Utilization of Solar Energy for Electric Vehicle Charging and the Energy Consumption of Residential Buildings in Northern Cyprus: A Case Study

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ABSTRACT

Solar energy represents an opportunity to facilitate the operation of Electric Vehicle (EV) charging stations and cover the energy demand of households, contributing to sustainability and reducing carbon emissions. In light of the emerging need for solar energy as a source of electricity generation for building and charging electric vehicles, this study aimed to assess the technical and economic feasibility of using photovoltaic (PV) systems to generate electricity for residential buildings and meet the changing needs of EVs to reduce energy demand on the grid. To achieve this objective, monthly solar radiation data were collected from the NASA power dataset to assess solar radiation levels in the region and determine the suitability and potential for harnessing solar energy for various applications. The results showed that northern Cyprus has exceptionally abundant and consistently stable solar energy resources. The daily energy for selected residential households and the GÜNSEL B9 and J9 electric cars was estimated to determine the capacity of the required PV systems. In addition, information was collected on the prices of solar panels, inverters, energy storage systems, etc., which were taken into account to evaluate the economic viability of the developed systems. The results demonstrate that the use of solar energy to charge EVs and meet the energy demands of households is technically viable and economically feasible. The use of electric cars offers nearly double the advantages compared to conventional fuel-powered ones, making them a more environmentally sustainable option.

Keywords-northern Cyprus; solar energy; techno-econmic fesibility, electic vehicle; GÜNSEL B9; GÜNSEL J9; energy demand

I. INTRODUCTION

Transportation plays a crucial role in all societies, facilitating lifestyle and enabling the delivery of goods and services that contribute to societal progress. As global efforts to promote sustainable development patterns continue, various strategies have emerged to enhance the sustainability of transportation. These strategies encompass advances in vehicle technology and the adoption of clean fuels. Consequently, the transportation system holds significant importance in fostering the balanced development of a country's economic and social systems. However, a major challenge for the global transport system is its heavy reliance on fossil fuels, particularly oil and gas [1]. Approximately one-third of the total final energy consumption stems from the transport sector, encompassing both passenger and freight travel, which predominantly rely on fossil fuel sources [2].

Oil is the primary energy source for transportation, accounting for 94% of the total energy demand in the sector, while natural gas and other fuels contribute 3%, biofuels 2%, and electricity 1% [3]. These non-renewable fossil fuels have the significant drawback of emitting substantial amounts of harmful pollutants, including sulfur dioxide, nitrogen oxides, and especially carbon dioxide when burned [4]. These emissions are directly involved in the pressing issue of global warming [4]. As a result, there has been a growing focus on the electrification of mobility as a means to address these emission concerns. Recently, substantial efforts have been made to assess the impacts and present approaches to reduce pollutant emissions from on-road traffic and the subsequent effects on air quality [5-7]. Currently, the primary objectives of these initiatives are: (a) to reduce emissions per vehicle by implementing cleaner fuels and technologies, such as renewable fuels or biofuels, natural gas vehicles, and fuel cell vehicles, and (b) to adopt mobility management strategies that aim to decrease the overall speed of traffic circulation. By pursuing these methods, there is a concerted effort to mitigate the harmful environmental effects associated with transportation and pave the way for a more sustainable and environmentally friendly mobility system. The adoption of Electric Vehicles (EVs) offers several potential advantages, depending on the type of power plant that generates electricity for them. EVs can lead to improvements in energy efficiency and reduce energy dependence, fossil fuel consumption, and greenhouse gas (GHG) emissions [8]. However, it is important to consider that the environmental benefits of EVs are influenced by the composition of the electricity-power mix [9]. Although EVs themselves produce zero tailpipe emissions, the overall emissions associated with their use depend on the sources of electricity used for charging. If electricity comes from renewable sources, such as wind, solar, or hydroelectric power, the emissions and environmental impact can be significantly reduced.

Solar energy has emerged as a highly promising renewable energy source for powering EV charging stations [10]. Solar power systems use PV technology to convert sunlight into electricity. Solar energy offers several advantages for EV charging. At first, it is a renewable source, meaning that it is virtually inexhaustible and does not deplete over time. This reduces the dependence on finite fossil fuel resources and contributes to a more sustainable energy system [11]. Additionally, solar power systems produce electricity with minimal environmental impact, since they do not emit GHG or pollutants during operation, resulting in reduced carbon emissions and improved air quality. This is in line with the goals of mitigating climate change and reducing the overall environmental footprint. Solar energy can also provide greater energy independence. By generating electricity on-site through solar panels installed at EV charging stations, there is less dependence on the traditional electricity grid and external energy sources [12]. This can enhance energy resilience and reduce vulnerability to power outages or fluctuations in the energy supply. In addition, solar-powered EV charging stations can be strategically located in areas with ample sunlight, such as parking lots, highways, or urban spaces. This enables convenient and accessible charging options for EV owners while using underutilized spaces for renewable energy generation. Integration of solar energy into the EV charging infrastructure contributes to a cleaner and more sustainable transportation system. As solar technology continues to advance and become more affordable, it has significant potential to reduce the environmental impact of EV charging and promote the widespread adoption of EVs.

The energy sector of northern Cyprus relies heavily on imported fossil fuels, exposing it to fluctuations in global fuel prices and geopolitical uncertainties that can affect energy security and affordability. Northern Cyprus has a significant potential for renewable energy sources, including solar energy [13-19], as it has abundant sunshine throughout the year, which can be used to diversify the energy mix and reduce dependence on imported fossil fuels. Furthermore, the favorable climate makes it suitable for solar installations, both for utility-scale projects and distributed solar systems on rooftops. This study investigated the techno-economic viability of implementing PV with energy storage systems in northern Cyprus. The system was designed for home use, primarily focusing on charging an owner's EV and meeting the energy needs of the house. The main goal was to improve the use of PV energy for EV charging and household consumption, reducing the dependence on grid power. The incorporation of an energy storage system enables the use of stored energy during unfavorable conditions, ensuring uninterrupted EV charging regardless of weather or time of day. By integrating PV generation, energy storage, and EV charging, the system aimed to maximize solar energy use while minimizing dependence on grid electricity. This approach promotes sustainability and offers potential economic benefits by lowering electricity costs and reducing dependence on external energy sources.

II. MATERIAL AND METHODS

A. *The GÜNSEL Electric Car*

GÜNSEL is an electric car developed in northern Cyprus. Its development began in 2016. The project aimed to create a car that would be environmentally friendly, cost-effective, and meet the needs of the modern driver. The GÜNSEL electric car is a sleek and stylish vehicle powered by a lithium-ion battery located underneath. The battery can be charged using a standard electrical outlet or a dedicated charging station. The GÜNSEL electric car has a range of up to 350 km on a single charge, which is more than enough for most drivers. It can reach a top speed of 170 km/h and can go from 0 to 100 km/h in just 8 s. The car is equipped with a variety of advanced features, including a touchscreen display that provides access to different functions, such as music, navigation, and climate control. The car also has a variety of safety features, including lane departure warning, automatic emergency braking, and adaptive cruise control. The GÜNSEL electric car has a low-slung profile that gives it a sporty appearance. Its interior is spacious and comfortable, with plenty of legroom and headroom for passengers. Seats are upholstered in high-quality materials and the dashboard is designed to be easy to read and use. The GÜNSEL electric car is environmentally friendly and cost-effective.

B. The Intensity of Sunlight in Northern Cyprus

To assess the potential success of solar-powered Battery Electric Car (BEC) charging stations, it is essential to initially assess the solar energy resource throughout the country. Solar energy is one of the most abundant, clean, affordable, and sustainable energy resources, particularly in arid or semi-arid regions. In general, global solar radiation is defined by the Global Horizontal Irradiance (GHI) and Diffused Horizontal Irradiance (DHI) [20]. GHI is a significant factor to assess energy generation for flat-plate PVs. Figure 1 shows the long-term average of solar resources, including GHI generated by the Global Solar Atlas. PV power potential is a comprehensive assessment of the power generation capabilities of renewable energy sources that represents the average yearly and daily potential energy generation from a 1 kW solar PV plant over a long period, as shown in Figure 2.

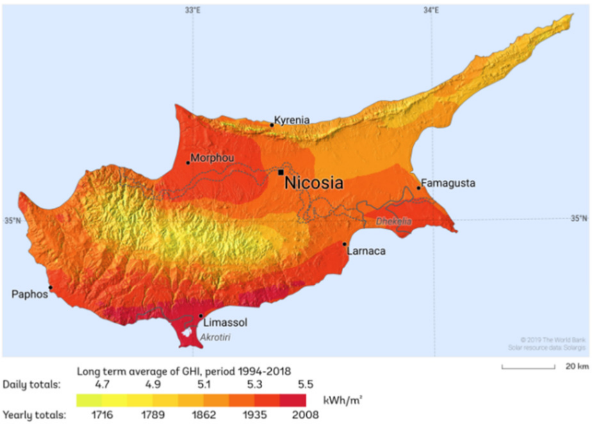

Fig. 1. GHI map of Cyprus.

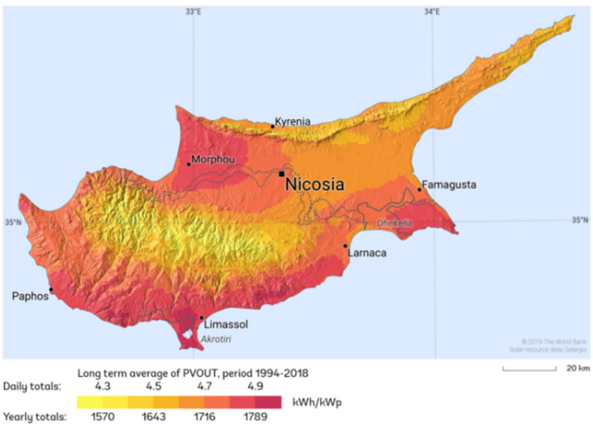

Fig. 2. PV power potential map.

C. Dataset

This study evaluated the solar potential in 33 selected regions distributed over northern Cyprus. Table I shows geographic information including latitude (Lat), longitude (Long), and elevation (El) above sea level of the selected locations. The lack of availability of high-quality meteorological data has led to the use of satellite-generated or interpolated synthetic meteorological data available in grids with various spatiotemporal resolutions [21]. Several studies have evaluated the potential of solar energy at specific locations using satellite data such as the NASA Power Dataset [22-24]. The NASA POWER dataset is a comprehensive set of meteorological data used for research and analysis of renewable energy resources, particularly solar and wind energy that contains hourly, daily, and monthly data on a range of meteorological variables, such as solar radiation and wind speed [25]. Monthly data, including GHI and Air Temperature (AT), were used to assess the economic feasibility of solar PVs to generate electricity as a power source for the 33 selected locations shown in Table I. It can be observed that the solar radiation levels remain consistent throughout the region. This suggests that any part of the region has the potential to establish a solar-powered charging station. The uniformity of radiation levels also implies that a single charging station design could be implemented effectively in various geographic regions of northern Cyprus, as the annual GHI values ranged from 1704.07 kWh/m^2 to 1948.00 kWh/m^2. The minimum and maximum GHI were recorded in Beylerbeyi and Ercan, respectively. Figure 3 shows that the lowest and highest GHI were recorded in December and June. Table I also lists the optimum orientation angles in terms of Slope (S) and Azimuth (A), which were found using the PVGIS simulation tool [18].

TABLE I. INFORMATION ON THE SELECTED AREAS

Location	El [m]	Lat [°N]	Long [°E]	GHI [kWh/m^2]	AT [°C]	S [°]	A [°]
Akdeniz	89.0	35.3	33.0	1914.0	20.7	31.0	2.0
Camlibel	277.0	35.3	33.1	1918.4	19.5	31.0	3.0
Lapta	168.0	35.3	33.2	1865.3	19.2	29.0	-5.0
Girne	10.0	35.3	33.3	1920.6	19.5	31.0	-1.0
Beylerbeyi	225.0	35.3	33.4	1704.1	19.9	28.0	-22.0
Bogaz	300.0	35.3	33.3	1919.0	19.7	31.0	0.0
Tatlisu	168.0	35.2	33.5	1944.5	20.1	32.0	-3.0
Kantara	480.0	35.4	33.9	1877.8	20.3	31.0	-4.0
Esentepe	183.0	35.3	33.6	1925.8	20.0	31.0	0.0
Guzelyurt	52.0	35.2	33.0	1929.5	19.5	31.0	0.0
Gaziveren	19.0	35.2	32.9	1930.0	19.5	31.0	0.0
Lefke	129.0	35.1	32.8	1925.1	16.3	30.0	-8.0
Yesilirmak	20.0	35.2	32.7	1916.1	18.2	30.0	-2.0
Ercan	119.0	35.2	33.5	1948.0	20.4	32.0	-4.0
Serdarli	111.0	35.3	33.6	1920.3	20.5	32.0	-5.0
Degirmenlik	168.0	35.3	33.5	1916.3	20.1	31.0	-1.0
Gecitkale	45.0	35.2	33.7	1946.5	20.8	32.0	-2.0
Gonendere	75.0	35.3	33.7	1924.8	20.5	32.0	-3.0
Vadili	54.0	35.1	33.7	1947.0	20.7	32.0	-2.0
Beyarmudu	87.0	35.0	33.7	1946.9	20.7	31.0	0.0
Cayirova	67.0	35.3	34.0	1910.4	20.5	31.0	2.0
Iskele	39.0	35.3	33.9	1923.8	21.0	31.0	0.0
Mehmetcik	99.0	35.4	34.1	1910.2	20.5	31.0	2.0
Gazimagusa	10.0	35.1	33.9	1941.6	21.0	31.0	2.0
Salamis	6.0	35.2	33.9	1941.7	21.0	31.0	1.0
Alevkaya	623.0	35.3	33.5	1925.4	20.2	31.0	2.0
Zumrutkoy	129.0	35.2	33.0	1933.9	19.5	31.0	0.0
Alaykoy	166.0	35.2	33.3	1925.4	19.8	32.0	-2.0
Lefkosa	134.0	35.2	33.4	1945.4	20.1	32.0	-3.0
Ziyamet	82.0	35.5	34.1	1908.1	20.3	30.0	3.0
Dipkarpaz	136.0	35.6	34.4	1896.1	20.5	31.0	5.0
Yenierenkoy	123.0	35.5	34.2	1893.4	20.8	31.0	5.0
Dortyol	54.0	35.2	33.8	1942.4	21.0	32.0	-1.0

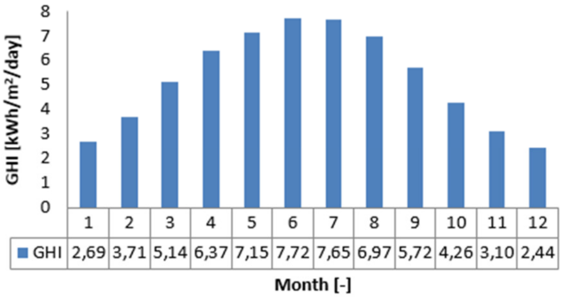

Fig. 3. Monthly GHI value for northern Cyprus.

D. *Solar PV System*

A solar PV system harnesses sunlight through PV modules to generate electricity, which can be used directly, fed back into the grid, or stored in batteries. PV panels convert solar energy into DC electricity, have a lifespan of 20 to 30 years, and are available in different technologies, such as monocrystalline silicon, polycrystalline silicon, etc. [17]. Inverters are essential components that convert the DC output to usable AC, ensuring safety and efficiency. Solar batteries store the excess electricity from PV systems, providing reliable power on cloudy days, at night, or during outages, enhancing sustainability, and allowing for a continuous energy supply [4, 17].

E. *Power Demand by an EV*

The power consumption of an EV is influenced by several factors, including distance traveled, battery capacity, and driving mode. These variables play a significant role in determining electric vehicle power consumption (P_D) [11]. The following equations were used to estimate P_D [26]:

$$P_D = \frac{K_d E_k}{T} \quad (1)$$

$$P_D = \frac{Q_{bat}(SOC_{max} - SOC)}{T} \quad (2)$$

where K_d is the number of km driven, E_k is the energy required per km, T is the time required to charge the vehicle battery, Q_{bat} is the battery capacity, SOC is the state of charge and SOC_{max} is the upper limit of the battery SOC. Consequently, the power demanded by EVs can be expressed using:

$$P = \sum_{i=1}^{N} P_{Di} \quad (3)$$

F. *Inverter Sizing*

Inverter sizing (SI) depends on two key factors: (1) the total wattage of the energy consumed (*EC*), and (2) the applied safety factor (*SF*). These considerations determine the appropriate size of the inverter required for the project.

$$SI = EC \times SF \quad (4)$$

G. *Battery Sizing*

Equation (5) can be employed to estimate the capacity of the battery for a PV project. For solar energy projects, it is recommended to utilize a deep cycle battery specifically designed for low energy level discharges [11]. The lead-acid battery serves as the foundation of the energy storage system and should be adequately sized to store enough energy to power an EV.

$$CB = \frac{ECN \times DA}{BE \times DD \times BNV} \quad (5)$$

where *ECN* is the energy consumption need, *DA* is the days of autonomy, *BE* is battery efficiency, *DE* is the depth of discharge, and *BNV* is the battery's nominal voltage.

H. *Mathematical Modeling of Economic Viability*

To calculate the cost of a solar plant for charging electric cars, several factors should be considered as follows:

- Determination of the power requirements: the power rating of the electric car charger can be estimated using :

  $$P = VI \quad (6)$$

  where *P* is the power rating in kW, *V* is the voltage in V, and *I* is the current in A.

- Energy consumption calculation (*E*): the amount of energy the charger will consume over a given time (*t*) can be found using:

  $$E = P \times t \quad (7)$$

  Note that the power consumption rate throughout the charging period was assumed to be constant. In reality, the power consumption may vary depending on the charging technology and the car's battery charging characteristics.

- Assessing solar plant capacity: Consider the average amount of sunlight available at the location. Solar panels have a capacity rating, usually given in W or kW. The number of solar panels (N_{sp}) needed was calculated based on the capacity required to generate the energy consumed by the charger as:

  $$N_{sp} = \frac{E}{S_c \times SPF} \quad (8)$$

  where S_c is the solar panel capacity in W and *SPF* is the solar panel efficiency in %.

- Calculation of the total energy generation: Estimate the total energy that the solar plant will generate annually using:

  $$E_{total} = 365 \times S_c \times ASL \times SPF \quad (9)$$

  where *ASL* is the average number of sunlight in hours/day.

- Determining the size of the solar plant (*SPZ*): The size of the solar plant in kW based on the total energy generation and the average number of sunlight is assessed by:

  $$SPZ = \frac{E_{total}}{365 \times ASL} \quad (10)$$

  This equation assumes consistent energy generation throughout the year and does not account for factors such as system losses, shading, and panel orientation.

- Calculation of the cost of the solar plant: The cost of a solar plant can vary depending on several factors, including the size, location, quality of the components, and installation costs.

- Consideration of additional costs: In addition to the solar plant itself, costs such as wiring, inverters, mounting structures, permits, and maintenance should be estimated.

I. The Energy Required for Household and EV

In this study, a typical household was selected to establish a load profile based on monthly electric bills, as shown in Figure 4. It was found that the average monthly energy demand was within the range of 482 (October) - 958 kWh (July) with an average value of 24.76 kWh/day. GÜNSEL B9 and J9 are electric vehicle models produced by GÜNSEL, and Table II shows their technical characteristics. Table III presents the main parameters of the battery used in GÜNSEL B9.

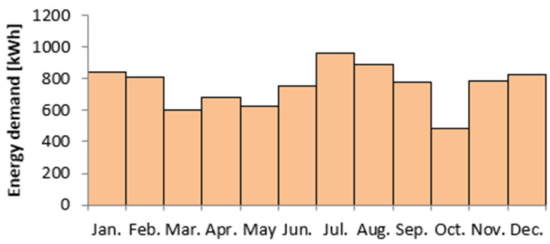

Fig. 4. Monthly energy demand for the selected household during 2022.

TABLE II. TECHNICAL CHARACTERISTICS OF GÜNSEL B9 AND J9

Electric Vehicle Model	B9	J9
Acceleration [km/h]	0-100	0-100
Charging Time [min]	30	30
Maximum Speed [m/s]	150	200
Maximum Power [kW]	140	280
Weight [kg]	1420	2000

TABLE III. TECHNICAL CHARACTERISTICS OF GÜNSEL B9 BATTERY PACK

Electric Vehicle Model	B9
Battery power capacity [Ah]	148
Nominal energy @ 0.2C [kWh]	52.6
Nominal voltage [V]	355
Maximum charge current [A]	125
Maximum discharge current [A]	350
Cell type	Li-ion cylindrical cell

In general, the daily energy required for an electric car can be estimated as shown below:

- Determination of the energy required (E_R) in kWh for a full charge by:

$$E_R = P_{max} \times C_t \quad (11)$$

where P_{max} is the maximum power of the car in kW and C_t is the charging time in h.

- Determination of the adjusted Energy required (AE_R) in kWh by:

$$AE_R = E_R \times C_e \quad (12)$$

where C_e is the charging efficiency percentage. Electric car charging is not 100% efficient, and there are losses during the charging process. Thus, it is assumed that C_e= 90%.

- Calculation of the daily energy required (DE_R) in kWh/day:

$$DE_R = AE_R \times NC \quad (13)$$

where NC is the number of charges per day given by:

$$NC = \frac{Daily\ Distance\ Traveled}{B_{pc} \times B_f} \quad (14)$$

where B_{pc} is battery power capacity in kWh and B_f is battery efficiency in km/kWh. It should be noted that the battery efficiency for EVs was assumed to be 90%.

- The Charger Power (CP) of an EV can be estimated by:

$$CP = P_{max} \times \frac{Range}{S_{max}} \times \frac{B_{pc}}{Range} \quad (15)$$

where S_{max} is the maximum wind speed in km/h and *Range* is in km. In general, the charging power of electric cars using a solar station can vary depending on several factors, including the capacity of the solar panels, the charging infrastructure, and the specific electric car model being charged [28-30]. In addition, charging power may also depend on other factors, such as the charging rate supported by the electric car's onboard charger and the compatibility between the charging station and the car [28]. In the literature, solar charging stations often have charging power capacities in the range of 3-22 kW per charging point. In this study, the charging power capacity was assumed to be 7, 11, and 22 kW.

III. RESULTS AND DISCUSSION

A. Survey Results Related to Major Equipment Price Details

As there is a wide variety of PV modules and inverters available in the market, it is important to consider parameters such as cell type, system cost, warranty, and size [29]. Besides, it is significant to consider factors such as the output AC power, the efficiency of DC-AC conversion, and the capital cost for the selected suitable inverter. In this study, the economic and environmental analysis of installing a grid-connected PV system was conducted using the RETScreen software. It is important to note that the lowest GHI values of 1.66 kWh/m^2/day and 2.53 kWh/m^2/day were recorded at Beylerbeyi and Ercan, respectively, in December. Additionally, the maximum daily power consumption for a household is observed in July at 31 kWh/day. According to [29-30], the capacity of a PV system can be calculated by:

$$P_{max} = \frac{E_{AC} P_i}{G_{SR} f_{PV} \eta_{inv}} \quad (16)$$

where P_i is the solar radiation at STC in kW/m^2, G_{SR} is the global solar radiation (kWh/m^2/d), f_{pv} is the PV derating factor, E_{AC} is the daily power consumption in kWh/d, and η_{inv} is the inverter yield.

Therefore, the PV capacity was estimated to be 32 kW, 36 kW, and 47 kW in Beylerberyi, with an average value of 38 kW based on the lowest value of 1.66 kWh/m^2/day. Based on the minimum GHI value in Ercan, the capacity of the PV plant was found to be 23, 27, and 38 kW with an average value of 30 kW. Table IV shows the specifications of the PV module used. In addition, a 40 kW pure sine wave inverter was selected, with an efficacy of 94% [17]. Moreover, the primary objective of the study was to reduce energy bills and meet energy requirements for EVs and households. However, grid power will be used at night or on cloudy, overcast, and rainy days for the household, while the energy storage system will be used to power electric cars during the nighttime. Thus, by storing the excess solar energy generated during the day, electric car owners can rely on their own stored energy rather than solely relying on the grid. This promotes energy independence and reduces the dependence on external energy sources. The specification of the energy storage system is available in [28]. Table V provides the list prices for the selected equipment.

TABLE IV. SPECIFICATION OF USED PV PANEL

PV module Technology	Mono-si
Manufacturer	Jinko Solar
Model	JKM545M-72HL4
Maximum Power [W]	545.00
Maximum Power Voltage [V]	40.80
Maximum Power Current [A]	13.36
Open-circuit Voltage [V]	49.52
Short-circuit Current [A]	13.94
Module area [m^2]	2.58
Module Efficiency [%]	21.13
Warranty [Year]	25.00
Cost [USD/Wdc]	0.37

TABLE V. ECONOMIC PARAMETERS USED IN THIS STUDY

Parameter	Unit	Value
PV module cost	$	202
Cost of 40kW inverter	$	13990
Cost of 19.2kW energy storage system	$	8430
Miscellaneous/contingency fund	% of the total initial cost	3
Installation and spare parts	% of the total initial cost	8
Feasibility study, development, and engineering cost	% of the total initial cost	0.6

B. *Economic Feasibility of the Proposed System*

For simplicity, a fixed solar tracking system was employed in this analysis. The economic feasibility of PV systems with various capacities was carried out using the RETScreen software. The initial financial parameters for the economic analysis were derived from the existing literature on the economic study of PV installations in northern Cyprus [30]. These sources provided relevant and reliable information on the financial aspects associated with PV projects in the region. Using these data, the economic analysis was able to incorporate the specific financial conditions and considerations relevant to PV installations in northern Cyprus [29]. RETScreen assists in the evaluation and optimization of renewable energy and energy efficiency projects and provides a comprehensive platform to conduct feasibility studies, assess energy production, calculate financial analysis, and evaluate the environmental impact of various project options. As mentioned above, the findings demonstrate that solar radiation levels remain uniform, indicating that any area of the region is suitable for a solar-powered charging station. This consistency in radiation levels also suggests the feasibility of implementing a single charging station design that would work effectively across different geographical regions in northern Cyprus. The energy generation of a solar PV system is influenced by the solar radiation available at the location and the number of clear sunny days [31]. These factors directly impact both the annual energy exported to the grid by the panel and the capacity factor. Figure 5 illustrates the monthly variation of energy production for Beylerbeyi and Ercan, showing that maximum energy production occurs in July, while minimum energy production occurs in December. These variations in energy production throughout the year emphasize the importance of considering seasonal factors when evaluating the performance and planning the utilization of solar PC systems. Figure 6 shows the annual value of energy production at both selected locations. The annual values of the proposed systems were found to be in the range of 48528.1-71275.65 kWh for Beylerbeyi and 35094.12-57981.58 kWh for Ercan.

(a)

(b)

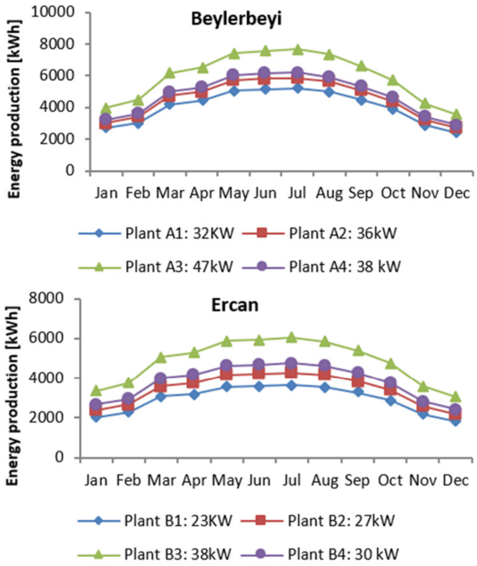

Fig. 5. Monthly variation of power generation from the PV system with different capacities: (a) Beylerbeyi and (b) Ercan.

(a)

(b)

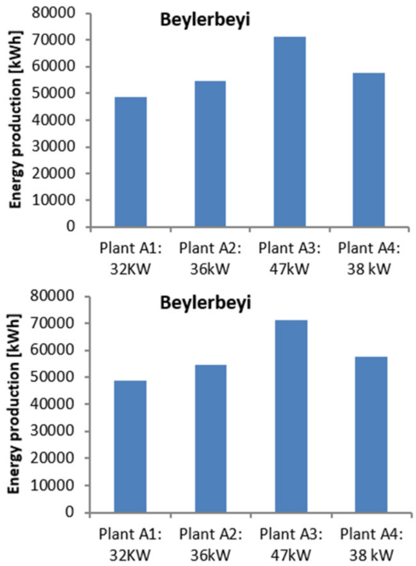

Fig. 6. Annual value of energy generation from the PV system with different capacities.

The annual CF values were 17.31% for Beylerbeyi and 17.48% for Ercan. These results are supported by [29-34]. For example, in [31], it was found that the CF values were in the range of 17.54-27.42% for grid-connected PV systems that employed different sun-tracking modes. In [30], a CF of 16-23% was reported for the PV systems developed in Oman, while in [34], the CF values ranged between 15.37 and 15.75% for grid-connected PV systems using various technologies. Therefore, the annual energy production and the corresponding capacity factors at the selected locations meet the acceptable values. This implies that it is technically feasible to construct and operate solar PV plants in these locations considering the technical viability of the solar systems. These findings are valuable for decision-making processes related to renewable energy investments and further emphasize the suitability of solar energy as a viable and sustainable source of electricity. Furthermore, the economic viability of the proposed systems was explored. The economic assessment took financial metrics as input variables, including an inflation rate of 8%, a discount rate of 6%, a reinvestment rate of 9%, a debt ratio of 70%, a debt interest rate of 0%, and an electricity export escalation rate of 5%. The economic viability of a project is assessed using indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), payback period, and Annual Life Cycle Savings (ALCS) [35-36]. Figures 7-8 illustrate the values of these indicators for Beylerbeyi and Ercan, respectively. The NPV, which represents the difference between the present value of cash inflows and outflows over a specified period, was found to be positive for the selected locations, indicating that the project is financially and economically feasible [35-37]. In addition, the IRR, a measure of project profitability, was determined to be higher than the required rate of return for the project at all locations [37]. According to [31, 37], to consider a project successful, it must be both fiscally and economically feasible. Additionally, the internal rate of return profitability assessment indicates that the projects at the selected sites are financially viable [4, 37]. Therefore, projects in these locations are economically viable compared to the required rate of return, which serves as the discount rate for the project. Based on these assessments, the projects in both locations are considered financially and economically acceptable. ALCS is a term commonly used to gauge the benefits of a project, calculated based on factors such as the net present value, project life, and discount rate. Figures 7-8 illustrate the results of ALCS, showing that they range between 4546.9 and 9705.8 USD/year. Furthermore, the payback period is a measure that indicates the time needed to recoup the initial investment made in a project through the net positive income. RETScreen considers two types of payback periods: equity payback and simple payback. Equity payback represents the time required to recover the initial investment considering only the equity portion. On the other hand, simple payback covers the entire investment, including both equity and debt. A shorter payback period is desirable as it signifies a faster return on investment. The payback period is a valuable tool to assess the risk associated with an investment, as it provides insight into the time frame required to recover the initial investment and helps evaluate the project's financial viability. The equity and simple payback periods were within the ranges of 2.4-2.9 years and 6.8-8.0 years, respectively.

(a)
(b)
(c)
(d)
(e)

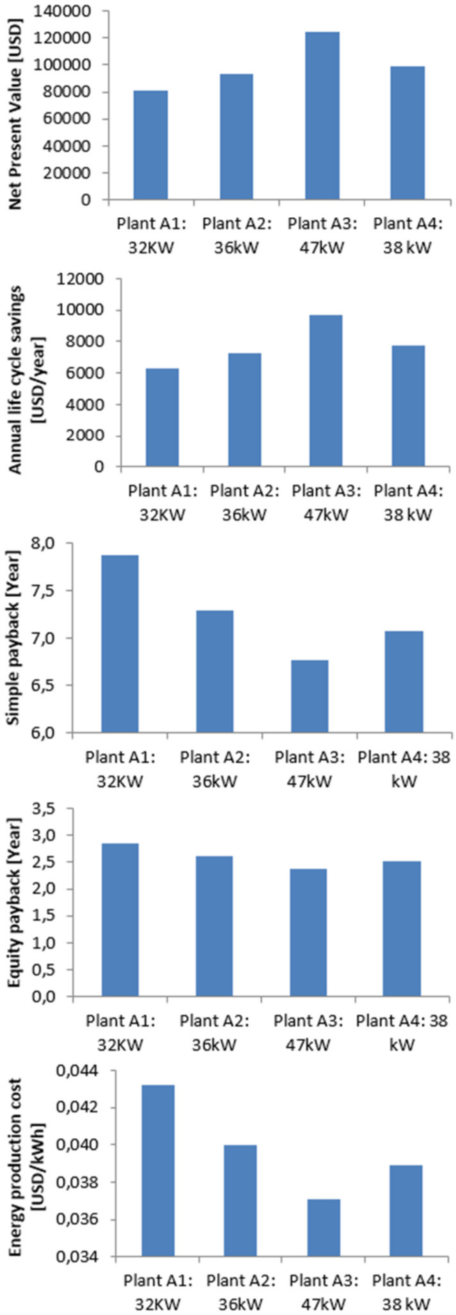

Fig. 7. Economic performance of proposed PV systems for Beylerbeyi.

These findings indicate that the developed systems are financially feasible in all regions. In addition, the Electricity Production Cost (EPC) of the developed systems varies between 0.0371 and 0.0437 USD/kWh, as shown in Figures 7-8. The EPC values of the proposed systems fall within the respective ranges of [38]. This observation indicates that the established systems offer valuable information on the financial feasibility of the project in all regions.

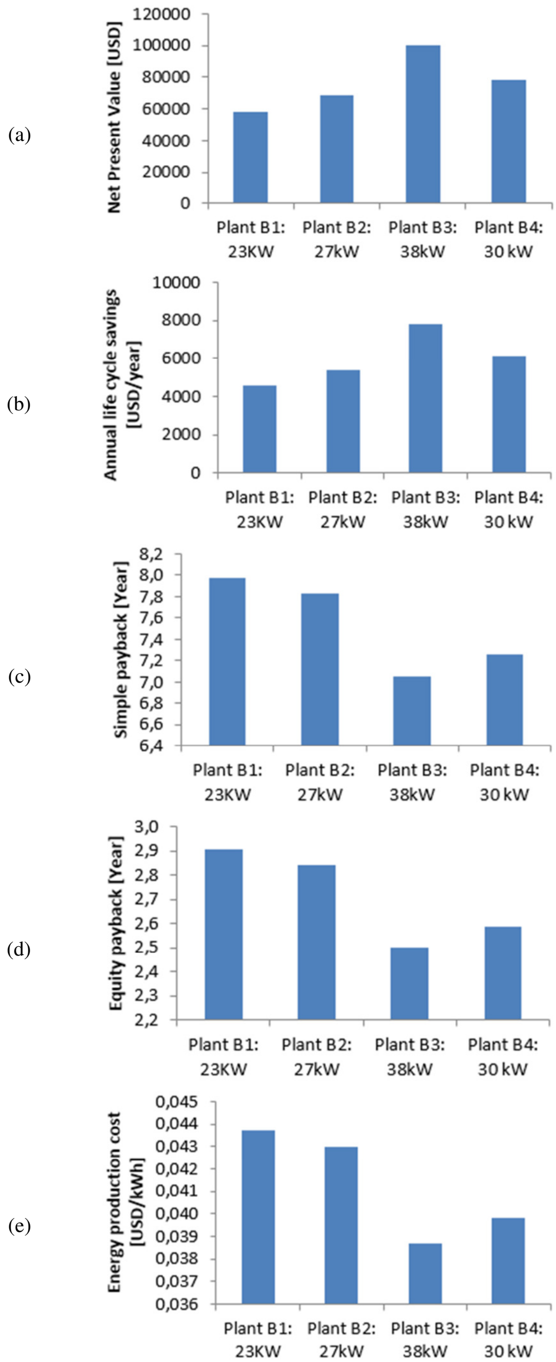

Fig. 8. Economic performance of proposed PV systems for Ercan.

C. Comparison Between EVs and Fuel Cars

Several factors should be considered when measuring the savings in money from an electric car powered by a solar station compared to a fuel car, such as the energy consumption of the electric car, the energy required for a specific distance, the solar station's energy generation capacity, and the cost of electricity from the solar station. Before comparing EVs and fuel cars, this study considered the following assumptions:

- It was assumed that each BEC or fuel car would operate every day throughout the year. This assumption accounts for the possibility that both types of cars may require regular use and maintenance.
- The study did not consider the maintenance costs typically associated with the maintenance and repair of vehicles. Omitting these costs allowed for a simplified analysis that focused on other factors.
- The fuel price was assumed to remain constant at the current level, with a slight degree of variability of approximately 5%. This assumption acknowledged the potential for slight fluctuations in fuel prices but maintained a relatively stable reference point for comparison.

By establishing these assumptions, the study set the basis for evaluating the relative performance and costs of BECs and fuel cars while accounting for specific factors. Table VI lists the money savings from BEC powered by a solar station compared to a fuel car. It is a justifiable assertion that the implementation of renewable energy systems and the substitution of fuel cars for BECs is economically feasible.

TABLE VI. ECONOMIC PARAMETERS USED IN THIS STUDY

Variable	Model: B9	Model: J9
Range [km]	350.0	350.0
Energy Required [kWh/day]	465.8	941.9
Average of electricity production cost from the solar system in Beylerbeyi [USD/kWh]	0.0398	0.0398
Average of electricity production cost from the solar system in Ercan [USD/kWh]	0.0413	0.0413
Cost of charging the electric car [USD/year] in Beylerbeyi	6766.38	13683.12
Cost of charging the electric car [USD/year] in Ercan	7021.39	14198.82
Average litter required for fuel car [Lt]	44.16	44.16
Cost of fueling the car [USD/year]	15313.57	15313.57
Average savings [USD/year] in Beylerbeyi	8547.19	1630.45
Average savings [USD/year] in Ercan	8292.18	1114.75

IV. CONCLUSIONS

Solar projects have gained worldwide prominence as a means to shift from fossil fuel-based electricity generation to cleaner and renewable energy production. Their ability to promote economic growth, enhance energy security, and contribute to reducing greenhouse gas emissions has been widely recognized. This study assessed the economic viability of solar energy potential as a power source for households and EVs in northern Cyprus. Based on potential estimates, it was determined that Ercan was the most optimal location for the construction of PV plants. In addition, the feasibility analysis revealed promising results for using solar charging to power available EV types on the market and meet the energy demands of households. These findings are of particular significance for countries reliant on expensive and imported fuel. However, if the focus shifted solely to the use of solar power for EV charging without incorporating an energy storage system, the associated plant cost would be reduced by almost half and the relevance and viability of this study would be further enhanced. This study introduces a novel aspect by exploring the exclusive use of solar energy to generate electricity for households and

EVs, contributing a unique addition to existing studies. The robust technical foundation, economic feasibility, and environmentally sustainable implications of the study make it a valuable resource for policymakers in northern Cyprus.

Future research should be directed toward exploring the feasibility of charging battery electric vehicles using a hybrid system that combines solar and wind energy. This investigation aims to optimize the use of the most suitable renewable energy sources for EV charging while simultaneously meeting the energy demands of households throughout the day.

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