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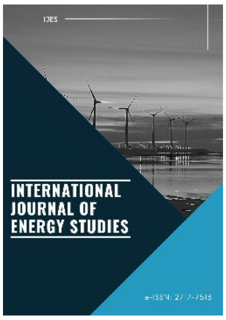

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Utilization of project support for renewable energy financing in public buildings: A solar carport feasibility example

Serkan Sezen*

**Kocaeli University, Uzunçiftlik Nuh Çimento Vocational School, Departmant of Electric and Energy, Kocaeli, Türkiye, ORCID: 0000-0001-7273-7376*

*(*Corresponding Author: serkan.sezen@kocaeli.edu.tr)*

Highlights

- Under Kocaeli Province's climatic conditions, the annual specific yield of a photovoltaic system with an east-west tilt is 1119 kWh/kWp.
- In countries where the price of purchasing energy from the grid exceeds the selling price, achieving zero annual energy costs necessitates selling more energy to the grid than is drawn from it.
- Photovoltaic systems' broader adoption in public buildings can play a pivotal role in climate change mitigation within the context of sustainable environmental practices.

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ABSTRACT

Energy consumption and adverse environmental impacts have increased because of urbanization and intense construction following industrialization. Increasing the number of buildings with green building certification is important and necessary to reduce the negative effects of the construction sector on the environment. One of the significant factors in green building certification scoring systems is the utilization rate of renewable energy sources to meet the building's energy needs. The generally high costs associated with renewable energy investments often emerge as a restrictive factor, especially in public buildings with limited budgets. It is crucial to utilize project support related to financing to meet the required funding. Conducting a proper feasibility study within the scope of the project application serves as a convincing factor in the project evaluation process and increases the likelihood of project acceptance. This study presents a detailed technical and economic feasibility study conducted for the solar carport planned to be installed as part of the Public and Municipal Renewable Energy Project (KAYEP) carried out by Kocaeli University (KOÜ) Uzunçiftlik Nuh Çimento Vocational School as a step toward becoming a green building. The design and analysis were conducted using PV*SOL software. According to the results of the study, it is projected that the planned 49 kWp photovoltaic (PV) system will generate approximately 55 MWh of electricity annually, resulting in a total income or savings of 183,967₺. It is expected to reduce annual energy costs by 99% and prevent the annual emission of 25,844 kg of CO_2 into the environment.

Keywords: Renewable energy, Sustainable environment, Green building certification, Solar carport, Feasibility

1. INTRODUCTION

The industrial revolution has brought about urbanization and intense construction, resulting in increased energy consumption and environmental impacts [1,2]. One of the fundamental components of sustainable economic and social development is environmental sustainability. Buildings constructed using traditional construction techniques contribute to global warming and climate change by increasing energy consumption and carbon emissions. In response, the construction sector is developing the concept of green buildings, which are environmentally friendly, sustainable, and use natural resources efficiently to mitigate these negative effects [3].

Buildings that consider environmental compatibility and efficient use of natural resources throughout their lifecycle (design, construction, maintenance, etc.) are termed green buildings. Upon completing the necessary application processes, buildings with these features are awarded green building certification. Green building certifications promote environmentally friendly buildings, reduce energy and resource consumption, ensure healthy indoor conditions, and minimize environmental impacts. Additionally, buildings with green building certification may increase property value, lower energy costs, and play a leadership role in sustainability [4].

Several green building certification systems exist worldwide, including international standards such as Leadership in Energy and Environmental Design (LEED), BREEAM (Building Research Establishment Environmental Assessment Method), and DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) [5]. In Turkey, the National Green Certificate System (YeS-TR) has been established for green building certification. This system enables the certification process for green buildings and settlements to be conducted online, along with defining the certification procedures, qualifications of green certificate experts, and green certificate evaluation experts [6].

Using renewable energy sources to meet the energy demands of buildings is a significant factor in achieving green building certification. Green building certification systems typically encourage energy efficiency and sustainable energy use. Many green building certification systems evaluate measures to reduce energy consumption, including energy-efficient lighting systems, insulation materials, HVAC systems, and energy recovery. Renewable energy sources such as solar, wind, hydroelectric, biomass, and geothermal energy reduce carbon emissions and dependency on fossil fuels because of their environmentally friendly nature.

The use of renewable energy to meet a building's energy needs often is a crucial factor in green building certification scoring systems. To achieve a high score, buildings must meet some or all of their energy needs from renewable energy sources. However, the investments required to meet this condition often entail high costs, which pose a challenge, especially for public buildings with limited budgets. To address this issue, various project calls are periodically announced to provide the necessary financing. Utilizing project support related to renewable energy financing is crucial in meeting the required funding. One recent initiative is the Public and Municipal Renewable Energy Project (KAYEP), which was recently introduced.

This study presents a detailed feasibility study conducted using PV*SOL software for the solar carport planned as part of the application for the KAYEP carried out by Kocaeli University (KOÜ) Uzunçiftlik Nuh Çimento Vocational School as a step toward becoming a green building. The aim of this study is to increase the number of buildings with green building certification and mitigate the negative environmental impacts of the construction sector by guiding institutions and organizations seeking to meet some or all of their energy needs from renewable sources, thus providing a method for feasibility studies to be conducted in the application processes for similar project calls.

The remainder of the paper is organized as follows: Section 2 provides information about green building certification. Section 3 presents the details of the KAYEP project. Section 4 presents the feasibility study conducted with PV*SOL and its results.

2. GREEN BUILDING CERTIFICATION

Green building certification is a system that verifies buildings designed, constructed, and operated in accordance with environmentally friendly and sustainable principles. These certifications are awarded by independent organizations that assess and evaluate a building's environmental performance. Green building certifications assess compliance with various sustainability criteria such as energy efficiency, water conservation, material selection, indoor air quality, and waste management. Buildings are evaluated on the basis of these criteria using specific scoring systems, and if they exceed a certain score, they become eligible to receive green building certification. According to the records of the Environmentally Friendly Green Buildings Association (ÇEDBİK), the number of buildings in Turkey with green building certification is 484 [7].

Owners of buildings/sites seeking green building certification contact a Green Certificate Expert (GCE), and upon agreement, they sign a contract. Green Certificate Experts access the system through the "yestr.csb.gov.tr" address to submit the contract and project information to the Turkey Environmental Agency. After the application, the building or site owner deposits the designated registration fee on Emlak Katılım Bank and submits the receipt to the Turkey Environmental Agency. If the documents are complete, the Turkish Environmental Agency approves the application made through Yes-TR. After approval, the GCE uploads evidence documents of module criteria to the system via Yes-TR and submits them to the Turkey Environmental Agency. The evidence documents are reviewed by relevant Green Certificate Evaluation Experts (GCEE), and if the criteria are met, the draft certificate is shared with the GCE. If the necessary criteria are met, the certificate is approved, signed, and sent to the owner and recorded in the YeS-TR database [8].

There is no flow diagram showing the process for obtaining the YeS-TR Green Building Certification. However, owners of buildings/sites wishing to obtain YeS-TR certification [9] can contact the GCEs listed on the website. Building or site owners initiate the certification process by signing a contract with the agreed GCE. Under the YeS-TR certification system, various modules are used to evaluate the green and sustainable characteristics of buildings. These modules cover various aspects of buildings, eco-friendly practices, and energy efficiency [10,11].

Obtaining the YeS-TR Green Building Certification offers numerous benefits across various domains. First, it contributes to environmental conservation by promoting energy and water conservation, sustainable material usage, and waste reduction. Economically, it leads to significant long-term cost savings through energy and water-efficient systems, while also attracting tax incentives in certain regions. Moreover, green buildings enhance indoor air quality, ensuring the health and comfort of occupants, and can increase a building's market value and rental rates due to growing sustainability preferences among tenants and buyers. Additionally, it demonstrates corporate responsibility and fosters a positive reputation among customers and stakeholders. Furthermore, it aids in risk management by mitigating uncertainties in energy prices and future regulatory requirements. Green building certification also fosters innovation, leadership, and awareness of sustainability, and in some areas, it is a prerequisite for regulatory compliance. Ultimately, it signifies a commitment to safeguarding the future by leaving a sustainable legacy for generations to come.

There are also various studies in the literature regarding the integration of photovoltaic systems into green buildings. Some of these studies can be summarized as follows; In [12], an evaluation example has been presented for university campus buildings in Turkey with the Turkey Green Building Council (BEST) certification system. A comparison has been made between BEST, LEED, and BREAM. In addition, the importance of establishing a local certification system has been discussed. In [13], the feasibility of a net-zero energy home design aiming for energy balance, financial and environmental sustainability has been evaluated for Northern China, from the initial planning to the final construction stage. A residential house in Datong, located in China's Shanxi Province, has been chosen as an example of an application area. In [14], the design results of a 56.7 kW capacity rooftop solar energy system for a research institute building in Vietnam have been analyzed. With this study, the electricity production, performance, and potential to reduce the amount of CO_2 released into the environment by the rooftop solar energy system have been calculated. In [15], a dynamic model that can integrate different RESs and a storage device is presented. This model is used to meet the thermal and electrical energy needs of a "Green" building in a sustainable way. In [16], a case study for a residential house in Cairo, Egypt is discussed, and a comparison is made between two different renewable energy systems that meet the typical electricity demand for this region.

3. PUBLIC AND MUNICIPAL RENEWABLE ENERGY PROJECT (KAYEP)

Funded by the World Bank and guaranteed by the Ministry of Treasury and Finance, the KAYEP project will be implemented by the General Directorate of Building Works of the Ministry of Environment, Urbanization, and Climate Change. The project aims to increase the use of renewable energy in public buildings by installing solar energy power plants on the open parking lots and rooftops of central government buildings to meet all or part of their electricity consumption needs (subject to own consumption). The project budget is set at $508 million. This budget includes $250 million for renewable energy investments in central government facilities, $250 million for renewable energy investments in municipal facilities, and $8 million for technical assistance and project implementation support. KAYEP consists of three main components, each with its subcomponents summarized in Table 1.

Component 1-Renewable Energy Investments in Central Government Facilities: This component will finance investments in renewable energy facilities that will be used to balance the electricity consumption of public facilities according to the unlicensed Renewable Energy (RE) regulation plan. The project will primarily support distributed RE installations that are allocated for their own consumption. Estimates in the project assessment indicate that renewable energy installations in central government facilities financed under the project will save over 470 million TL in annual energy costs. The project will mainly include rooftop, ground-mounted solar, and PV installations over parking lots.

Component 2-Pilot Implementation Combining RE Investments with Lighting Upgrades and Heat Pump Installation: This will enable the activation of additional renewable energy capacity by electrifying inefficient lighting technologies and heating (e.g., capacity of heat pump fuel boilers to support both heating and cooling), leading to a reduction in building emissions. While the project targets buildings with sufficient energy performance and external shells, the combination of solar energy and heat pumps enhances building self-sufficiency, reduces the load on the electricity grid, and contributes further to decarbonizing the building.

Component 3-Capacity Building and Technical Support: This includes project development, preparation of feasibility studies, and/or technical reviews; project management, such as preparing tender documents, managing the tender process, contract management, installation, and work supervision; implementation of financing requirements in accordance with the Bank's fiduciary policies and guidelines; ensuring satisfactory implementation of the environmental and social framework; project monitoring and evaluation, capacity building, and knowledge sharing, project communication, and incremental operational activities.

Table 1. Investments to be made within the project

Renewable energy systems	▪ Solar carport application ▪ Rooftop PV system application ▪ Ground-mounted PV system application ▪ Solar water heating systems ▪ Microwind turbines
Heating and cooling systems and hot water systems	Heat pumps
Lighting	LED lamp conversion

The initial presentation meeting of the project was held online on March 28, 2023. During the initial application process, institutions are requested to provide energy consumption data for the years 2019-2021 and the solar power plant information form. More detailed information about the project can be found on the project website [17].

4. FEASIBILITY STUDY OF THE SOLAR CARPORT

4.1. Creating the PV*SOL Simulation Model

In this study, feasibility analysis of a 15-vehicle capacity solar carport, planned to be installed within the premises of Kocaeli University Uzunçiftlik Nuh Çimento Vocational School, was conducted using PV*SOL software. PV*SOL was developed by Valentin Software for modeling photovoltaic systems and subsequently analyzing them technically and economically. It is a widely used and reliable software in the photovoltaic sector. There exists an academic study demonstrating its 98% accuracy in predicting energy production under Kocaeli province's climate condition [18].

In PV*SOL, the design of grid-connected with own consumption PV systems is carried out in 10 main stages, as indicated numerically in Figure 1, which includes "Welcome (1)", "Project Data (2)", "System Type, Climate, and Grid (3)", "Consumption (4)", "3D Design (5)", "Cables (6)", "Plans and Parts Lists (7)", "Financial Analysis (8)", "Results (9)", and Presentation (10)". In the Project Data stage, some identification information related to the project, such as project number, project designer, and customer information, is entered. In the System Type, Climate, and Grid stage, the type of PV system (grid-connected, off-grid, etc.) is determined, the installation location is selected, and grid-related definitions are made. In the Consumption stage the user's own consumption data is entered. In the 3D Design stage, there are various predefined roof structures and building types that may create shading, such as trees and chimneys. Using these structures, a 3D model can be created, or alternatively, 3D drawing files created with different programs can be imported. Additionally, the latest versions of PV*SOL offer 3D design support via map databases like Google Earth. In the Financial Analysis stage, the necessary parameters for the economic analysis of the PV system are entered. After completing all data entries, calculations and reporting procedures can be carried out. Figure 2 shows the campus building and the designed solar carport created in PV*SOL using Google Earth maps, while Figure 3 illustrates the circuit diagram of the PV system.

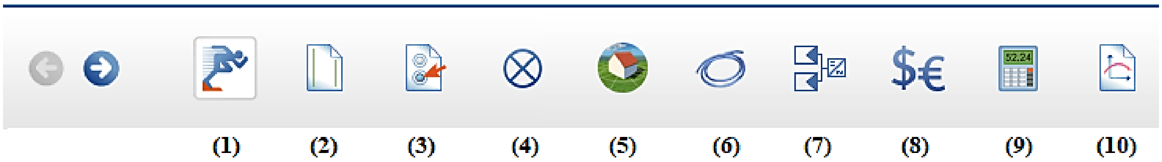

Figure 1. PV*SOL Design Stages Palette

Figure 2. PV*SOL 3D terrain view (southwest view)

The designed PV system, as seen in Figure 4, consists of two separate sections. The first section comprises 36 panels, whereas the second section contains 72 panels, totaling 108 panels. The panels in the PV system are oriented in an East-West direction with a horizontal surface and a 10° inclination to utilize the parking area more effectively. The height from the ground to the lower edge of the panel is set at 2.5 meter. The other technical design parameters for the PV system are provided in Table 2.

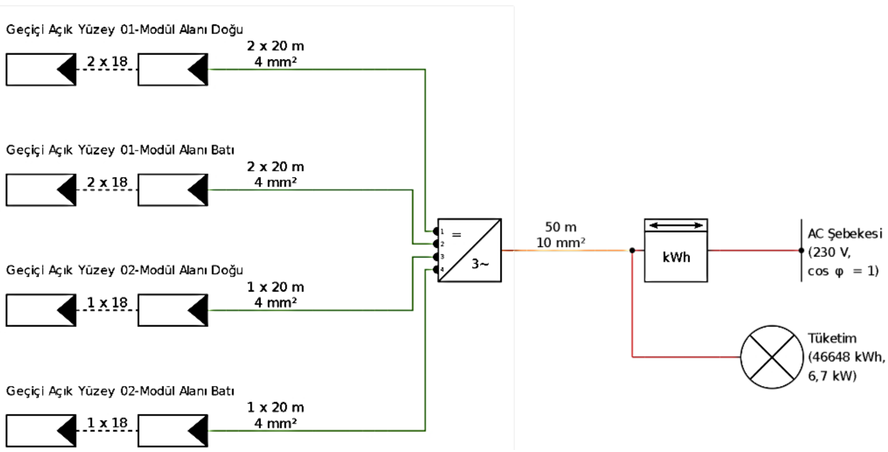

Figure 3. Circuit diagram of PV system

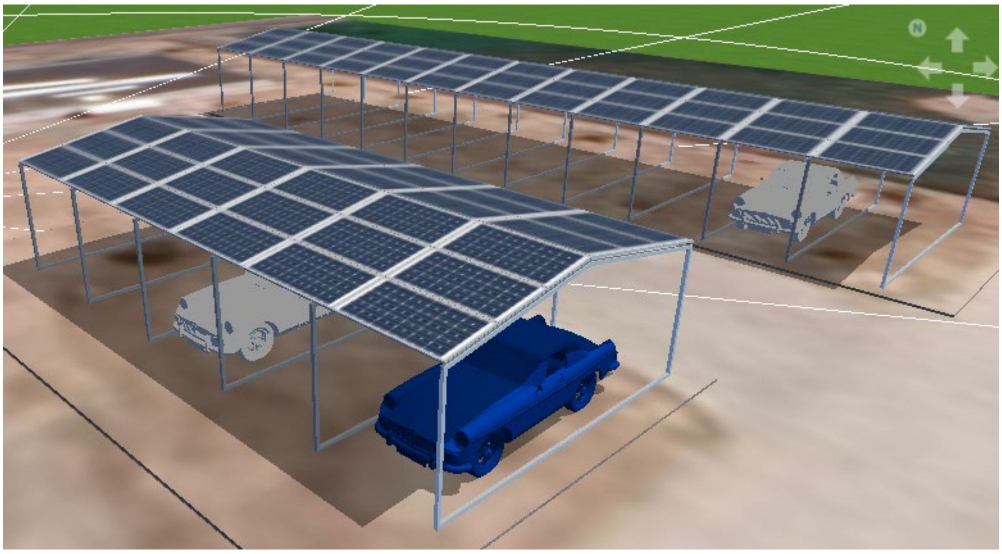

Figure 4. Solar carport assembly system (South-East view)

Table 2. Technical design parameters for the PV*SOL simulation

PV System Type	Grid-connected with own consumption
Location	Uzunçiftlik/Kartepe/Kocaeli
Latitude/Longitude:	40° 45′ 3″/30° 3′ 17″
PV Panel Brand/Model:	CW Energy / CWT455-144PM-V (455Wp@STC)
PV Panel Technology	Monocrystalline-Si
PV Panel Mounting System:	East-West tilt
Number of PV Panels	108
PV Panel Tilt Angle	10°
PV Panel Surface Area	235 m²
PV Panel Output Power	49.14 kWp
PV Panel Performance Guarantee	Initial year: 2.5% efficiency decrease – 80% after 30 years
Inverter Brand/Model	Huawei Technologies / SUN2000-40KTL-M3
Number of Inverters	1
Inverter Configuration	MPP 1: 2 x 18, MPP 2: 2 x 18, MPP 3: 1 x 18, MPP 4: 1 x 18
Inverter Sizing Factor	122%
AC Grid	3-phase (Phase-neutral voltage: 230V)
DC Cable Length/Cross-section/Type	120 m / 4 mm^2 / Copper
AC Cable Length/Cross-section/Type	50 m / 10 mm^2 / Copper

Through PV*SOL, it is possible to analyze the financial aspect of the designed PV system, but for this, certain parameters need to be defined. Among these parameters, the initial installation cost of the system, operation and maintenance expenses, and tariff information valid for electricity exchange with the electricity distribution company (EDC) are essential. In this study, the tariff information provided by the Energy Market Regulatory Authority (Enerji Piyasası Düzenleme Kurulu, EPDK) for the first quarter of 2024 (January 1-March 31) was used [19]. PV*SOL analyzes the project economically based on these parameters and calculates certain parameters that constitute the economic dimension of the system, such as the investment payback (amortization) period, annual income and expenses, and investment profitability ratio. Table 3 shows the financial analysis parameters determined for this study.

Table 3. PV*SOL financial analysis parameters

Energy purchase price from the grid	3.706589 ₺/kWh (Public and private service sector and others, over 30 kWh/day)
Energy selling price to the grid	2.828414 ₺/kWh (Public and private service sector, over 30 kWh/day)
Energy balance/Feed-in concept	Net-metering (Mountly)
System installation cost	$1000/kWp (1$=31.85₺, as of March 8, 2024)
Evaluation period of the PV system	20 years
Annual operating cost	0.2% of the investment rate/year
Credit usage	None
Inflation rate for energy prices	8% /year

In PV*SOL, another design stage for PV systems with own consumption is entering energy consumption data. There are three main methods available in PV*SOL for entering consumption data. The first method uses the ready-made load profiles available within PV*SOL. Examples of these profiles include "2-Person and 1-Child Household", "BDEW Operating Sector Load Profile", and "400-Bed Hospital". Another method involves determining the daily usage hours of individual electrical appliances such as washing machines, refrigerators, and lamps. This method is more suitable for small-scale applications. The third method involves entering Monthly/Yearly Consumption data in a tabular form. In this study, the third method was used, and the three-year consumption average between 2019 and 2021 was taken as the consumption data for the Kocaeli University Uzunçiftlik Nuh Çimento Vocational School, as shown in Table 4. These data are based on actual figures obtained from the institution's electricity bills. The institution's annual electricity consumption varies from year to year but averages 46.6 MWh.

Table 4. Electrical energy consumption data between 2019-2021 years

Year / Mounth	2019 (kWh)	2020 (kWh)	2021 (kWh)	2019-2021 Average (kWh)
January	5815	4531	2950	4432
February	4811	4811	3179	4267
March	5513	5513	3094	4707
April	5211	5211	3960	4794
May	4025	4025	3611	3887
June	3164	3164	2554	2961
July	3093	3093	2460	2882
August	2668	2668	2823	2720
September	3352	3352	3153	3286
October	3874	3874	3202	3650
November	4492	4492	3911	4298
December	4825	4825	4643	4764
TOTAL	**50843**	**49559**	**39540**	**46647**

4.2. Results of the Feasibility Study

The solar carport planned to be installed within the Kocaeli University Uzunçiftlik Nuh Çimento Vocational School campus area has been analyzed technically and economically through PV*SOL. Table 5 summarizes the simulation results in five categories: PV System Technical Quality, PV Energy Utilization, Meeting the Demand, System Integration, and Financial Analysis.

Specific annual yield is a term used to measure the performance of PV systems and represents the amount of electrical energy produced by a PV system per unit installed capacity (1 kWp) over one year. It is used to evaluate the efficiency of PV systems and compare the performance of different systems. Due to the varying solar irradiance conditions in different regions, the same type of PV system may have different specific annual yield values in different areas [20,21]. According to the analysis results, under Kocaeli/Kartepe climatic conditions, 1,119 kWh of electrical energy can be obtained annually from a 1 kWp capacity PV system. On the basis of this value, the required PV power capacity can be calculated for regions with similar climatic conditions according to their electricity demand.

Table 5. PV*SOL simulation results

Technical Quality of the PV System	
Specific annual yield	1,119 kWh/kWp
Performance ratio (PR)	87.2 %
Loss due to shading	1.4 %/year
Wiring losses	945 W (%1,92)
CO_2 emissions avoided	25,844 kg/year
PV Energy Use	
PV generator energy (AC grid)	55,012 kWh
• Direct own consumption	17,952 kWh
• Grid feed-in	37,060 kWh
Own consumption ratio	32.6 %
Meeting the Demand	
Consumption	46,648 kWh/year
Standby consumption (inverters)	24 kWh/year
Total consumption	46,672 kWh/year
• Covered by PV	17,952 kWh/year
• Covered by grid	28,720 kWh/year
Level of self-sufficiency	38.5 %
System Integration	
Energy taken from the grid	28,720 kWh/year
Grid feed-in	37,060 kWh/year
Financial Analysis	
Total investment cost	1,565,109 ₺
Return on assets	16.83 %
Amortization period	7.0 Years
Revenue or savings	183,967 ₺/year
Accrued cash flow (cash balance)	6,839,774 ₺
Electricity production costs	1.41 ₺/kWh

The performance ratio (PR) is a measure of the system's specific yield in relation to its nominal capacity. It represents the ratio between the actual and theoretically achievable energy outputs. In addition, it is defined as the overall system efficiency concerning the nominal installed capacity and received energy. The mathematical expression for the performance ratio is given in Equation (1).

$$Performance\ Ratio\ (PR) = \frac{Yf}{Yr} \tag{1}$$

$$Yf = \frac{Final\ energy\ output\ (kWh)}{Nominal\ DC\ power\ (kWp)} \tag{2}$$

$$Yr = \frac{Total\ inplane\ irridiance\ (kWh/m^2)}{PV\ reference\ irridiance\ (kW/m^2)} \tag{3}$$

Equation (2) defines the final system efficiency, which is defined as the ratio of the actual energy output of the PV system to its nominal DC power. The reference efficiency (Yr) given in Equation (3) is the ratio between the total plane irradiance and the reference irradiance of PV. The reference irradiance of PV at STC is 1000 W/m^2 [22]. In modern solar power plants, the performance ratio is generally expected to be above 85% [23]. For the PV system considered in this study, the annual performance ratio was calculated to be 87.2%.

Shadows cast by nearby and distant objects can significantly affect the overall efficiency of photovoltaic systems. To minimize shading losses, solar panels should be positioned away from shading objects such as buildings, trees, etc., and panel mounting parameters should be accurately determined. The annual shading loss of the designed PV system was determined to be 1.4%, indicating that the location where the PV system is installed and the panel mounting structure are suitable in terms of shading.

On the other hand, cable selection is crucial for designing a technically and economically sound PV system. Cable calculations are performed in two parts: the DC section between panels and inverters and the AC section between inverters and energy meters. When considering the system as a whole, cable losses on both the DC and AC sides should ideally be maintained between 1% and 2%. Proper calculation of cable cross-section and length is essential to keep losses within the desired limits. After voltage drop calculations, it is also important to ensure that the total power loss does not exceed 2% [24,25]. Cable cross sections and lengths determined for this study are listed in Table 2. According to these parameters, the total power loss occurring under standard test conditions is calculated to be 945 W (1.92%), which is considered acceptable.

Figure 5 depicts the monthly energy production estimation graph with consumption. The increasing PV energy production as of May reaches its peak in July with 7,674 kWh. Conversely, consumption decreases in the summer months because of the absence of educational activities at our university. In the winter months, PV energy production decreases because of decreased irradiance levels and sunlight hours, while energy demand increases because of educational activities. This results in a higher amount of energy being drawn from the grid during the winter months. The different energy production and consumption values in summer and winter balance each other out on an annual scale. The energy balance at the grid connection point is illustrated in Figure 5 along with the cumulative total energy production graph. A negative value indicates that cumulatively more energy is drawn from the grid than is sold back to it. From the beginning of the year, the energies supplied to and taken from the grid are equalized around mid-May, and then the graph shifts to positive values. Ending the year (December) with a positive value (+8340 kWh) indicates that more energy was sold back to the grid than was drawn from it throughout the year.

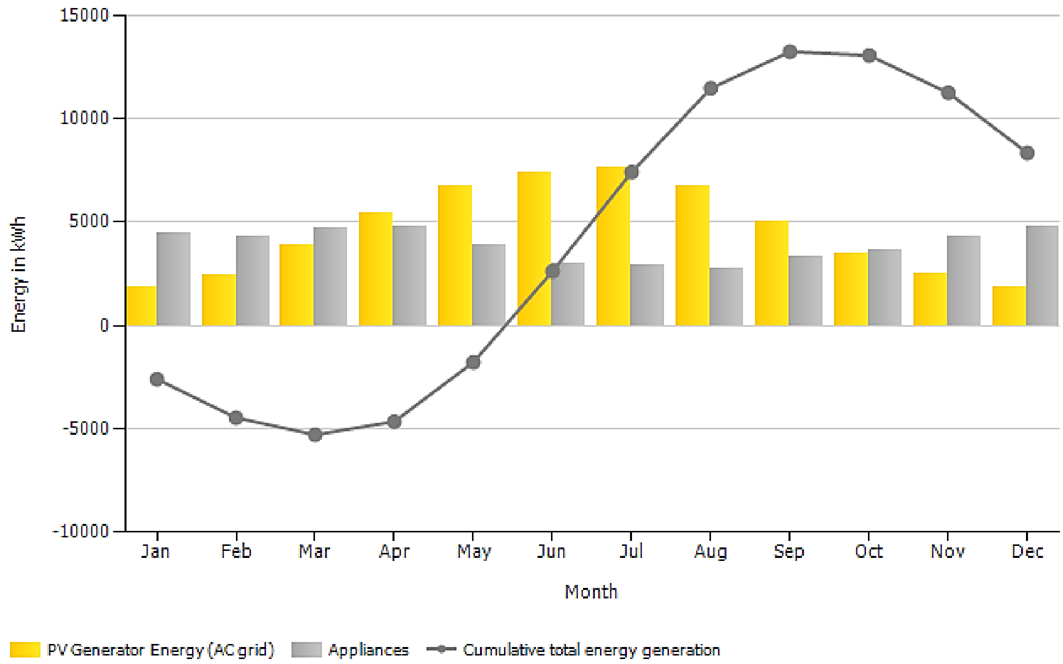

Figure 5. Production forecast with consumption

Figure 6 schematically illustrates the year-scale energy exchange between the PV system, load, and grid. Of the total 55,012 kWh of energy generated, 17,952 kWh is used to power the loads, while the remaining 37,060 kWh is transferred to the grid. According to these data, the own consumption ratio of the PV system is 32.6%. On the other hand, out of the annual energy requirement of 46,672 kWh for the campus building, 17,952 kWh is provided by the PV system, while the remaining 28,720 kWh is supplied from the grid. Accordingly, the solar energy ratio for meeting the own consumption (level of self-sufficiency) is 38.5%.

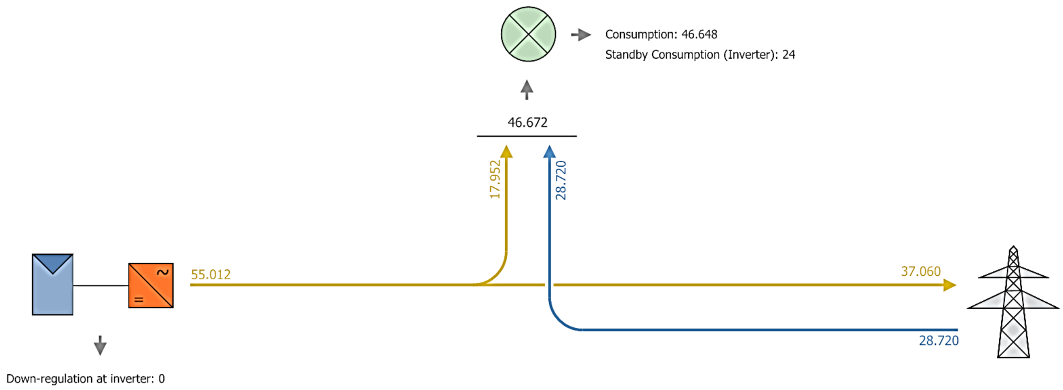

Figure 6. Energy flow graph

From the perspective of grid integration, it can be observed that while 28,720 kWh of energy is obtained from the grid annually, 37,060 kWh of energy is transferred to the grid. In grid-connected PV systems without energy storage, the grid serves as a storage mechanism. Excess energy generated during daylight hours is transferred to the grid, whereas energy is drawn from the grid during hours of insufficient or no sunlight.

In the energy tariffs applicable in our country, the selling price of energy to the grid is lower than the buying price. Therefore, by transferring more energy to the grid than is drawn from it over the course of the year, the system approaches a balance, offsetting the energy costs to be paid to the electricity distribution company (EDC). The energy cost balance data calculated under the assumption of a fixed tariff for the first year of PV system operation are shown in Table 6.

Before the installation of the PV system, the cost to be paid to the EDC amounts to 172,900₺, which is reduced to 1,630₺ after the installation of the PV system. Consequently, the institution's electricity energy cost is reduced by 99%, bringing it down to a significantly low level. Figure 7 illustrates the comparative change in monthly energy costs before and after the installation of the PV system. Following the installation, energy costs notably decrease, particularly during the summer months, compared with the period before the installation. In the graph represented by the yellow line, during the period from April to September, when the cost value turns negative, surplus electricity is sold to the EDC, resulting in revenue generation.

Table 6. Annual electricity energy cost balance before and after PV system installation (first year)

Before the installation of the PV system		
Energy from the grid	**Energy price**	**Money paid to the EDC**
46,648 kWh	3.7065 ₺/kWh	172,900 ₺
After installation of the PV system		
Energy from the grid	**Energy price**	**Money paid to the EDC**
28,720 kWh	3.7065 ₺/kWh	106,450 ₺
Feed-in Energy	**Feed-in price**	**Money received from the EDC**
37,060 kWh	2.8284 ₺/kWh	104,820 ₺
	Post-installation net cost balance	1,630 ₺
	Rate of cost reduction	99.05%

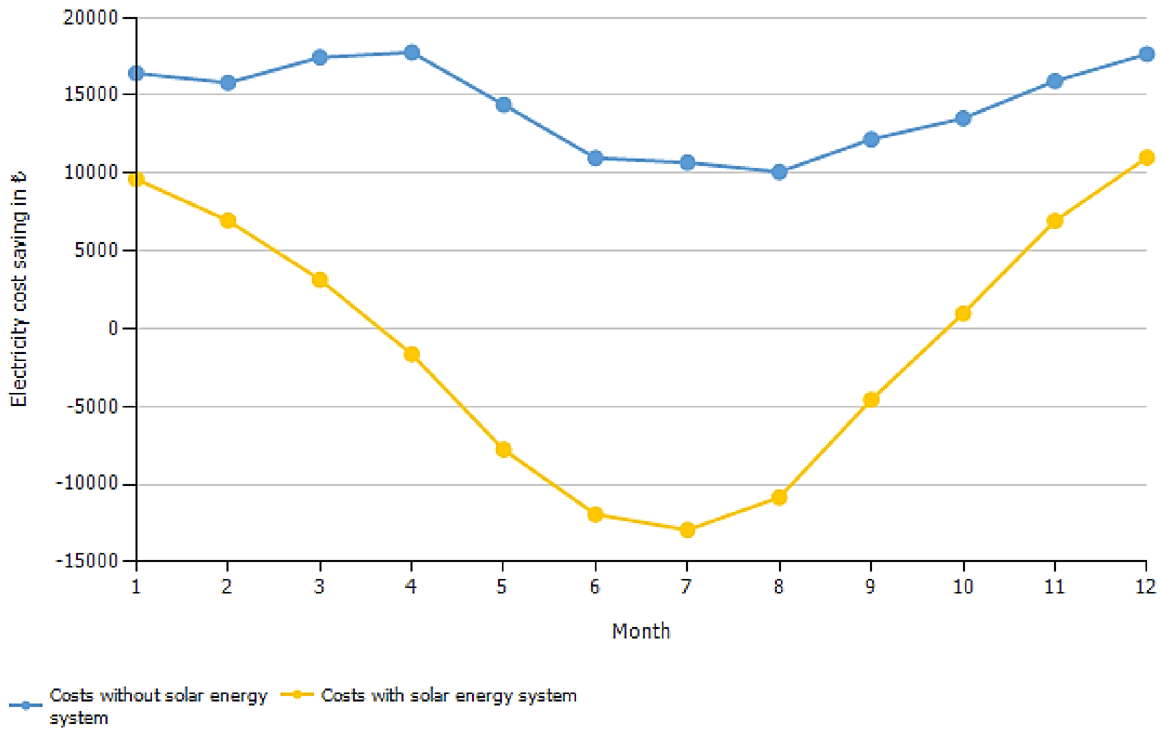

Figure 7. Electricity cost saving

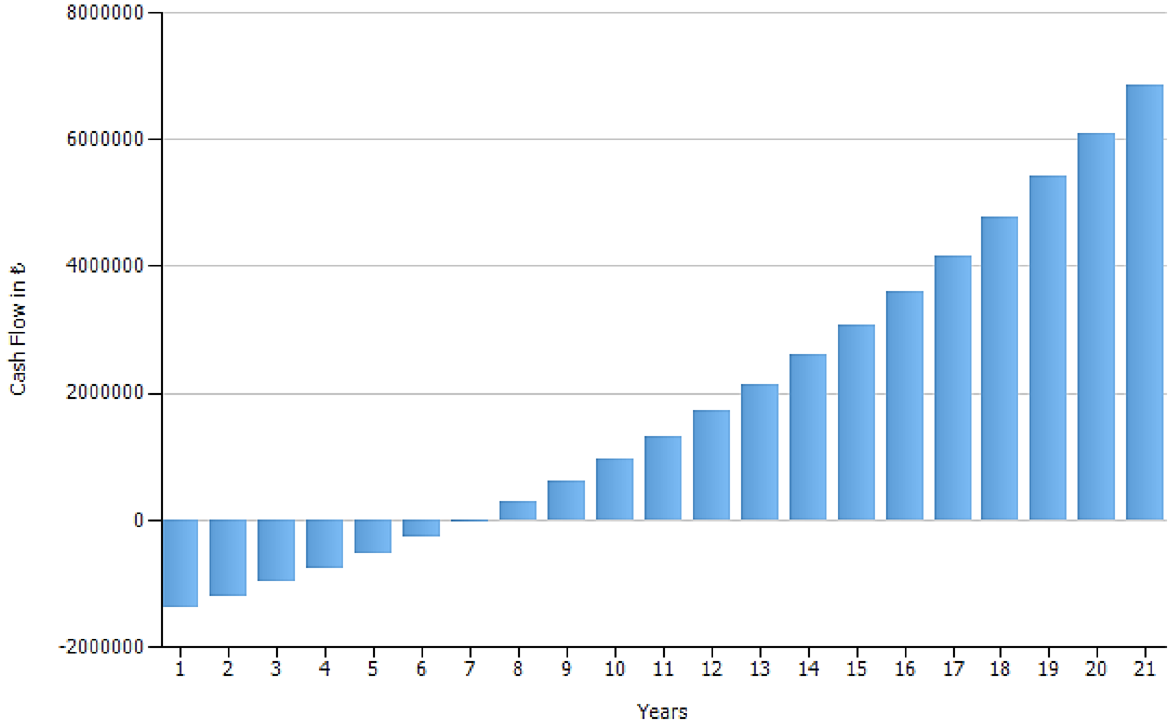

Figure 8. Accrued cash flow (cash balance)

Figure 10 illustrates accrued cash flow over the years. In this graph, expenses are represented on the negative side of the y-axis, whereas income and savings are depicted on the positive side. The initial installation cost of the PV system is only accounted for in the first year, and in subsequent years, only annual operating/maintenance expenses are included. Grid feed-in and loads met by PV are considered as income. After a certain period, the generated revenues reach a level equal to the total expenses, including the initial installation cost. This period is referred to as the amortization period, as 7 years for this study.

5. CONCLUSION

This article discusses a feasibility study conducted by Kocaeli University Uzunçiftlik Nuh Çimento Vocational School toward its goal of becoming a Green Building. The study involves the planned installation of a photovoltaic system with a capacity of 49 kWp on a carport rooftop using PV*SOL software. According to the results, the system is expected to generate approximately 55 MWh of electricity annually, yielding a total income and savings of 183,967₺, reducing energy costs by 99.05%, and preventing the emission of 25,844 kg of CO_2 per year. The study aims to increase the number of buildings with green building certificates, reduce negative environmental impacts, and guide institutions and organizations that want to meet their energy needs from renewable sources. The key findings of this study can be summarized as follows:

- The planned installation of a 49.14 kWp solar carport is projected to generate 55,012 kWh (55 MWh) of electricity from renewable energy sources annually. A significant portion of Turkey's current account deficit stems from energy imports. One way to close this gap is to increase the share of renewable energy sources in energy production. In this context, increasing the number of green buildings that use renewable energy sources is necessary and important for sustainable development and reducing energy costs.
- In Kartepe/Kocaeli, the installation conditions determined (10° panel inclination facing East-West) for a 1 kWp photovoltaic system are expected to produce 1,119 kWh of electricity annually with a performance ratio of 87.2%. The high level of specific annual energy yield (specific gain) and performance ratio is a good indicator that grid-connected PV system installations in the Kocaeli region are technically and economically viable energy solutions for urban areas and public buildings.
- Achieving sustainable economic and social development is only possible when coupled with a sustainable environment. The planned photovoltaic system is expected to prevent the annual emission of 25,844 kg of CO_2. Given that photovoltaic systems are technically and economically feasible in the Kocaeli region, their wider implementation in public buildings can contribute significantly to energy savings and combat climate change within a sustainable environmental approach.
- In countries like Turkey, where grid energy purchase prices exceed selling prices, achieving zero annual energy costs requires that the amount of energy sold to the grid be somewhat higher than the energy drawn from it. This consideration is crucial when determining the installed capacity for grid-connected, non-storage photovoltaic systems.

NOMENCLATURE

KAYEP	: Public and Municipal Renewable Energy Project
KOÜ	: Kocaeli University
PV	: Photovoltaic
YeS-TR	: Turkey's National Green Certificate System
GCEE	: Green Certificate Evaluation Expert
ÇEDBİK	: Environmentally Friendly Green Buildings Association
RE	: Renewable Energy
3D	: Three dimensional
EDC	: Electricity Distribution Company

EPDK : Energy Market Regulatory Authority

PR : Performance Ratio

STC : Standard Test Conditions

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DECLARATION OF ETHICAL STANDARDS

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Serkan Sezen: Performed the whole processes.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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