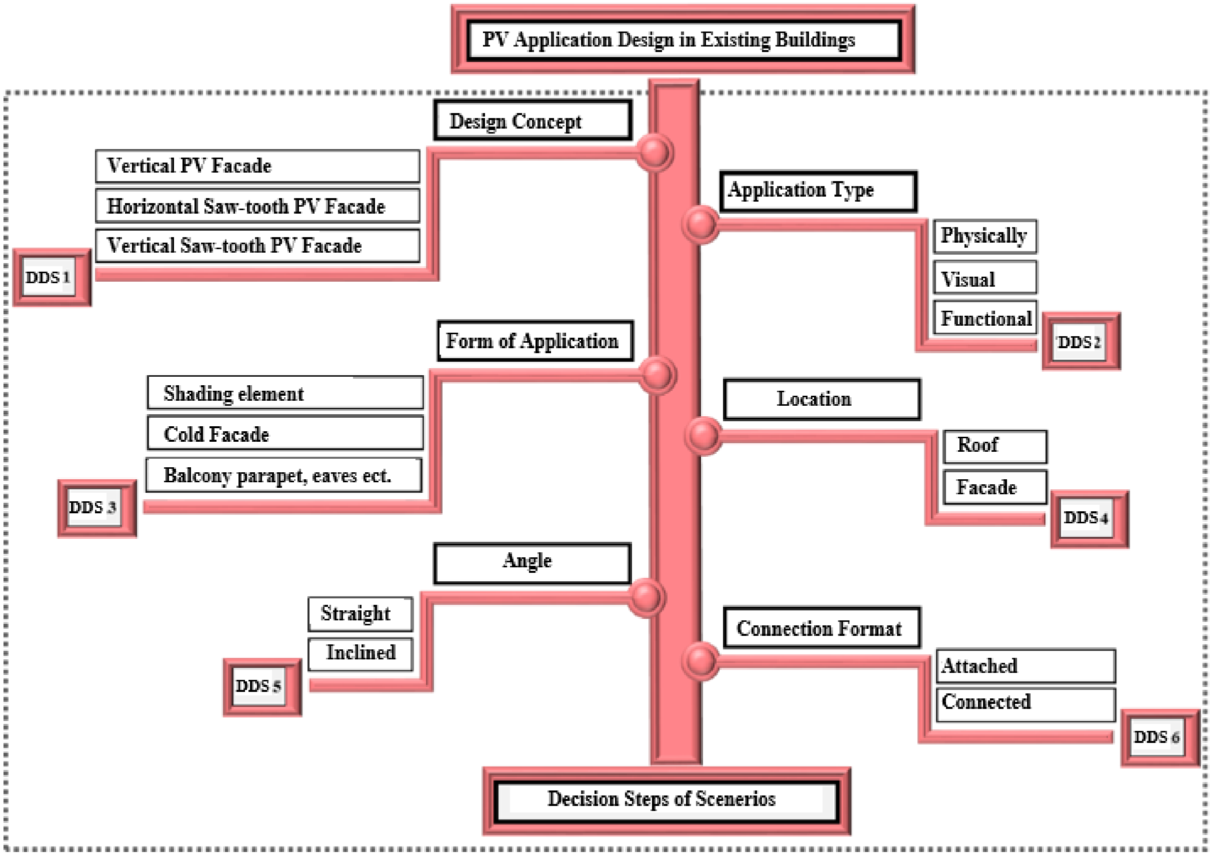
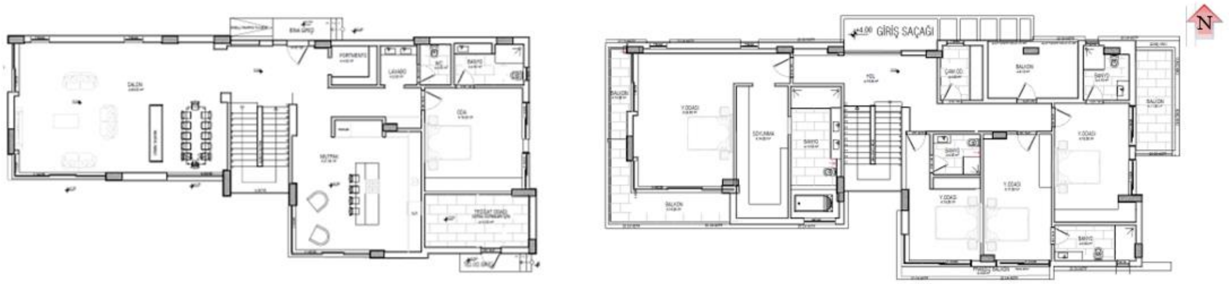


Figure 5 PV panel application design decision steps in existing buildings

Finally, the analysis results of the developed scenarios were evaluated and the different results of the different positions and inclination angles from the design on the facade surface were compared in energy production.

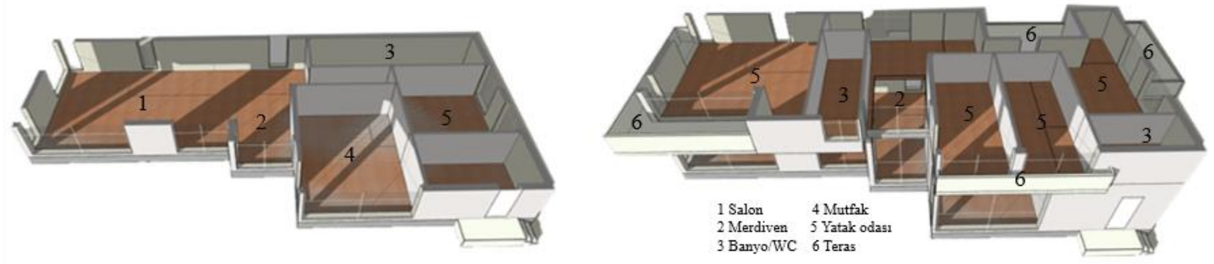
2.1. Findings and Discussion

In order to examine the effect levels of the designs that foresee the use of active solar systems in existing buildings, a residential building has been determined in the province of Antalya, which has a hot humid climate with intense sunlight potential and high cooling loads. Attention has been taken to avoid any shading caused by neighboring buildings around the designated residential building. Antalya is in the 1st Region climate class according to TS 825 Thermal Insulation Rules in Buildings Standard. The entrance of the residential building consisting of ground +1 floor is located in the north. On the ground floor there is the living room, kitchen, bedroom and wet areas. On the upper floor, there are four bedrooms, three terraces and four wet areas (Figures 6 and 7).



(a) (b)

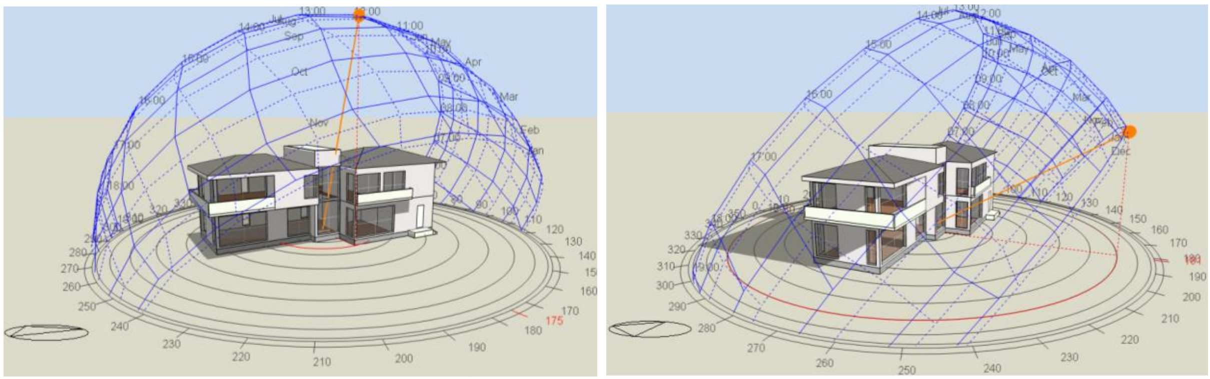
Figure 6 *(*a) residential ground floor plan, (b) first floor plan



(a) (b)

Figure 7 Ground and first floor interior organization of the house modeled in Design Builder simulation

The residential building, which has a 180 m2 floor area and a total area of 482.79 m2 and a height of 9.1 m, is positioned on the east-west axis so that it opens to the south. For the modeling of the building, the Design Builder simulation program, which includes the climate data of Antalya province and can calculate the energy production and consumption values of the building and environmental comfort, was used (Figures 8 and 9). In the simulation, the indoor temperature was kept at 22 °C for the winter months and 24 °C for the summer months.



(a) (b)

Figure 8 (a) 15 July and (b) 15 December solar orbit analysis of current residential building

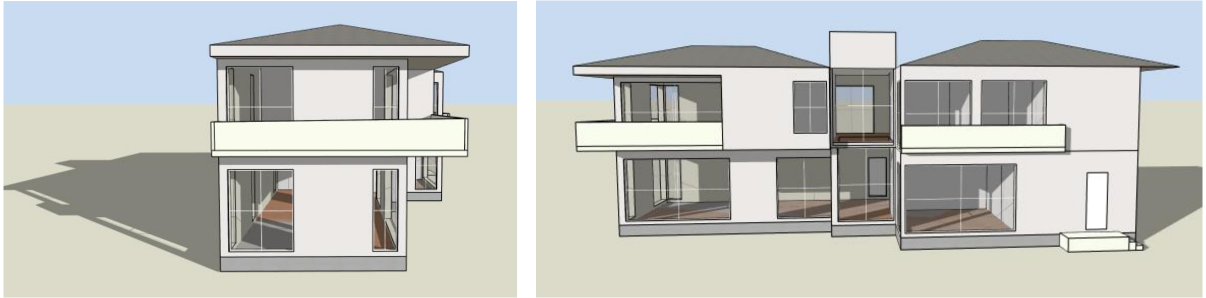

(a) (b)

Figure 9 (a) West and (b) south views

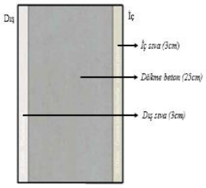
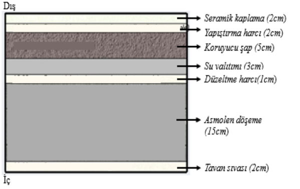
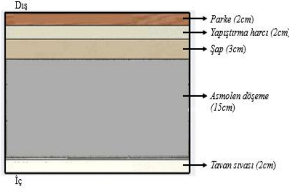
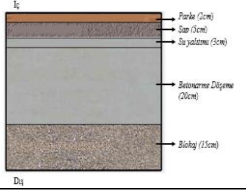
The current residential building is in the 'Döşemealtı' district of Antalya, and 36.87 north latitude and 30.73 east longitude coordinates were entered into the simulation program as data. The transparency ratios of the building envelope are higher on the south façade in order to receive the highest level of daylight depending on the location of the spaces (Table 1).

Table 1 Transparency/filling ratios of the building envelope of the residential building

Building Envelope	North (315-45°)	East (45-135°)	South (135-225°)	West (225-315°)
Wall (m^2)	324,70	184,70	324,70	184,70
Window (m^2)	30,64	35	158,70	46,42
Window/ Wall ratio (%)	9,44	18,95	48,88	25,13

The information of the building materials used in the residential building located in the first degree day zone was entered into the simulation program and the U values of the building elements (floor, roof, wall) were calculated. The U values were determined as 1.809 W/m2K for the outer wall, 0.904 W/m2K for the ground floor, 0.916 W/m2K for the interior floor, 1.189 W/m2K for the roof and 1.960 W/m2K for the windows, respectively. It was determined that the values obtained as a result of the simulation were higher than the desired U values for the 1st degree day region in TS 825 (Table 2). This situation, in which the highest U-Values are exceeded, causes the annual energy consumption of the structure to be higher. In this context, it is necessary to evaluate and improve the building envelope in terms of heat preservation by considering the TS 825 values (Atmaca, 2016). However, this situation has been neglected due to the purpose and content of the study, and the study has been carried out by examining the potential of obtaining the energy needed in the current situation through PV systems.

Table 2 Existing building envelope components U-Values

WALL	ROOF	FLOOR	GROUND FLOOR	WINDOW
TS 825 U Value: 0,66 W/m^2K	TS 825 U Value: 0,43 W/m^2K	TS 825 U Value: 0,66 W/m^2K	TS 825 U Value: 0,66 W/m^2K	TS 825 U Value: 1,8 W/m^2K
				Existing U Value: 1,960 W/m^2K
Existing U Value: 1,809 W/m^2K	Existing U Value: 1,189 W/m^2K	Existing U Value: 0,916 W/m^2K	Existing U Value: 0,904 W/m^2K	

As a result of transferring the data of the determined existing building to the Design Builder program, the annual energy consumption values of the building were calculated. Housing data is selected in the program for interior lighting and equipment. It has been determined that most of the energy is consumed by cooling, interior lighting and socket equipment (Table 3).

Table 3 Current residential building energy consumption values

Building Energy Consumption	**Energy Consumption Areas**					**Total Energy Consumption (kWh/y)**	**Annual Consumed Energy (kWh/m^{2}y)**
	Interior Equipment (kWh)	Interior Lighting (kWh)	Heating (kWh)	Cooling (kWh)	Hot Water (kWh)		
Existing Building Envelope	20 925	24 670	7 317	61 974	1 609	116 497	241,30

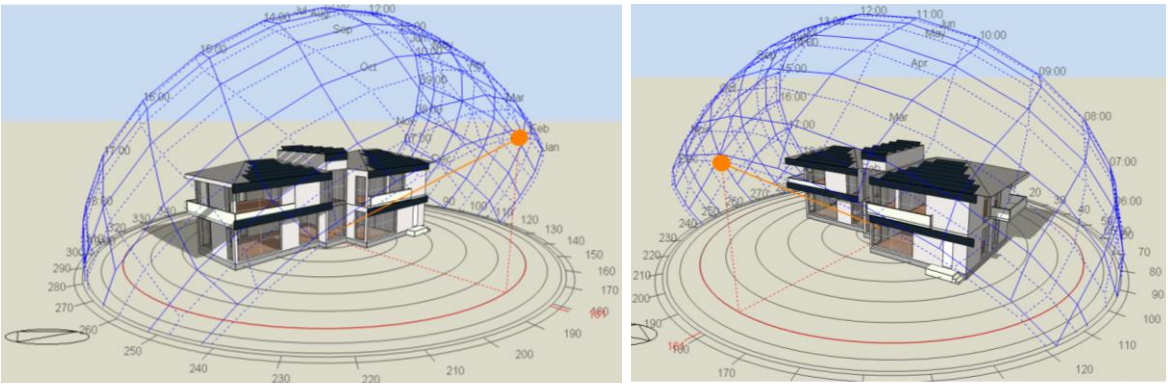
In the simulation program, the annual energy used in the residential building was calculated as 241.30 kWh/m2 per m^2, while 116 497 kWh was calculated as kWh. As a result of the current situation determination, three different building improvement scenarios were created in order to meet the electrical energy of the building from renewable solar energy. Scenarios were created in the Design Builder simulation program and energy productions were compared with each other.

In order to provide the energy consumption values calculated for the existing residential building from solar energy as a renewable energy source, three scenarios that can be applied to the wall surfaces on the south façade of the building are designed. In order to reveal the energy production potential of the building, the same number and shape of PV panels were placed on the south-facing surface of the existing hipped roof based on the roof slope. This approach is considered constant for all three scenarios. On the south façade, the same number (30 modules) and features of PV panels were placed by varying the design concept, application type, application method, location and inclination angle. In order to determine the panel positions, the positions that are not exposed to shading and can receive sunlight at the best level were analyzed. It is envisaged that the PV panels will be applied adjacent to the existing wall construction and in conjunction with the intermediate carrier construction. Decision steps and design information of the designed scenarios are given in Table 4.

Table 4 Scenario design decisions

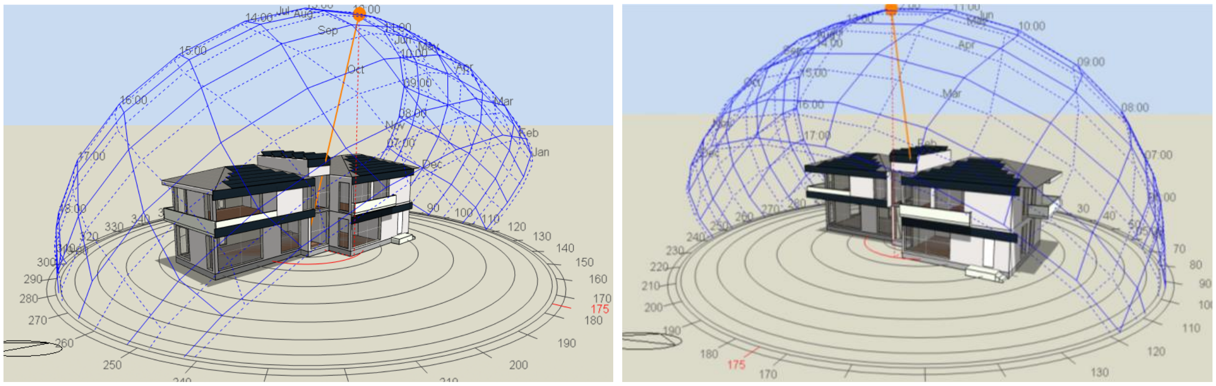
DESIGN DECISION STEPS	**FACADE SCENARIOS**		
	S1	**S2**	**S3**
Design Consept	Vertical PV System	Horizontal saw tooth PV System	Vertical saw tooth PV System
Location	South Facade	South Facade	South Facade
PV module/area (m^2)	30 modül / 30,99 m^2	30 modül / 30,99 m^2	30 modül / 30,99 m^2
Application Type	Visual/Physical	Visual/Physical /Functional	Visual/Physical
Application Format	Cold Facade	Shading Element	Cold Facade
Tilt Angle	90 degree	35 degree	90 degree
Connection Format	Attached	Attached	Attached
	ROOF SCENARIOS		
	Eastern Part	Stairwell	West Part
Location	Eastern	Eastern	Eastern
PV module/area (m^2)	29 module/ 29,96 m^2	10 module/ 10,33 m^2	21 module/21,69 m^2
Application Type	Visual/Physical	Visual/Physical	Visual/Physical
Tilt Angle	33 degree	35 degree	33 degree
Connection Format	Attached	Attached	Attached
TOTAL NUMBER OF PV MODULE / AREA (m^2):	**90 module / 92,98 m^2**		

For each scenario developed, trajectory analyzes were made based on December 15, when the lowest efficiency could be achieved, and July 15, when the highest efficiency could be achieved. The solar trajectory analyzes of the S1 scenario, in which a total of 30 PV panels are placed vertically, 14 on the western part of the south façade, 14 on the eastern part and 2 on the façade of the stairwell, are given in Figure 10 and Figure 11.



(a) (b)

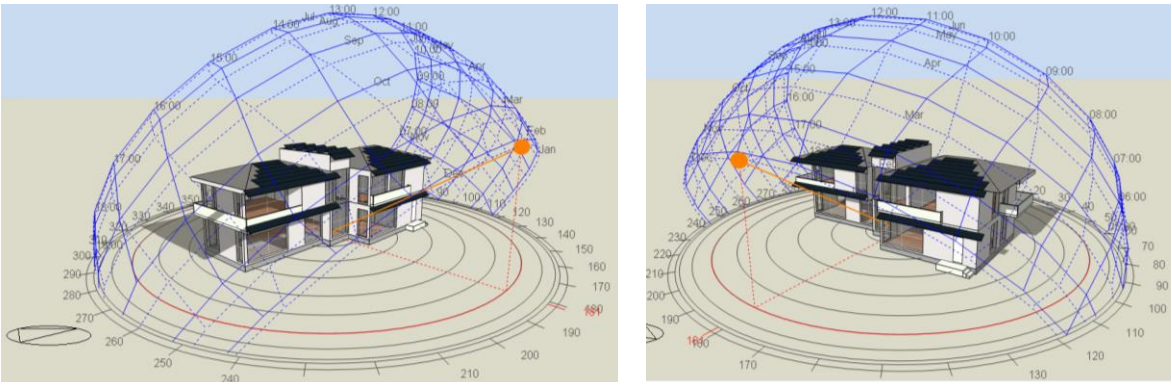
Figure 10 (a) S1 scenario vertical PV front solar orbit analysis December 15



(a) (b)

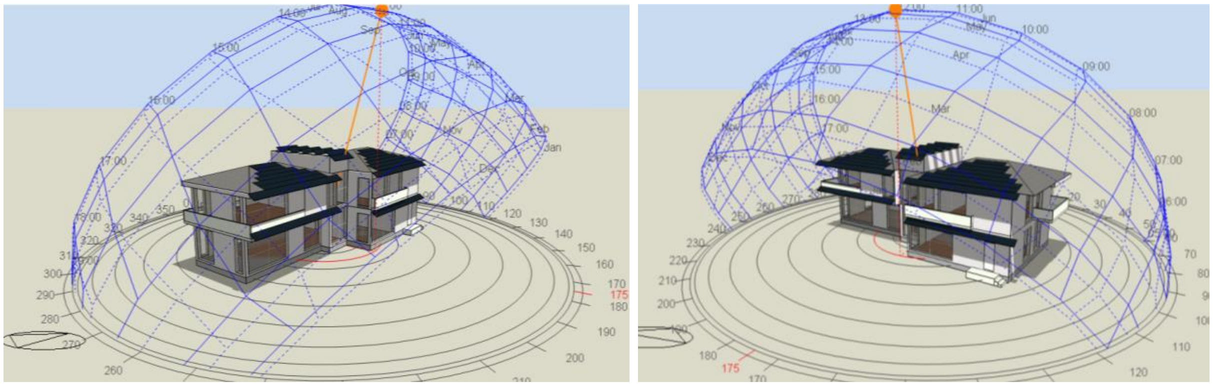
Figure 11 (a) S1 scenario vertical PV front solar orbit analysis 15 July

The trajectory analyzes of the S2 scenario, in which 30 modules of the same size and number, in the same position as the S1 scenario, are placed as horizontal saw tooth with an inclination angle of 35°, are also given in Figure 12 and Figure 13.



(a) (b)

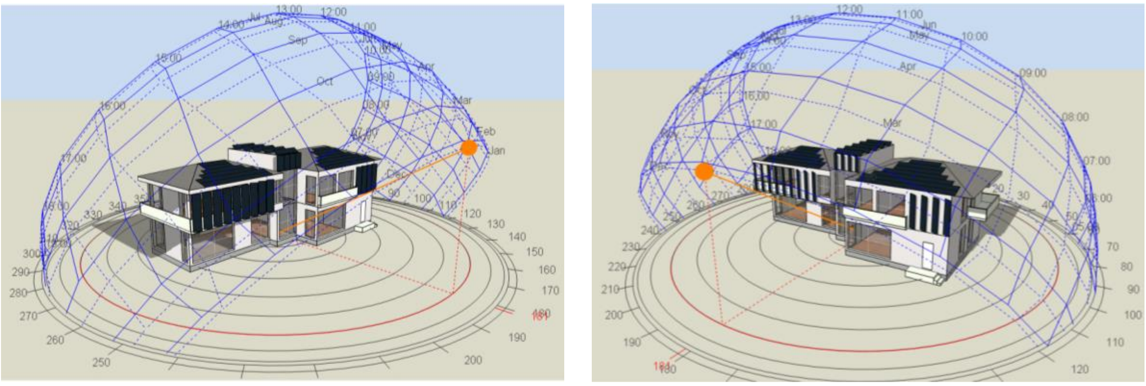
Figure 12 (a) Scenario S2 horizontal gear PV facade solar orbit analysis December 15



(a) (b)

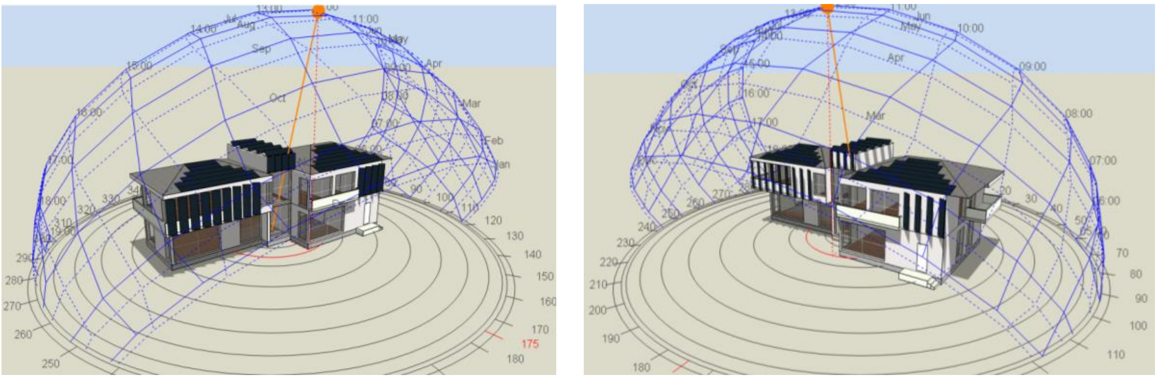
Figure 13 (a) Scenario S2 horizontal gear PV facade solar orbit analysis July 15

In the S3 scenario, 30 PVs were pleased as a vertical saw tooth system at an angle of 30 degrees to the west on the south façade. Trajectory analyzes of the S3 scenario are also given in Figure 14 and Figure 15.



(a) (b)

Figure 14 (a) Scenario S 3 vertical saw tooth PV front solar orbit analysis December 15

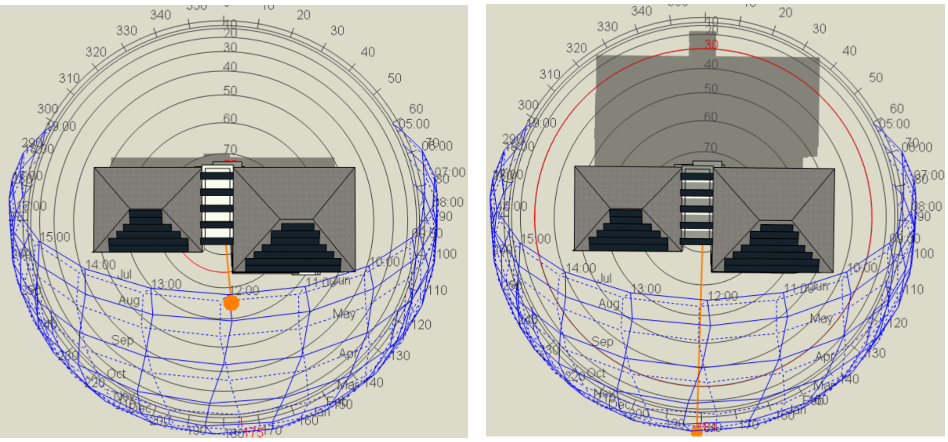


(a) (b)

Figure 15 (a) Scenario S3 vertical saw tooth PV front solar orbit analysis July 15

In Figure 16, the status of the PV panels placed on the roof, which is considered the same in all scenarios, is shown according to the solar trajectory analysis.

As a result of the analysis of the simulation data of the three different improvement scenarios prepared, the energy use per m^2 of the scenarios, the energy production from the photovoltaic panels used on the roof and the facade, and the energy consumption coverage ratios have been reached. In this direction, when Table 5 is examined, it is determined that the annual total building energy uses and energy uses per m^2 are the same for all scenarios, since the improvement of the building envelope in the context of heat conservation was neglected in the study.



(a) (b)

Figure 16 (a) Locations of photovoltaic panels used on the roof in all scenarios 15 July and 15 December

Table 5 Energy consumption per m^2 of improvement scenarios

Improvement Scenarios		Building Energy Consumption (kWh/y)	Building Total Area (m^2)	Annual Consumed Energy (kWh/m^{2}y)
S1	Vertical PV Facade	116 497	482,79	241,30
S2	Horizontal Saw Tooth PV Facade			
S3	Vertical Saw Tooth PV Facade			

In each of the improvement scenarios, the building energy consumptions were calculated as constant in the simulation. The system that has the highest share in the energy consumption of the building is the cooling system with a ratio of 53.20%, which is due to the hot humid climate in which the building is located. Cooling systems are followed by interior lighting with a rate of 21.18% and socket equipment with a rate of 17.96% (Table 6).

Table 6 Percentage values of the improvement scenarios according to the energy consumption areas in the structure

Energy Consumption Area		Building Energy Consumption				
		Interior Equipment	Interior Lighting	Heating	Cooling	Water Heating
Improvement Scenarios	S1 Vertical PV Façade (%)	%17,96	%21,18	%6,28	%53,20	%1,38
	S2 Horizontal Saw Tooth PV Façade (%)					
	S3 Vertical Saw Tooth PV Façade (%)					

Among the improvement scenarios where the PV panels have the same number and value on the façade, the highest energy produced from the PV panels is 30 976 kWh, and it has been determined that the S2 horizontal gear PV scenario, in which the PV panels are placed with the appropriate inclination angle, is obtained. In this direction, it has been calculated that 26.59% of the building's electrical energy consumption can be met with the PV panels used in the building. Among the scenarios, the scenario in which the lowest efficiency was achieved was the S3 vertical saw tooth PV scenario, which produced 25 106 kWh with a rate of 21.55%. Although the number of PV panels used in scenario S1 vertical PV application and the areas where they are located are the same as in scenario S2, the energy production they bring to the structure decreased to 26 632 kWh and the efficiency rate to 22.86% due to the vertical application of PV panels in scenario S1 (Table 7).

Table 7 Energy consumption and production values of improvement scenarios

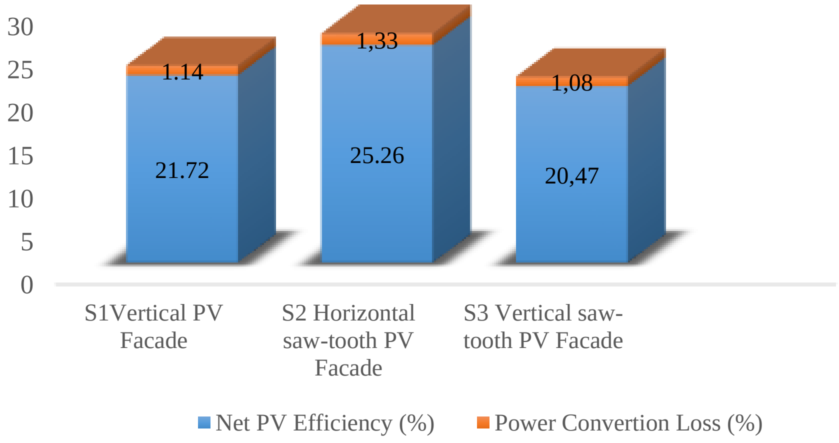
Improvement Scenarios		Building Energy Consumption (kWh/y)	PV Energy Production (kWh/y)	Efficiency (%)	Net Efficiency (%)
S1	Vertical PV Façade	116 497	26 632	22,86	21,72
S2	Horizontal Saw Tooth PV Façade	116 497	30 976	26,59	25,26
S3	Vertical Saw Tooth PV Façade	116 497	25 106	21,55	20,47

When the energy production of the PV panels on the roof and facades is examined, it is calculated that the energy production from the roof is constant for all scenarios, producing 21 141 kWh of energy annually and providing 18.14% efficiency to the building. In the scenario horizontal saw tooth PV S2, which has the highest energy production, the energy production from the facades was 9 835 kWh and the efficiency rate was 8.44%. As a result of the energy generation from the facades in Scenario S1, an annual efficiency rate of 5 491 kWh and 4.72% was achieved. Annual energy production of 3 965 kWh and an efficiency rate of 3.40% were obtained from the vertical saw tooth S3 scenario, which is the front with the lowest energy production (Table 8).

Table 8 Improvement scenarios roof and facade energy productions

Improvement Scenarios		Photovoltaic Energy Production					
		Roof		Facade		Total (kWh/y)	Total Efficiency (%)
		(kWh/y)	Efficiency (%)	(kWh/y)	Efficiency (%)		
S1	Vertical PV Façade	21 141	18,14	5 491	4,72	26 632	22,86
S2	Horizontal Saw Tooth PV Façade	21 141	18,14	9 835	8,44	30 976	26,59
S3	Vertical Saw Tooth PV Façade	21 141	18,14	3 965	3,40	25 106	21,55

In the improvement scenarios, losses occurred in the efficiency of photovoltaic panels due to power conversion. The scenario with the highest energy loss occurred in the S2 scenario with a rate of 1.33% (Table 8 and Figure 17).



(a) (b)

Figure 17 Energy coverage ratios of PV panels according to improvement scenarios

3. CONCLUSION

In this study, the performance of PV panels added to the roof and south façade of an existing residential building in Antalya was investigated. In this direction, first of all, the application of PV systems to the building envelope was examined in the research, and then the energy efficiency of the existing building was tested through the Design Builder simulation program by creating improvement scenarios with the systems selected from these applications. In all scenarios, the same number and characteristics of PV panels were used, so that the efficiency of the systems was compared only due to their design style, location and inclination angles. In order to question the energy production capacity of the existing building, PV modules were placed on the south-facing surface of the building roof, which was kept the same in all scenarios. The scenario in which the highest efficiency was achieved in the improvement scenarios was the horizontal saw tooth PV S2 scenario with a net efficiency of 25.26% and positioned with the optimum tilt angle. The lowest efficiency was the vertical saw tooth S3 scenario with 20.47%. The efficiency rates obtained from PV panels, which are applied considering the appropriate angle and orientation in many energy efficient buildings examined around the world, are generally between 7% and 30%. The calculation of the efficiency obtained in the study carried out on the residential building within the scope of the subject as 25.26% indicates that an above-average energy production has been achieved.

In today's world, where regulations are developed in the context of almost zero, zero or positive energy oriented designs that foresee the use of clean energy sources and the applications in this direction are increasing day by day, it will be an initiative with a lot of potential to improve existing buildings with approaches based on their own energy production. Attempts to provide even some of the energy consumed by a large number of existing building stocks over their own potential should be considered as an effective solution in the fight against energy problems. In this context, the use of PV panels in the appropriate building envelope components with the possibilities offered by today's technology by analyzing the relationship of the building envelopes with the sun within the framework of the location of the existing buildings and the neighborhood relations in the existing built environment is a matter to be considered.

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