Techno-Economic Feasibility of Grid-Connected Solar PV System at Near East University Hospital, Northern Cyprus

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Abstract: The growth of populations and economy in Northern Cyprus has led to continuing utilization of fossil fuels as the primary source of electricity, which will raise environmental pollution. Thus, utilizing renewable energy, particularly solar energy, might be a solution to minimize this issue. This paper presents the potential of grid-connected solar PV power generation at Near East University Hospital (NEU Hospital), one of the largest and leading medical facilities in Northern Cyprus, to meet the energy demand during the daytime to reduce energy bills. For this purpose, the first objective of the study is to evaluate the solar energy potential as a power source for the NEU Hospital based on four datasets (actual measurement, Satellite Application Facility on Climate Monitoring (CMSAF), Surface Radiation Data Set-Heliosat (SARAH), and ERA-5, produced by the European Centre for Medium-range Weather Forecast). The results showed that the solar resource of the selected location is categorized as excellent (class 5), that is, the global solar radiation is within the range of 1843.8–2035.9 kWh/m². The second objective is to investigate the impact of orientation angles on PV output, capacity factor, economic feasibility indicators, and CO2 emissions by using different PV modules. The results are compared with optimum orientation angles found by Photovoltaic Geographical Information System (PVGIS) simulation software. This objective was achieved by using RETScreen Expert software. The results demonstrated that the highest performance of the proposed system was achieved for orientation angles of 180° (azimuth angle) and ~35° (tilt angle). Consequently, it is recommended that orientation angles, PV modules, and market prices are considered to maximize energy production and reduce electricity production costs.

Keywords: Near East University Hospital; Northern Cyprus; PV system; grid-connected; orientation angles; economic feasibility indicators; CO2 emissions

1. Introduction

Due to the growing population, the number of buildings has increased, leading to increased energy consumption and greenhouse emissions that rely mainly on fossil fuels. Therefore, many scientific researchers found that renewable energy, such as solar and wind energy, is a good solution to reduce greenhouse gas (GHG) emissions. For instance, Lazarous et al. [1] concluded that utilizing zero-emission energy production such as renewable energy will help achieve Paris Agreement requirements via substantial reduction of carbon emissions. Schnitzer et al. [2] concluded that utilizing solar thermal energy provided an essential step towards sustainable zero-emission production in the industry. Shahsavari and Akbari [3] found that renewable energies have high potential for reducing GHG emissions.

Thus, solar power has been considered as one of the main potential, economically viable, and environmentally friendly energy sources among renewable energy sources.
Many studies have investigated the potential for generating electricity with photovoltaic (PV) systems in different locations worldwide. For example, Nassar and Alsadi [4] evaluated solar energy potential in Gaza Strip, Palestine, utilizing hourly solar radiation data. The results indicated that Gaza Strip has high potential for generating electricity from solar energy due to the high value of direct normal irradiance and global tilted irradiance. Martin–Pomares et al. [5] evaluated Qatar’s long-term solar energy potential as an electricity generation source. The results showed that Qatar’s large-scale PV grid-connected plant could be considered an alternative solution for electricity generation. Almarshoud [6] investigated the PV system performance in different locations in Saudi Arabia using measured solar irradiance data. It is found that the Najran has the highest solar energy among 32 locations, while the lowest solar energy potential was recorded in Qunfudhah. Lau et al. [7] evaluated the solar energy potential in Dares Salaam, Tanzania, based on the solar irradiance models. The results demonstrated that solar energy could help improve the living quality in the area by reducing fossil energy consumption from fossil fuel. Mardonova and Choi [8] investigated the solar energy potential in mining sites in Uzbekistan to install 1 MW PV systems. The results showed that the iron mine Tebinbuloq in Karakalpak has the highest solar potential compared to other sites. Al Ghaithi et al. [9] analyzed the viability of off-grid solar PV systems in Masirah Island, Oman. The results indicated that a hybrid energy system including wind, photovoltaic, and diesel generators were the most economically feasible option and improved the voltage profile at the connection point.

Moreover, numerous researchers have focused on solar PV systems’ solar energy potential and viability as power generation sources in buildings, like hospitals, departments, and more [10–17]. For instance, Al-Najdeen and Alrwashdeh [10] designed a 56.7 kW grid-connected PV system to cover the demand for electricity in the Faculty of Engineering at Mu’tah University in Jordan. The results showed that the proposed PV system would reduce the electricity bill and cover the faculty’s energy demand. Manoj–Kumar et al. [11] investigated the feasibility of a 1 MW PV system at two different campuses of Universiti Malaysia Pahang based on simulation results collected from PVGIS and PVWatt software. They found that the proposed project would meet 50% of its energy requirements during the daytime, and the university could save around RM 700,699 annually. Alghamdi [12] investigated the feasibility of a grid-connected-diesel generator-PV system for a hospital building in Dammam, Saudi Arabia. The results demonstrated that utilizing the grid-connected PV system in the hospital was a feasible and lower solution than the conventional grid and standby diesel engine system. Imam et al. [13] explored the potential of a grid-connected PV system for typical residential buildings in Jeddah, Saudi Arabia. The results showed that the proposed PV system produced 87% of the electricity needs of the building. Carlos et al. [17] determined the practical potential for PV power generation in the Putumayo department of Colombia. They concluded that the PV system could cover the department’s consumption by producing self-generating electricity and distributed generation. In the end, the scientific researchers concluded that utilizing renewable energy as a powerful energy source can reduce the total energy consumption and potentially provide a promising solution for reducing the energy demand for the building [10–17].

1.1. Solar Energy Potential in Northern Cyprus

Northern Cyprus has an area of 3354 km² and a population of about 326,000, and it has a Mediterranean climate. The power in Northern Cyprus is heavily dependent on non-renewable energy resources, and the production of electrical energy is mainly generated from four power plants [18]. In Northern Cyprus, there are four solar PV plants at Middle East Technical University Northern Cyprus Campus with a capacity of 1 MW (2015), Cyprus International University with a capacity of 1.3 MW (2016), KKTCell Main Building with a capacity of 50 kW (2017), and Levent College with a capacity of 120 kW (2018) [19,20].
Northern Cyprus has vast solar energy potential. The highest and lowest annual values of global horizontal irradiation in Northern Cyprus are estimated at 2000 kWh/m² and 1800 kWh/m², respectively. These values indicate that the solar resource is classified as good (class 4) and excellent (class 5) according to Kassem et al. [21] and Právělí et al. [22]. Additionally, the maximum and minimum values of direct normal irradiation are about 2230 kWh/m² and 1710 kWh/m², respectively. Thus, solar energy potential for Northern Cyprus is classified as good, excellent, and outstanding based on DNI values [21,22]. In the end, it can conclude that all regions in Northern Cyprus have a vast resource energy potential for generating energy from flat-plate PV and concentrating PV systems. Additionally, it should be noted that the solar radiation intensity is varied in different regions. Besides, İlkan et al. [23] concluded that solar power systems could be alternative sources to fulfill the electrical power required and reduce the CO₂ emissions in the country. Pathirana and Muhtaroglu [24] concluded that utilizing solar energy in Northern Cyprus can help to produce power and become more independent from fossil fuels. Radmehr et al. [25] found that Northern Cyprus has a remarkable ability to utilize building-integrated PV systems as a power source in the house. Agboola and Egelegno [26] concluded that solar energy could be considered an alternative solution to reduce the energy demand and water scarcity in Northern Cyprus.

Furthermore, several authors have studied the potential of solar energy and techno-economic feasibility of PV systems in different regions in Northern Cyprus, as shown in Table 1. Based on the previous studies (Table 1), it can be concluded that utilizing solar energy can be an alternative solution for reducing fuel consumption, water scarcity, and greenhouse gas emissions.

### Table 1. Summary of previous studies focusing on solar energy potential in Northern Cyprus.

| Reference | Year | Description/Aim | Remarks and Key Findings |
|-----------|------|-----------------|--------------------------|
| [27] | 2011 | Feasibility of a 1 MW grid-connected PV system in Nicosia (Lefkoşa), Morphou (Güzelyurt), and Rizokarpas (Dipkarpaz) | The feasibility of a two-axis PV system was higher than a fixed-structure solar system |
| [28] | 2012 | Evaluate and compare the use of the solar thermal energy collectors (Parabolic Trough and Fresnel systems) over Northern Cyprus topography | Fresnel systems have an advantage over Parabolic Trough due to higher solar irradiation absorption, lower CO₂ emissions, and lower operating cost. |
| [29] | 2014 | Installing a 30 MW hypothetical solar chimney power plant under Northern Cyprus conditions | The annual electrical energy from the proposed system was estimated to be 94.5 GWh. This amount of energy output would contribute significantly to meeting 22,126 residences household’s electrical energy demand. |
| [30,31] | 2015 | Build 1.275 GW PV plant in Serhatkoy site | The plant will improve the electricity sector and will be able to reduce emissions to an acceptable level. |
| [32] | 2016 | Design and techno-economic analysis of a standalone PV system to meet the electricity of a house in the rural fringe of Famagusta | The electricity generation cost was 0.73 TL/kWh, and the developed system is a viable technology for the electrification of a house in Cyprus. |
| [33] | 2016 | The performance and economic viability of two different PV plants (Fixed-tilt and parabolic trough) with a capacity of 40 MW in Nicosia and Famagusta | The highest profitability was found in Nicosia, and utilizing solar power plants will help to reduce large amounts of CO₂ emissions. |
| [34] | 2017 | Develop a hybrid system to generate electricity for a household in Nicosia | The hybrid system is considered an economical option for electricity generation in the selected location. |
| [35] | 2018 | Develop a 12 MW grid-connected wind farms and fixed-tilt PV power plants in Lefkoşa and Girne | The selection locations were found suitable to build a PV system for energy production and reduce fuel consumption. |
| [36] | 2018 | Propose a 1 MW grid-connected PV power plant with the various sun-tracking systems in Lefke town | The electricity cost was found within 0.109–0.150 $/kWh, and annual GHG emission reduction was varied from 1321 to 1829 tCO₂. |
| Year | Proposal |
|------|----------|
| 2018 | Investigate the utilizing of solar energy Famagusta (Gazimağusa) city | Famagusta City has huge potential for solar energy, but the city is not able to generate the required amount of solar energy because of its inappropriate urban design. |
| 2018 | Find the best location for installing a PV power plant based on the highest profitability of the project. | Güzelyurt region has the highest solar energy potential and economic feasibility to install a PV power plant in the future. |
| 2018 | Propose a 4.85 kW grid-connected PV rooftop systems in Nicosia (Lefkoşa), Morphou (Güzelyurt) and Dipkarpaz | All selected locations have a higher potential for solar energy. |
| 2019 | Develop a 6.4 kW grid-connected PV wind systems for household in Lefkoşa, Girne and Gazimağusa | The PV systems are an economical option for generating electricity in the selected location compared to wind systems. |
| 2019 | Propose a 45 kW rooftop-building grid-connected PV power system in Lefke town | The electricity cost of the proposed system was found to be 0.056$/kWh, which is lower than the energy cost of traditional energy (0.158$/kWh). |
| 2019 | Using of PV as a shading device for solving the heating problems in the residential sector in Famagusta | The developed system produced around 50% of the electricity needs of the building. |
| 2019 | Present the performance assessment of 110 kW grid-connected solar system with various PV technologies | The CdTe PV system has a higher performance ratio than other PV technologies, and the proposed system can help reduce the green gas emissions and supply electricity to the Near East University. |
| 2019 | Present the performance assessment of 110 kW grid-connected solar system at a different location in Northern Cyprus | The annual average performance ratio was within the range of 75-80% for all PV technologies. |
| 2019 | Techno-economic feasibility evaluation for a solar-powered seawater desalination plant in Gazimağusa | The proposed system can be considered as a good solution for solving water scarcity and reducing greenhouse gas emissions. |
| 2019 | Technical, environmental and economic aspects for developing PV/wind hybrid system in Middle East Technical University Northern Cyprus Campus | The proposed system will reduce the annual fuel consumption of the island by 9920 barrels which will also reduce the annual CO2 emissions by 3622 tons. |
| 2020 | Develop a 30 kW grid-connected PV system for Near East University grand library with various types of PV systems used on building PV technologies | The performance of freestanding mounting position system with thin-film (CdTe) was found better than building-integrated PV. |
| 2020 | The feasibility of 100 MW grid-connected PV plant in Lefkoşa | The proposed system would help to reduce fuel consumption, electricity tariffs, and greenhouse gas emissions. |
| 2020 | Develop a 6 kW PV-Wind hybrid system to meet a single household electricity demand in Gazimağusa | The proposed system helped to reduce the electricity bill of the household. |

1.2. Importance of the Study and Research Gap

According to the Ref. [50], the Turkey–Northern Cyprus electricity project will be a similar Turkey–Northern Cyprus water project that aims to supply electricity from Turkey to Northern Cyprus. Therefore, utilizing renewable energy systems can be an alternative solution for generating electricity on the island and reducing gas emissions to an acceptable level.

The literature reveals an evident lack of forecasting energy and economic benefits of the grid-connected PV system to reduce energy consumption, which relies on fossil fuel and decreasing air pollutants for a hospital building in Northern Cyprus. Additionally, most works related to Northern Cyprus studied the techno-economic feasibility of standalone, grid-connected, and hybrid systems for different regions in Northern Cyprus. Moreover, in the available literature, the scientific researchers have focused on finding the optimum angles (tilt and azimuth angles) of fixed PV systems for different solar energy
applications in certain areas around the world, for example, Saudi Arabia [51], Brisbane, Australia [52], Abu Dhabi, United Arab Emirates [53], and Palestine [54]. Besides, numerous researchers concluded that the optimum orientation angles (tilt and azimuth angles) of fixed solar modules help maximize the performance of fixed-tilt PV systems and reduce greenhouse gas emissions [55–63]. Additionally, various theoretical models and simulation tools have been utilized to estimate the optimum orientation angles for the fixed-tilt PV system [51,58]. Thus, according to the authors’ review, the available literature does not explicitly concentrate on the impact of the orientation angle accuracy of the PV system on energy production, capacity factor, economic feasibility indicators, and CO₂ emissions in Northern Cyprus.

As a continuation of authors’ studies on the performance, economic viability, and environmental sustainability of solar PV technology in Northern Cyprus, this study had the goal of putting forward the new investigation to achieve an economic and environmental feasibility study of using green and clean energy provided by solar photovoltaic (PV) modules for the Near East University Hospital located in Lefkoşa, Northern Cyprus. This study has been focused on two objectives. Due to the limitation of meteorological stations in Northern Cyprus, the first objective is to ensure that the meteorological data of Lefkoşa can be considered constant and used for forecasting the solar energy potential for Near East Hospital. In order to work on the first objective, four datasets (actual measurement, Satellite Application Facility on Climate Monitoring (CM SAF), Surface Radiation Data Set-Heliosat (SARAH), and ERA-5, produced by the European Centre for Medium-range Weather Forecast) are compared and analyzed regarding their accuracy and provide a comparative analysis for estimating the potential of solar energy in the selected location. The second objective is to investigate the impact of orientation angles (azimuth and tilt angles) on PV output, capacity factor, economic feasibility indicators, and GHG emissions. The results are compared with optimum orientation angles found by PVGIS (Photovoltaic Geographical Information System) simulation software. This objective was achieved by using RETScreen Expert software.

2. Materials and Methods

The solar energy potential in the Near East University Hospital is presented in this section. Furthermore, the techno-economic feasibility of grid-connected PV plants in the selected location is discussed. Figure 1 illustrates the analysis procedure of the current study.
2.1. Energy Situation at the Near East University Hospital

The proposed location is located in Near East University, a private university located in Lefkoşa, Northern Cyprus (Latitude: 35.229 and Longitude: 33.320). Near East University Hospital was open to public use in 2010 after construction in 2008 as the first and only private university hospital with 36 service departments equipped with high technology. The hospital building, which has an indoor space of 55,000 m², is situated within the Near East University Campus in Nicosia. The building consists of three blocks with three, four, and nine stores. There are 209 single-bed patient rooms, eight surgery rooms, 30 intensive care units, and 17 newborn intensive care units. Apart from that, it is the only hospital with a high-tech Radiotherapy center and only a PET/CT Scanner. Moreover, it has been fully equipped with laboratories to carry out all medical tests and RIS (Radiology Information System) and LIS (Laboratory Information System). The Faculty of Medicine also uses the hospital building to carry out lectures and practices. In addition to the hospital,
the building also provides accommodation for students with 60 rooms. Figure 2 shows a panoramic view and architectural overview of Near East University Hospital.

![Panoramic view of Near East University Hospital.](image)

The electricity consumption data are measured and recorded using a powerful automation system device with Azeotech DAQFactory HMI/SCADA Software installed at Near East University (NEU) hospital. The study involved collecting and analyzing the historical hourly electricity consumption data and electricity costs for January 2017 to December 2018 to evaluate the tendency of electricity demand.

Figure 3 illustrates the monthly electricity composition and costs during the investigated period. It was found that the highest electricity demand was recorded in the summer (June, July, and August) and autumn (September, October, and November) seasons, ranging from 6540.655–9978.682 kWh for 2017 and 6935.316–10,635.170 kWh for 2018. During this period (summer and autumn seasons), the average, minimum, and maximum temperatures are within the range of 15.57–38.72 °C, 11.69–28.41 °C, and 32.83–13.60 °C for 2017 and 18.27–35.15 °C, 14.40–28.11 °C and 331.28–16.30 °C for 2018, respectively, according to the National Aeronautics and Space Administration (NASA) database. Because of a higher temperature, the usage of air conditioners for cooling increased. Furthermore, it can be seen that the annual electricity bill in 2017 and 2018 for NEU hospital was 1.41 and 1.86 million TL in 2017 and 2018, respectively. As shown in Figure 3, the electricity bill increased by 31.91% due to new technologies with a high quality of care, and technically advanced facilities attracted patients. It can be concluded that NEU hospital suffers from high electricity bills exceeding 1.860 million TL/year.
2.2. Data

The accurate measurement of the solar resource at the selected location is not available due to the meteorological stations in Northern Cyprus. Additionally, the measurement data, such as solar radiation and air temperature, are essential factors to estimate the performance of PV systems [64]. According to Maammeur et al. [65] and Akinsipe et al. [66], the size of a PV plant can be determined based on the highest value of global solar radiation. Moreover, according to Bhatia [67], solar radiation can be assumed to be constant in large areas, neglecting cloud absorption’s effect on solar radiation. As mentioned previously, the actual measurement data (solar radiation, air temperature) are not available for the selected location; thus, it is considered one of the critical limitations of this present study.

Therefore, the meteorological data (global solar radiation, sunshine duration, relative humidity, and ambient temperature) of NEU hospital are assumed to be the meteorological data of the Lefkoşa. To achieve this:

- The hourly meteorological data of the Lefkoşa location are compared with three databases, namely, the Satellite Application Facility on Climate Monitoring (CMSAF), Surface Radiation Data Set-Heliosat (SARAH), and ECMWF ERA-5 produced by the European Centre for Medium-range Weather Forecast to show the accuracy of the database. In general, the accuracy of the satellite database is enough to decide on the design of the solar PV system [68].
Based on the results of the first criteria, the satellite database of the Lefkoşa location and NEU hospital location are compared to verify that both values are closed to each other, and to verify that solar radiation can be considered constant in a wide area. The meteorological data and satellite database were gathered from January 2014 to December 2016.

2.3. On-Grid Solar PV System

2.3.1. PV System Sizing

In this work, grid-connected PV plants were developed to cover the energy demand at NEU hospital during the daytime. Thus, the PV energy amount injected into the grid \( E_{\text{inj}} \) should be greater than the electricity amount purchased by the system from the grid \( E_{\text{abs}} \) as expressed in Equation (1) [69].

\[
E_{\text{inj}} > E_{\text{abs}} \quad (1)
\]

It should be known that the hospital is considered as a micro-grid, which can produce parts of its energy by solar energy and the remaining energy from the grid.

Generally, the grid-connected PV system consists of PV modules, an inverter, distribution controller, and load. According to the previous studies [70,71], utilizing the grid-connected PV systems helps to reduce the energy consumption, capacity losses in the utility distribution network and delays upgrades to the transmission and distribution (T&D) network. Furthermore, the developed system is not dependent on the battery type used and required capacity [72]. Thus, this system can be considered as an economic benefit for reducing system costs.

As mentioned previously, the maximum power \( P_{\text{max}} \) of the proposed plant using Equation (2) [65] is:

\[
P_{\text{max}} = \frac{E_{\text{AC}} P_{\text{f}}}{G_{\text{SR}} f_{\text{PV}} \eta_{\text{inv}}} \quad (2)
\]

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

2.3.2. PV-Module Selection and Inverter

There are many different PV modules, such as mono-crystalline, poly-crystalline cells and amorphous silicon modules in the Turkey and Northern Cyprus market. Hence, cell type, system cost, the warranty, and the size and watts are required parameters to select the suitable PV module [73]. Besides, Balo and Şağbanuşu [74] concluded that the PTC (PV USA Test Conditions) power rating and material type are essential factors for selecting solar panels. Rehman et al. [75] found a suitable PV panel based on the ratio of module capacity to its price and module area. Recently, El-Bayeh et al. [76] concluded that the characteristics of the PV module (module area, power rate, cost, and efficiency) are one of the essential categories for developing a PV system. Moreover, Sasikumar and Ayyappan [77] found that the power rate and weight of the panel are the most important criteria for selecting the best solar panel.

Consequently, Equation (3) was utilized to select the suitable PV-module for the proposed PV plant. It should be known that the efficiency of the PV modules, which are selected in this study, is above than 16%.

\[
\text{Panel selection} = \frac{\text{PV module capacity} \times \text{Module efficiency}}{\text{module price} \times \text{Frames area of the module}} \quad (3)
\]

Table 2 lists the PV modules from different manufacturing companies in Turkey and Northern Cyprus. Among the 14 solar panels, it is found that the panel, which was manufactured by Horay Solar and Ankara Solar, are the most suitable, with a performance
score of 51.11 and 46.93, respectively. Table 3 summarizes the specification of the selected module.

Table 2. Selection criteria ratio for PV modules.

| Manufacturer          | Module Type        | Maximum Power [W] | Efficiency [%] | Module Area [m²] | Module Price [$] | Selection Term |
|-----------------------|--------------------|-------------------|---------------|------------------|-----------------|----------------|
| Jinko                 | JKM330M-60-V       | 330               | 19.78         | 1.668            | 115             | 34.03          |
| Solar Fabrik          | -                  | 340               | 20.14         | 1.687            | 237             | 17.13          |
| Panasonic             | -                  | 325               | 19.40         | 1.674            | 257             | 14.66          |
| Ankara Solar          | AS-M60-310W        | 310               | 19.00         | 1.630            | 77              | 46.93          |
| AXITEC                | AC-430MH/144V      | 430               | 19.33         | 2.174            | 120.4           | 31.76          |
| Suntech               | STP325-24/Vfw      | 335               | 17.20         | 1.944            | 81              | 36.59          |
| Tide Solar            | -                  | 435               | 20            | 2.1073           | 105             | 39.32          |
| Regitec Solar         | RMH60/380S1        | 380               | 20.9          | 1.853            | 110             | 38.96          |
| Austa Energy          | AU410-27V-MHB      | 410               | 20.97         | 1.955            | 99              | 44.42          |
| Horay Solar           | HS166-380-120M     | 380               | 20.50         | 1.823            | 84              | 51.11          |
| München Energieprodukte GmbH | - | 440 | 19.9 | 2.209 | 110 | 36.03 |
| Fortunes Solar        | FDS-M6M-60-355BK    | 355               | 19.26         | 1.868            | 82              | 44.64          |

Table 3. Specification of the used PV modules at Standard Test Conditions.

| Item                          | Specification                  |
|-------------------------------|--------------------------------|
| Manufacturer                  | Horay Solar HS166-380-120M     |
| Manufacturer Model            | Ankara Solar AS-M60-310W       |
| Maximum Power \( P_{max} \) [W] | 310                            |
| The voltage at Maximum Power \( V_{mp} \) [V] | 34.5                            |
| Current at Maximum Power \( I_{mpp} \) [A] | 11.04                           |
| Open Circuit Voltage \( V_{oc} \) [V] | 41.7                            |
| Short Circuit Current \( I_{sc} \) [A] | 11.55                           |
| Operating Temperature Range \( °C \) | -40–85                         |
| Temperature Coefficient of \( P_{max} \) [%/°C] | -0.36                           |
| Temperature Coefficient of \( V_{oc} \) [%/°C] | -0.28                           |
| Temperature Coefficient of \( I_{sc} \) [%/°C] | 0.05                            |

Moreover, the inverter is an electrical converter that converts the produced direct current for the PV panel into alternating current fed into the commercial electrical grid. There are several types of inverters in the market. The output AC power, DC–AC conversion efficiency, and capital cost are considered essential factors for selecting a suitable inverter. Thus, two units of central inverters of Sunny Central 850CP XT with a capacity of 954 kW and 98.6% efficiency were utilized. The characteristics of the used inverter are available from the Ref. [78].

2.3.3. Simulation Tool

There are many simulation tools, such as RETScreen, HOMER, PVsyst, TRANSYS, and so on to estimate the performance of PV power plants. The comparison between these simulation tools is available from the Ref. [79]. In recent years, RETScreen has been widely used to analyze different renewable energy infrastructures and their feasibility. RETScreen was developed by Natural Resources Canada (NRC). It aims to estimate the energy production and savings, costs, emissions reduction, financial viability, and risk of various
renewable energy technologies. The RETScreen utilizes the long-term monthly average meteorological data from the National Aeronautics and Space Administration (NASA) database to source meteorological information for the specific location. It is a rapid and efficient tool for examining the renewable energy system’s energy performance and for environmental impact reduction. It has many advantages, such as being relatively easy to use, being free, and accurately evaluating both electrical and thermal systems [80,81].

In the literature, many research papers studied the techno-economic of grid-connected PV systems using RETScreen software. For instance, Mardonova and Choi [8] utilized the RETScreen software to estimate the PV systems’ energy production, greenhouse gas reduction, and financial factors in a different location in Uzbekistan. Ahmed et al. [58] used the software to analyze the impact of orientation angles on the PV output of the proposed system. Mondal and Islam [70] used the software to examine the economic feasibility of a 1 MW grid-connected PV plant in Bangladesh. Sreenath et al. [82] used the software to perform the energy, economic and environmental analysis of conceptual 5 MW land-based solar photovoltaic power plants in different locations in Malaysia. Owolabi et al. [83] used RETScreen software for the techno-economic feasibility of a 6 MW grid-connected PV plant in various locations in the northeastern state of Nigeria. Kassem et al. [84] studied the feasibility of a 4.2 MW grid-connected PV plant in 25 selected coastal Mediterranean cities located in different Arabic countries using RETScreen software. Sreenath et al. [85] assessed solar photovoltaic power plants’ energy generation, economic, and environmental performance in seven airports by utilizing RETScreen software. Farrangi et al. [86] determined the technical, economic, and environmental aspects of the 20 kW and 1 MW grid-connected PV system in Iran using RETScreen software. Cristofari et al. [87] utilized the software to analyze the energy performance of the building-integrated solar thermal system. Li [88] investigated the techno-economic feasibility of a 1 MW grid-connected PV system in Jiangsu Province, China using RETScreen software. Ahmed et al. [89] utilized RETScreen software to investigate the environmental issue’s impact on the energy of PV system and GHG mitigation potential.

In the present study, RETScreen software was used to evaluate the techno-economic feasibility of the grid-connected PV development. Additionally, it was utilized to investigate the impact of orientation angles on the PV power output, capacity factor (Equation (4)), economic feasibility indicators such as Net present value (Equation (5)), Levelized cost of energy (Equation (6)), Simple payback (Equation (7)). Equity payback (Equation (8)), Annual life cycle savings (Equation (9)) and greenhouse gas (GHG) emissions (Equation (10)). It should be noted that these economic feasibility indicators were estimated to assess the benefits of investment and profitability of the proposed PV project. Additionally, RETScreen is capable of estimating these indicators.

Capacity factor (CF)

$$CF = \frac{P_{out}}{P \times 8760}$$  \hspace{1cm} (4)

Net present value (NPV)

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1 + r)^n}$$ \hspace{1cm} (5)

Levelized cost of energy (LCOE)

$$LCOE = \frac{\text{sum of cost over lifetime}}{\text{s of electricity generated over the lifetime}}$$ \hspace{1cm} (6)

Simple payback (SP)

$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RH} + C_{GHG}) - (C_{opM} + C_{fuel})}$$ \hspace{1cm} (7)

Equity payback (EP)
\[ EP = \sum_{n=0}^{N} C_n \]  

Annual life cycle savings (ALCS)
\[ ALCS = \frac{NPV}{\frac{1}{r}(1 - \frac{1}{(1 + r)^N})} \]

Annual GHG emission reduction (A-GHG)
\[ A - GHG = [(\text{Base case GHG emission factor}) \]
\[ - (\text{Proposed case GHG emission factor})] \times \text{End use energy delivered} \]

GHG emission reduction cost (GHG-E-RC)
\[ \text{GHG} - \text{E} - \text{RC} = \frac{ALCS}{\Delta_{GHG}} \]

Benefit-Cost ratio (B-C)
\[ B - C = \frac{NPV + (1 - f_d)C}{(1 - f_d)C} \]

where \( P_{out} \) is the energy generated per year, \( P \) is installed capacity, \( N \) is the project life in years, \( C_n \) is the after-tax cash flow in year \( n \), \( r \) is the discount rate, \( C \) is the total initial cost of the project, \( f_d \) is the debt ratio, \( B \) is the total benefit of the project, \( IG \) is the incentives and grants, and \( C_{ener} \) is the annual energy savings or income. \( C_{capa} \) is the annual capacity savings or income, \( C_{REE} \) is the annual renewable energy (RE) production credit income, \( C_{GHG} \) is the GHG reduction income, \( C_{o&M} \) is the yearly operation and maintenance costs incurred by the clean energy project. \( C_{fuel} \) is the annual cost of fuel, which is zero for renewable projects, and \( \Delta_{GHG} \) is the annual GHG emission reduction.

3. Results
3.1. Characteristics of Global Solar Radiation

3.1.1. Comparison of Satellite Database with Actual Data for Lefkoşa

In this section, the actual data (global solar radiation (GSR)) are compared with different satellite databases (Satellite Application Facility on Climate Monitoring (CMSAF), Surface Radiation Data Set-Heliosat (SARAH), and ECMWF ERA-5, produced by the European Centre for Medium-range Weather Forecast) to show the accuracy of the estimated data. The comparison between the actual mean hourly of solar radiation (SR) and the estimated SR computed by the three products (SARAH, CMSAF, and ERA5) is illustrated in Figure S1 as supplementary material for Lefkoşa. Additionally, the R-squared, mean absolute error (MAE), and root mean squared error (RMSE) are determined to select the best product for estimating the mean hourly of solar radiation (see Table 4). It is observed that the product ERA5 has produced the slightest error in terms of RMSE and MAE in estimating mean hourly solar radiation. Additionally, the highest value of R-squared is obtained by the product of ERA5. It has also been found that the CMSAF product has given the highest error values and lowest value of R-squared. In the end, the correlation between the satellite database and the measurement is highly accurate.

| Table 4. Performance evaluation of the products (SARAH, CMSAF, and ERA5). |
|-----------------|-----------------|-----------------|-----------------|
| Year | Statistical Indicators | SARAH | CMSAF | ERA5 |
|------|-----------------|-----------------|-----------------|-----------------|
| 2014 | R-squared | 0.9539 | 0.8276 | 0.9669 |
|      | RMSE        | 7.5109 | 10.0512 | 5.0139 |
In the literature, GSR can be considered constant in a wide area when neglecting the effect of cloud absorption of solar radiation [67]. Therefore, the GSR of the selected location (NEU hospital) is compared with the GSR of Lefkoşa to verify that both values are close to each other (see Figure S2 as supplementary material). It is found that the monthly SR of NEU hospital is primarily close to the SR values Lefkoşa with minimum relative errors. The relative error between the SR of NEU hospital and Lefkoşa is within the range of −4.63 to 0.383 kWh/m² for CMSAF, −0.001 to 0.016 kWh/m² for ERA5, and −2.361 to 0.438 kWh/m² for SARAH. It is concluded that minimum relative error is obtained by the ERA5 product, which is considered the best product to analyze the characteristics of solar energy potential in the selected location.

It is concluded that the best dataset found in this study is ERA5 and has the lowest error compared to other products. Additionally, several researchers concluded that the estimated data have high accuracy and can be utilized to evaluate the solar energy potential at specific regions [90,91]. Moreover, the monthly GSR value of Lefkoşa and the selected location (NEU hospital) are close to each other. Therefore, it is concluded that meteorological data values can be considered constant values for a broad region.

### 3.1.2. Monthly and Hourly Global Solar Radiation, Sunshine Duration, and Ambient Temperature

The characteristics of hourly and monthly actual data (GSR, sunshine duration (SD), and average ambient temperature (AT)) for a period of 2014–2018 are presented in this section.

Figure 4 shows the trend of yearly global solar radiation (GSR) for the selected location. It is observed that there is a similar trend in different years. The diurnal mean GSR varies within a 24 h period for a selected location in Northern Cyprus, as shown in Figure 4a. It is found that the highest mean hourly GSR is recorded at 11:00 a.m. for whole years and varied from 6232 kWh/m² to 6503 kWh/m². Additionally, the highest monthly GSR belongs to June 2016, with a value of 248.554 kWh/m², as shown in Figure 4b. Moreover, it is found that the annual GSR is varied from 1938 kWh/m² to 2010 kWh/m² with an average value of 1966 kWh/m², as shown in Figure 4c. It is concluded that the solar resource of the selected location is classified as excellent (class 5), that is, the GSR is within the range of 1843.8–2035.9 kWh/m² according to the Ref. [48,49]. Therefore, NEU hospital is a suitable location for installing a solar PV plant in due to the highest values of solar radiation.
As presented in Figure 5, the maximum SD is recorded in July and August during the investigated period. Additionally, it is found that the minimum monthly sunshine duration of 272.7 min/day was found in December 2016 while a maximum of 716.3 min/day in July 2017, as shown in Figure 5b. Furthermore, it is found that the annual SD is varied from 5934 min/day to 6173 min/day with an average value of 6037 min/day, as shown in Figure 5c.
Figure 5. Sunshine duration; (a) hourly, (b) monthly, and (c) annual during the period of 2014–2018.

Additionally, the variations of average ambient temperature (AT) for the selected location are shown in Figure S3 as supplementary material. The AT variation during the day (see Figure S3a as supplementary material) can be divided into the following: between 00:00 h and 04:00 h, the AT values are the lowest and varied between 15.2 °C (at 04:00 h) and 16.3 °C (at 00:00 h); between 05:00 and 12:00 h, the AT is ramping up to reach the maximum value of 26.3 °C at noon h; between 13:00 h and 23:00 h, the AT is declined and varied from 26.0 °C (at 13:00 h) and 16.8 °C (at 23:00 h). Additionally, it was found that the maximum and minimum monthly AT of 30.7 °C and 8.4 °C were recorded in July 2017 and January 2017, respectively, as shown in Figure S3b as supplementary material. The
annual value of AT is within the range of 19.1–20.4 °C, as shown in Figure S3c as supplementary material.

As can be seen from Figures 4 and 5, and Figure S3 as supplementary material, the mean GSR, SD, and AT characteristics may be somewhat different from year to year. Generally, more extended periods of weather parameters (GSR, SD, and AT) are preferable to obtain a quantitative, representative, and persuasive interpretation of weather parameters characteristics. Unfortunately, the long period of weather parameters is not available in this study. Thus, the relative error (RE) was calculated to account for the possible bias originating from insufficient actual data. The RE of each year is determined by using Equation (13) and illustrated in Figure S4 as supplementary material. The results indicate that during the five years, the maximum relative error occurs in the year 2016 (2.2%) for GSR, 2016 (2.3) for SD, and 2018 (3.9%).

\[
RE = \frac{\bar{P} - \bar{P}}{\bar{P}} \times 100\% \tag{13}
\]

where \(\bar{P}\) denotes the annual mean weather parameter (GSR or SD or AT) of the concerned period and \(\bar{P}_t\) denotes the concerned year’s annual mean weather parameter (GSR or SD or AT).

3.2. Project Development and Financial Assessment

In general, the price of the PV system has constantly been dropping by 80% since 2009 [92]. Therefore, this drop has encouraged utilizing grid-connected solar PV systems as a powerful energy source for a specific location with high solar potential.

In this study, the installation of 1789 kW grid-connected PV systems is economically and environmentally analyzed using RETScreen software. It should be noted that it was found that the highest value of GHI of 7.822 kWh/m²/day was obtained in July, and the maximum daily power consumption for NEU hospital was found in the summer season 2018 with a value of 10.635 MWh/day. By using Equation (2), the value of \(P_{max}\) was estimated to be 1789 kW. As mentioned previously, a grid-connected PV system does not depend on the battery type used and required capacity. Thus, the grid-connected PV system can be considered as an economic benefit for reducing system costs. Consequently, a fixed-tilt grid-connected PV system was used in this study as a solar shading of car parking. According to Al Awadhi et al. [93], solar shading of car parks can be installed practically anywhere, generate free electricity, and simultaneously provide shade. Figure 6 shows the details of the selected car parks in Near East University.
It should be noted that the main aim of the proposed project (1789 kW grid-connected PV system) was to reduce the energy bill and cover the energy demand for NEU Hospital during sunlight, while the use of power from the grid will be during the night or on cloudy, dull, and rainy days. Therefore, future research should be focused on estimating the size of the batteries needed to provide electricity to the NEU Hospital when the solar resource is not available, mainly at night.

3.2.1. Technical Viability

Based on the previous studies [94,95], the value of annual energy exported to the grid and capacity factor of the plant are dependent on solar radiation and the number of clear sunny days. Figure 7 illustrates the monthly variation of the daily solar radiation and clearness index for the selected location. It is found that the maximum value of daily solar radiation (DSR) is varied from 2.2 kWh/m²/day to 8.12 kWh/m²/day. The maximum and minimum values of DSR are obtained in June and December, respectively. Additionally, it is found that the annual average DSR is estimated to be approximately 5 kWh/m²/day for the selected location.
To find the highest value of solar radiance and the electricity exported to the grid, tilt and azimuth angles are varied from $-55^\circ$ to $55^\circ$. Table 5 lists the daily solar radiation tilted, annual solar radiation-tilted, and the annual energy exported along with the capacity factor for some selected tilt angle, and azimuth angle $= 0^\circ$. It should be noted that the value of the tilt angle was chosen based on previous scientific studies [31,32,96]. Moreover, the optimum orientation angles (tilt and azimuth angles) can be found using a PVGIS simulation tool according to the Ref. [97–99]. For instance, Abdallah et al. [99] concluded that the slope angle and azimuth angle obtained by PVGIS is closed to calculated angles obtained by the mathematical equations. Thus, the optimum angles optimum slop angle for the proposed system is $31^\circ$. As shown in Table 5, it is found that the tilt angle of $30^\circ$ gives the highest value of daily solar radiation tilted, annual solar radiation-tilted and the annual energy exported to grid compared to other angles. Additionally, it is found that the value of annual energy exported to the grid and capacity factor is within the range of $2,633,554$–$2,853,019$ kWh and $16.8$–$18.2\%$, respectively. According to the results obtained by [78,100,101], it is technically sustainable to construct a PV plant at NEU hospital.

Table 5. Daily solar radiation tilted, annual solar radiation-tilted and the annual energy exported and the capacity factor for various tilt angle and azimuth angle $= 0^\circ$.

| Solar Panel used in the System | Tilt Angle [$^\circ$] | Daily Solar Radiation Tilted [kWh/m$^2$/day] | Annual Solar Radiation-Tilted [MWh/m$^2$] | Annual Energy Exported to the Grid [kWh] | Capacity Factor [%] |
|--------------------------------|----------------------|-------------------------------------------|---------------------------------|-----------------------------------|-----------------|
| AS-M60-310W                    | 20                   | 5.63                                      | 2.06                            | 2,835,190                        | 18.1            |
|                                | 25 [31]              | 5.67                                      | 2.07                            | 2,851,747                        | 18.2            |
|                                | 30                   | 5.67                                      | 2.07                            | 2,853,019                        | 18.2            |
|                                | 31 [*]               | 5.66                                      | 2.07                            | 2,851,437                        | 18.2            |
|                                | 35 [96]              | 5.63                                      | 2.06                            | 2,838,998                        | 18.10           |
|                                | 40                   | 5.57                                      | 2.03                            | 2,809,747                        | 17.9            |
|                                | 45 [96]              | 5.47                                      | 2.00                            | 2,765,404                        | 17.6            |
|                                | 50                   | 5.34                                      | 1.95                            | 2,706,117                        | 17.3            |
|                                | 55 [32]              | 5.34                                      | 1.89                            | 2,633,554                        | 16.8            |
| HS166-380-120M                  | 20                   | 5.63                                      | 2.06                            | 2,852,549                        | 18.2            |
|                                | 25 [31]              | 5.67                                      | 2.07                            | 2,869,207                        | 18.3            |
|                                | 30                   | 5.67                                      | 2.07                            | 2,870,487                        | 18.3            |
As mentioned previously, orientation angles directly impact the performance and efficiency of the PV system. Thus, the impact of orientation (tilt and azimuth) angles on the annual average daily solar radiations, annual average solar radiations, annual energy exported to the grid, capacity factor (CF), and annual GHG emission reduction using various PV modules are presented in Figure 8 (HS166-380-120M) and Figure S5 as supplementary material (AS-M60-310W). These figures give the following findings:

- The highest average annual daily solar radiation-tilted is obtained for a PV system that has a tilt angle of 25°, 30°, −25° and −30° and azimuth angle of 0° and 180°.
- The highest annual solar radiations-tilted is obtained for a PV system that has a tilt angle of 25°, 30°, 31°, −25°, −30° and −31° and azimuth angle of 0° and 180°.
- The highest annual energy exported to the grid (2998 MWh for module type of HS166-380-120M and 2980 MWh for module type of AS-M60-310W) is obtained from a PV system that has orientation angles of −35° (tilt angle) and 180° (azimuth angle).
- The highest capacity factor (CF) of 19% is obtained from a PV system that has a tilt angle of −40°, −35°, −31° and −30° and azimuth angle of 180°.
- The highest annual GHG emission reduction (2195.5 tCO₂/year for module type of HS166-380-120M and 2182.2 tCO₂/year for module type of AS-M60-310W) is obtained from a PV system that has orientation angles of −35° (tilt angle) and 180° (azimuth angle).
- Using the HS166-380-120M module led to an increase in the performance of the proposed PV system by 0.6%.
Figure 8. Azimuth and tilt angle impact on (a) annual average daily solar radiations, (b) annual average solar radiations, (c) output power of PV system, (d) capacity factor (CF), and (e) annual GHG emission reduction.

Based on the findings, it can be concluded that the performance of PV systems is affected by the azimuth and tilt angles and the type of solar panel. In addition, this study found that the best azimuth and tilt angles to install a grid-connected PV system at Near East University Hospital are 180° and −35°, respectively. The monthly average electrical energy produced by the proposed PV system and the electrical energy purchased from the grid for optimum angels found by PVGIS (azimuth = −1° and tilt = 31°) software and the current study (azimuth = 180° and tilt = 35°) is shown in Figure 9. The results indicate that the PV system of 1789 kW almost covers the hospital load throughout the year, except for the following months of January, December, and July.

Figure 9. Monthly average electric production for some selected orientation angles.

3.2.2. Economic Sustainability

In this section, the economic feasibility indicators are calculated using RETScreen software. These indicators are estimated based on the financial parameters, which are assumed based on the previous studies (Table 6). Additionally, the cost of the developed system is also presented in Table 6. It should be noted that the economic and financial parameters of the system are estimated/assumed based on recent market data and is consistent with cost prices available in the literature.
Table 6. Economic and financial parameters used for analysis.

| Parameter                              | Unit         | Value                  |
|----------------------------------------|--------------|------------------------|
| PV module cost                         | $            | 77 (AS-M60-310W)       |
|                                        |              | 84 (HS166-380-120M)    |
| Number of modules                      | -            | 5771 (AS-M60-310W)     |
|                                        |              | 4708 (HS166-380-120M)  |
| The lifetime of the PV module          | Year         | 25                     |
| Cost of each unit of inverter          | $            | 155,647                |
| Miscellaneous/contingency fund         | % of the total initial cost | 3                  |
| Installation and spare parts           | % of the total initial cost | 8.6                |
| O&M cost                               | Annual       | 1.5 c$/kWh             |
| Lifetime of inverter                   | Year         | 13                     |
| Feasibility study, development, and engineering cost | % of the total initial cost | 0.6                |
| Inverter replacement periodic cost     | Every thirteen years | Equal to inverter’s cost |
| Inflation rate                         | %            | 8                      |
| Discount rate                          | %            | 6                      |
| Project life                           | Year         | 25                     |
| Energy cost increase rate              | %            | 5                      |
| Reinvestment rate                      | %            | 9                      |
| Debt ratio                             | %            | 70                     |
| Debt interest rate                     | %            | 0                      |
| Debt term                              | Year         | 20                     |

According to previous studies [48,78,83,84], the NPV and payback period are important factors in evaluating economic viability. Thus, the main results regarding the economic performance of the 1789 kW grid-connected PV system for various orientation angles are illustrated in Figure 10. The results indicate that the proposed plant is financially and economically feasible based on the NPV value and the Ref. [78,83,84].
Generally, higher values of NPV and lower EP values is the most attractive combination. As shown in Figure 10, the most extended value of equity payback (EP) of 2.52 years was obtained for the proposed system used. AS-M60-310W has a tilt angle of −40° and azimuth angle of 0°, and lowest value of 1.10 for a tilt angle of −35° and azimuth angle of 180° if HS166-380-120M is used. Additionally, it was observed that the value of simple payback (SP) varied from 4.02 years to 7.10 years and 3.42 years to 6.03 years if AS-M60-310W or HS166-380-120M was used, respectively. The longest and lowest values of SP were recorded for tilt −40°, azimuth 0° and tilt −35°, azimuth 180°, respectively. These results indicate that the PV project in the selected location makes financial sense.

Moreover, the Benefit–Cost ratio (B–C) is a useful term used to estimate the viability of cash flows generated from the proposed project. According to Abdur–Rehman and Al–Sulaiman [102], the project is considered profitable when the B–C value is more significant than one. The comparative analysis shows that the orientation angles of −35° (tilt angle) and 180° (azimuth angle) had the highest value of B–C, followed by orientation angles of −31° (tilt angle) and 180° (azimuth angle). The value of B–C for all proposed systems
indicated the feasibility of the projects. The orientation angles of ~40° (tilt angle) and 0° (azimuth angle) had the lowest B–C value, as shown in Figure 10.

Additionally, ALCS is another term utilized to get an idea about the benefits of the project. This term is determined based on the NPV, lifetime of the project, and discount rate. The results of ALCS for all proposed projects are also illustrated in Figure 10. It was found that the ALCS values are within the range of 226,676–463,337 USD/year.

Furthermore, it was found that the value of energy production cost (EPC) is ranged from 0.0389 USD/kWh (tilt ~40°, azimuth 0° for AS-M60-310W) and 0.0187 USD/kWh (tilt ~35°, azimuth 180° for HS166-380-120M). Based on the result of EPC, the energy production cost of the proposed systems is competitive with the electricity company (Kibris Türk Elektrik Kurumu) tariff. The findings demonstrated the proposed project is economically acceptable due to the obtained favorable economic results.

4. Discussion

The analysis showed that the selected location has a high solar energy potential for the distribution of PV power systems. Based on the comparative study between ground-based measurement data and satellite-based solar data (Figures S1 and S2 as supplementary material), the results indicated that satellite-based measurement could be utilized in solar project studies where ground-based measurement data are not applicable. It should be noted that NEU Hospital is located in an area where ground measurements for solar radiance were not conducted. The selected location is located in Lefkoşa, where the ground-based measurement data were collected from the meteorological department. Based on the findings, the analysis demonstrated that the global solar radiation of Lefkoşa can be considered constant for a broad region based on the comparison between the ground-based measurement data and satellite-based solar data (Figures S1 and S2 supplementary material).

Due to rising electricity energy demand and reductions in the dependency on domestic power generators in Northern Cyprus, the feasibility of solar energy projects is limited (Table 1). Therefore, in the present paper, the feasibility of solar energy potential at NEU Hospital was investigated. This was achieved by finding the best orientation angles to maximize the performance of the grid-connected PV system and minimize the electricity production cost using RETScreen software. The results showed that the annual electrical energy from the proposed system at orientation angles of ~35° (tilt angle) and 180° (azimuth angle) was within the range of 2980–2998 MWh. This amount of energy output would contribute significantly to meeting NEU Hospital’s electrical energy demand. Moreover, the proposed PV system was financially and environmentally efficient, with a payback period of three years and four months and a considerable reduction in CO₂ emissions.

5. Conclusions and Future Work

The present study examined the potential and viability of a grid-connected PV system at Near East University Hospital. The results indicated that the solar resource of the selected location is categorized as excellent (class 5), that is, the global solar radiation is within the range of 1843.8–2035.9 kWh/m². Furthermore, it was determined that the annual electricity generated from the proposed PV system was varied between 2,633,554 kW and 2,853,019 kW. Additionally, it was found that the electricity production cost was within the range of 0.0187–0.0389 USD/kWh. Therefore, the energy production cost of the proposed systems is competitive with the electricity company tariff. Moreover, the results indicated that the maximum performance of the proposed system was achieved for orientation angles of 180° (azimuth angle) and ~35° (tilt angle). The conclusion in this paper has highlighted that the proposed system has many benefits, including reducing emissions, decreasing fuel use, and saving annually after a short payback period. In addition, this study demonstrates that the problem of the electricity crisis, which happens nowadays, can be solved by paying more attention to generating electricity from solar energy.
Finally, land availability was not taken into account in this study. Thus, measuring land availability for grid-connected PV plants will be our future research. A multi-criteria decision-making algorithm should be developed to become significant for selecting the best solar panel, which will help increase the system’s revenue. Besides, the effect of the financial parameters, including the discount rate and inflation rate, on the investment should be considered for future work. Moreover, the interaction between the distribution grid and the PV system should be investigated to understand the influence of grid-connected PV systems on the distribution grid.

**Supplementary Materials:** The following are available online at www.mdpi.com/article/10.3390/en14227627/s1, Figure S1: Hourly solar radiation of Lefkoşa during the period of 2014-2016, Figure S2: Comparison between GSR values of Lefkoşa and NEU hospital for the period of 2014-2016, Figure S3: Hourly and monthly average ambient temperature during the period of 2014-2018, Figure S4: Relative error of annual GSR, SD, and AT, Figure S5: Azimuth and tilt angle impact on (a) annual average daily solar radiations, (b) annual average solar radiations, (c) output power of PV system, (d) capacity factor (CF), and (e) annual GHG emission reduction.

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**References**

1. Lazarou, S.; Christodoulou, C.; Vita, V. Global Change Assessment Model (GCAM) considerations of the primary sources energy mix for an energetic scenario that could meet Paris agreement. In Proceedings of the 2019 54th International Universities Power Engineering Conference (UPEC), Bucharest, Romania, 3–6 September 2019; IEEE: Bucharest, Romania, 3–6 September 2019; pp. 1-5.

2. Schnitzer, H.; Brunner, C.; Gwehenberger, G. Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes. *J. Clean. Prod.* 2007, 15, 1271–1286.

3. Shaftsavari, A.; Akbari, M. Potential of solar energy in developing countries for reducing energy-related emissions. *Renew. Sustain. Energy Rev.* 2018, 90, 275–291.

4. Nassar, Y.F.; Alsadi, S.Y. Assessment of solar energy potential in Gaza Strip-Palestine. *Sustain. Energy Technol. Assess.* 2019, 31, 318–328.

5. Martín-Pomares, L.; Martínez, D.; Polo, J.; Perez-Astudillo, D.; Bachour, D.; Sanfilippo, A. Analysis of the long-term solar potential for electricity generation in Qatar. *Renew. Sustain. Energy Rev.* 2017, 73, 1231–1246.

6. Almarshoud, A. Performance of solar resources in Saudi Arabia. *Renew. Sust. Energy Rev.* 2016, 66, 694–701.

7. Lau, K.K.-L.; Lindberg, F.; Johansson, E.; Rasmussen, M.I.; Thorsson, S. Investigating solar energy potential in tropical urban environment: A case study of Dar es Salaam, Tanzania. *Sust. Cities Society*. 2017, 30, 118–127.

8. Mardonova, M.; Choi, Y. Assessment of photovoltaic potential of mining sites in Uzbekistan. *Sustainability* 2019, 11, 2988.

9. Al Ghaithi, H.M.; Fotis, G.P.; Vita, V. Techno-economic assessment of hybrid energy off-grid system – A case study for Masirah island in Oman. *Int. J. Power Energy Res.* 2017, 1, 103–116.

10. Al-Najideen, M.I.; Alrwashdeh, S.S. Design of a solar photovoltaic system to cover the electricity demand for the faculty of Engineering-Mu’tah University in Jordan. *Resource-Efficient Technol.* 2017, 3, 440–445.

11. Manoj Kumar, N.; Sudhakar, K.; Samykeno, M. Techno-economic analysis of 1 MWp grid-connected solar PV plant in Malaysia. *Int. J. Ambient. Energy* 2019, 40, 434–443.

12. Alghamdi, A.H.S. Technical and Economic Analysis of Solar Energy Application for a Hospital Building in Dammam, Saudi Arabia. Ph.D. Dissertation, Auckland University of Technology, Auckland, New Zealand, 2019.

13. Imam, A.A.; Al-Turki, Y.A.; Kumar, S. Techno-economic feasibility assessment of grid-connected PV systems for residential buildings in Saudi Arabia—A Case Study. *Sustainability* 2019, 12, 262.
14. Vaziri, S.M.; Rezaee, B.; Monirian, M.A. Utilizing renewable energy sources efficiently in hospitals using demand dispatch. Renew. Energy 2020, 151, 551–562.
15. Hijji, M.; Bauer, P.; Felgner, F.; Frey, G. Energy Management systems for hospitals in Gaza-strip. In 2015 IEEE Global Humanitarian Technology Conference (GHTC); IEEE: Manhattan, NY, USA, 2015; pp. 18–25.
16. Chilate, V.A.; Jayakumar, P.K.; Srinadh, K.V.S. Case Study on Solar-Powered Hospital Elevator to Push Green Energy for the Use of Alternative Energy Sources-Sunlight. Int. J. Innov. Res. Eng. Manag. 2016, 3, 494–502.
17. Luna Carlosama, C.F.; Moreno Chuquen, R.; Mulcue Nieto, L.F.; Jiménez García, F.N. Potential of Photovoltaic Generation in the Putumayo Department of Colombia. Appl. Sci. 2021, 11, 5528.
18. Egelioglu, F.; Mohamad, A.; Guven, H. Economic variables and electricity consumption in Northern Cyprus. Energy. 2001, 26, 355–362.
19. Al-Ghussain, L.; Taylan, O.; Samu, R.; Fahrioglu, M. Techno-economic analysis of photovoltaic-hydrogen fuel cell/pumped hydro storage system for micro grid applications: Case study in Cyprus. In 2018 International Conference on Photovoltaic Science and Technologies (PVCon); IEEE: Manhattan, NY, USA, 2018; pp. 1–6.
20. Greatest Renewable Energy Project of North Cyprus at UKÜ. Available online: https://mfa.gov.ct.tr/greatest-renewable-energy-project-north-cyprus-uku/ (accessed on 5 July 2021).
21. Kassem, Y.; Çamur, H.; Aateg, R.A.F. Exploring solar and wind energy as a power generation source for solving the electricity crisis in Libya. Energies 2020, 13, 3708.
22. Práválie, R.; Patriche, C.; Bandoc, G. Spatial assessment of solar energy potential at global scale. A geographical approach. J. Clean. Prod. 2019, 209, 692–721.
23. Ilkan, M.; Erdil, E.; Egelioglu, F. Renewable energy resources as an alternative to modify the load curve in Northern Cyprus. Energy 2005, 30, 555–572.
24. Pathirana, M.R.; Muhtaroglu, A. Multifaceted feasibility analysis of PV solar application in Northern Cyprus. Int. J. Renew. Energy Res. 2013, 3, 941–950.
25. Radmehr, M.; Willis, K.; Kenechi, U.E. A framework for evaluating WTP for BIPV in residential housing design in developing countries: A case study of North Cyprus. Energy Policy 2014, 70, 207–216.
26. Agboola, O.P.; Egehioglu, F. Water scarcity and solar desalination systems in the Eastern Mediterranean region: A case of Northern Cyprus. Int. J. Environ. Eng. 2014, 6, 436.
27. Abbasoglu, S. Techno-economic and environmental analysis of PV power plants in Northern Cyprus. Energy Educ. Sci. Technol. Part A 2011, 28, 357–368.
28. Yenen, M.; Ercan, F.; Fahrioglu, M. Solar thermal system analysis of Northern Cyprus. In Proceedings of the ECS 12—7th International Symposium on Electrical and Computer Systems, Lefke, Northern Cyprus, 29–30 November 2012.
29. Okoye, C.O.; Atikol, U. A parametric study on the feasibility of solar chimney power plants in North Cyprus conditions. Energy Convers. Manag. 2014, 80, 178–187.
30. Maltini, F.; Minder, R. The Serhatköy photovoltaic power plant and the future of renewable energy on the Turkish Republic of Northern Cyprus. Eco-Friendly Innov. Electr. Transmiss. Distrib. Netw. 2015, 377–402. https://doi.org/10.1006/B978-1-78242-010-1.00018-5
31. Ozerdem, O.C.; Tackie, S.; Biricik, S. Performance evaluation of Serhatköy (1.2 MW) PV power plant. In Proceedings of the 9th International Conference on Electrical and Electronics Engineering (ELECO 2015), Bursa, Turkey, 26–28 November 2015.
32. Kamali, S. Feasibility analysis of standalone photovoltaic electrification system in a residential building in Cyprus. Renew. Sustain. Energy Rev. 2016, 65, 1279–1284.
33. Dagbasi, M.; Bamisile, O.; Adii, C. The techno-economic comparison of solar power generation methods for Turkish Republic of North Cyprus. In 2016 HONET-ICT; IEEE: Nicosia, Cyprus, 2016; pp. 17–23.
34. Cabacaba, N.; Abbasoglu, S. Evaluation of Wind–Solar Hybrid System for a Household in Northern Cyprus. In Towards 100% Renewable Energy; Springer: Cham, Switzerland, 2017; pp. 313–321.
35. Kassem, Y.; Gökçekuş, H.; Çamur, H. Economic assessment of renewable power generation based on wind speed and solar radiation in urban regions. Glob. J. Environ. Sci. Manag. 2018, 4, 465–482.
36. Kassem, Y.; Gökçekuş, H. GHG Emissions and Energy Performance of 1MW Grid-Connected Solar PV Plant at Lefke in Northern Cyprus: Case Study. Disaster Sci. Eng. 2018, 4, 90–98.
37. Ouria, M.; Sevinc, H. Evaluation of the potential of solar energy utilization in Famagusta, Cyprus. Sust. Cities Soc. 2018, 37, 189–202.
38. Al-Ghussain, L.; Abujubbeh, M.; Fahrioglu, M. Assessment of PV investments in Northern Cyprus. In Proceedings of the 16th International Conference on Clean Energy, Famagusta, North Cyprus, 9–11 May 2018; pp. 9–11.
39. Hastunç, M.; Tekbıyık-Ersoy, N. Optimizing Residential Renewable Energy Utilization in North Cyprus: Case Study of Solar Energy. In Proceedings of the 16th International Conference on Clean Energy (ICCE-2018), Famagusta, North Cyprus, 9–11 May 2018.
40. Kassem, Y.; Al Zoubi, R.; Gökçekuş, H. The possibility of generating electricity using small-scale wind turbines and solar photovoltaic systems for households in Northern Cyprus: A comparative study. Environments 2019, 6, 47.
41. Kassem, Y.; Gokcekus, H.; Alsayas, S.M. Freestanding PV solar system—Example of Lefke town in Northern Cyprus. Inter. J. of Appl. Eng. Res. 2019, 14, 2522–2526.
42. Ogbeba, J.; Hoskara, E. The Evaluation of Single-Family Detached Housing Units in terms of Integrated Photovoltaic Shading Devices: The Case of Northern Cyprus. *Sustainability* 2019, 11, 593.

43. Kassem, Y.; Gökçekuş, H.; Güvensoy, A. Solar Potential assessment in Near East University, Northern Cyprus. *International J. Eng. Res. Technol.* 2019, 12, 3061–3069.

44. Gökçekuş, H.; Kassem, Y.; Abdì, S. Simulation and performance analysis of 110 KWP grid-connected photovoltaic (PV) systems for residential building in Northern Cyprus. *Int. J. Innov. Technol. Explor. Eng.* 2019, 8, 3082–3091.

45. Oner, H. Economic feasibility assessment of solar powered seawater desalination plants: Unconventional fresh water supply for Gazelyurt, Northern Cyprus. Master’s Thesis, Middle East Technical University, Ankara, Turkey, 2019.

46. Al-Ghussain, L.; Taylan, O. Sizing methodology of a PV/wind hybrid system: Case study in cyprus. *Environ. Prog. Sustain. Energy* 2019, 38, e13052.

47. Kassem, Y.; Goccekus, H.; Filitoglu, Ü.B. Performance Characteristics of Building Integrated and Freestanding Photovoltaic System with Various PV Technologies and Angles: A Case Study in NEU Grand Library, North Nicosia. *J. Eng. Appl. Sci.* 2020, 15, 1027–1042.

48. Kassem, Y.; Çamur, H.; Alhuotti, S.M.A. Solar energy technology for Northern Cyprus: Assessment, statistical analysis, and feasibility study. *Energies* 2020, 13, 940.

49. Al-Turjman, F.; Qadir, Z.; Abujabbeh, M.; Batunlu, C. Feasibility analysis of solar photovoltaic-wind hybrid energy system for household applications. *Comput. Electr. Eng.* 2020, 86, 106743.

50. The Power Struggle Over the North’s Electricity. 2016. Available online: https://cyprus-mail.com/2016/11/27/power-struggle-norths-electricity/ (accessed on 5 May 2021).

51. Al Garni, H.Z.; Awasthi, A.; Wright, D. Optimal orientation angles for maximizing energy yield for solar PV in Saudi Arabia. *Renew. Energy* 2019, 133, 538–550.

52. Yan, R.; Saha, T.K.; Meredith, P.; Goodwin, S. Analysis of yearel performance of differently tilted photovoltaic systems in Brisbane, Australia. *Energy Convers. Manag.* 2013, 74, 102–108.

53. Jafarkazemi, F.; Saadabadi, S.A. Optimum tilt angle and orientation of solar surfaces in Abu Dhabi, UAE. *Renew. Energy* 2013, 56, 44–49.

54. Abdallah, R.; Juaidi, A.; Abdel-Fattah, S.; Manzano-Agugliaro, F. Estimating the optimum tilt angles for south-facing surfaces in Palestine. *Energies* 2020, 13, 623.

55. Cheng, C.L.; Jimenez, C.S.S.; Lee, M.C. Research of BIPV optimal tilted angle, use of latitude concept for south orientated plans. *Renew. Energy* 2009, 34, 1644–1650.

56. Kaddoura, T.O.; Ramli, M.A.; Al-Turki, Y.A. On the estimation of the optimum tilt angle of PV panel in Saudi Arabia. *Renew. Sustain. Energy Rev.* 2016, 65, 626–634.

57. Desai, A.; Mukhopadhyay, I.; Ray, A. Effect of Azimuth and Tilt Angle on Ideally Designed Rooftop Solar PV Plant for Energy Generation. In Proceedings of the 2021 IEEE 48th Photovoltaic Specialists Conference (PVSC), Virtual, 20–25 June 2021; IEEE: Manhattan, NY, USA, 2021; pp. 0522–0527.

58. Ahmed, W.; Sheikhs, J.A.; Ahmad, S.; Farjana, S.H.; Mahmud, M.P. Impact of PV system orientation angle accuracy on greenhouse-gas emissions mitigation. *Case Stud. Therm. Eng.* 2021, 23, 100815.

59. Hartner, M.; Ortner, A.; Hiesl, A.; Haas, R. East to west–The optimal tilt angle and orientation of photovoltaic panels from an electricity system perspective. *Appl. Energy* 2015, 160, 94–107.

60. Baramonte, J.; Parada, J.; Díaz, J.; Baritto, M. Effect of the collector tilt angle on thermal efficiency and stratification of passive water in glass evacuated tube solar water heater. *Appl. Energy* 2015, 135, 648–659.

61. Manouchehri, R.; Banister, C.J.; Collins, M.R. Impact of small tilt angles on the performance of falling film drain water heat recovery systems. *Energy Build.* 2015, 102, 181–186.

62. Skerlić, J.; Radulović, J.; Nikolić, D.; Bojić, M. Maximizing performances of variable tilt flat-plate solar collectors for Belgrade (Serbia). *J. Renew. Sustain. Energy* 2013, 5, 041820.

63. Masrur, H.; Konneh, K.V.; Ahmadi, M.; Khan, K.R.; Othman, M.L.; Senjyu, T. Assessing the techno-economic impact of derating factors on optimally tilted grid-tied photovoltaic systems. *Energies* 2021, 14, 1044.

64. Li, C.; Zhou, D.; Yu, W.; Wang, H.; Zhu, D.; Sun, M.; Li, G. Performance of off-grid residential solar photovoltaic power systems using five solar tracking modes in Kunming, China. *Int. J. Hydrog. Energy* 2017, 42, 6502–6510.

65. Maammar, H.; Hamidat, A.; Loukarfi, L.; Missoum, M.; Abdeladim, K.; Nacer, T. Performance investigation of grid-connected PV systems for family farms: Case study of North-West of Algeria. *Renew. Sustain. Energy Rev.* 2017, 78, 1208–1220.

66. Akinsipe, O.C.; Moya, D.; Kaparaju, P. Design and economic analysis of off-grid solar PV system in Jos-Nigeria. *J. Clean. Prod.* 2021, 287, 120505.

67. Bhatia, S.C. *Advanced Renewable Energy Systems*; Woodhead: New Delhi, India 2014.

68. Belkili, K.; Othman, A.B.; Besbes, M. Assessment of global solar radiation to examine the best locations to install a PV system in Tunisia. *Appl. Phys. A* 2018, 124, 1–8.

69. Nacer, T.; Hamidat, A.; Nadjem, O.; Bey, M. Feasibility study of grid connected photovoltaic system in family farms for electricity generation in rural areas. *Renew. Energy* 2016, 96, 305–318.

70. Mondal, M.A.H.; Islam, A.S. Potential and viability of grid-connected solar PV system in Bangladesh. *Renew. Energy* 2011, 36, 1869–1874.
71. Tarigan, E.; Kartikasari, F.D. Techno-economic simulation of a grid-connected PV system design as specifically applied to residential in Surabaya, Indonesia. Energy Procedia 2015, 65, 90–99.
72. Ramli, M.A.; Hiendro, A.; Sedraoui, K.; Twaha, S. Optimal sizing of grid-connected photovoltaic energy system in Saudi Arabia. Renew. Energy 2015, 75, 489–495.
73. Said, M.; El-Shimy, M.; Abdelraheem, M.A. Photovoltaics energy: Improved modeling and analysis of the levelized cost of energy (LCOE) and grid parity–Egypt case study. Sustain. Energy Technol. Assess. 2015, 9, 37–48.
74. Balo, F.; Sağbanuşa, L. The selection of the best solar panel for the photovoltaic system design by using AHP. Energy Procedia 2016, 100, 50–53.
75. Rehman, S.; Ahmed, M.A.; Mohamed, M.H.; Al-Sulaimon, F.A. Feasibility study of the grid connected 10 MW installed capacity PV power plants in Saudi Arabia. Renew. Sustain. Energy Rev. 2017, 80, 319–329.
76. El-Bayeh, C.Z.; Alzaareer, K.; Brahim, B.; Zellagui, M.; Eicker, U. An original multi-criteria decision-making algorithm for solar panels selection in buildings. Energy 2021, 217, 119396.
77. Sasikumar, G.; Ayyappan, S. Multi-criteria Decision Making for Solar Panel Selection Using Fuzzy Analytical Hierarchy Process and Technique for Order Preference by Similarity to ideal Solution (TOPSIS): An Empirical Study. J. Inst. Eng. Ser. C 2019, 100, 707–715.
78. Mohammad, K.; Naderi, M.; Saghaififar, M. Economic feasibility of developing grid-connected photovoltaic plants in the southern coast of Iran. Energy 2018, 156, 17–31.
79. Markovic, D.; Cvjetkovic, D.; Masic, B. Survey of software tools for energy efficiency in a community. Renew. Sustain. Energy Rev. 2011, 15, 4897–4903.
80. Connolly, D.; Lund, H.; Mathiesen, B.V.; Leahy, M. A review of computer tools for analysing the integration of renewable energy into various energy systems. Appl. Energy 2010, 87, 1059–1082.
81. Lee, K.H.; Lee, D.W.; Baek, N.C.; Kwon, H.M.; Lee, C.J. Preliminary determination of optimal size for renewable energy resources in buildings using RETScreen. Energy 2012, 47, 83–96.
82. Sreenath, S.; Sudhakar, K.; Yusop, A.F. 7E analysis of a conceptual utility-scale land-based solar photovoltaic power plant. Energy 2021, 219, 119630.
83. Owolabi, A.B.; Nsafon, B.E.K.; Roh, J.W.; Suh, D.; Huh, J.S. Validating the techno-economic and environmental sustainability of solar PV technology in Nigeria using RETScreen Experts to assess its viability. Sustain. Energy Technol. Assess. 2019, 36, 100542.
84. Kassem, Y.; Gökkęş, H.; Lagili, H.S.A. A techno-economic viability analysis of the two-axis tracking grid-connected photovoltaic power system for 25 selected coastal mediterranean cities. Eng. Technol. Appl. Sci. Res. 2021, 11, 7508–7514.
85. Sreenath, S.; Sudhakar, K.; Yusop, A.F. Energy-energy-economic-environmental-energy-exergy-environeco (7E) analysis of solar photovoltaic power plant: A case study of 7 airport sites in India. Sustain. Energy Technol. Assess. 2021, 47, 101352.
86. Farangi, M.; Soleimani, E.A.; Zahedifar, M.; Amiri, O.; Poursafor, J. The environmental and economic analysis of grid-connected photovoltaic power systems with silicon solar panels, in accord with the new energy policy in Iran. Energy 2020, 202, 117771.
87. Cristofari, C.; Carutasiiu, M.B.; Caneletti, J.L.; Norvaišienė, R.; Motte, F.; Nottin, G. Building integration of solar thermal systems-example of a refurbishment of a church rectory. Renew. Energy 2019, 137, 67–81.
88. Li, C. Evaluation of the viability potential of four grid-connected solar photovoltaic power stations in Jiangsu Province, China. Clean Technol. Environ. Policy 2021, 23, 1–15.
89. Ahmed, W.; Sheikh, J.A.; Farjana, S.H.; Mahmud, M.A. Defects Impact on PV System GHG Mitigation Potential and Climate Change. Sustainability 2021, 13, 7793.
90. Babar, B.; Graversen, R.; Bostrom, T. Solar radiation estimation at high latitudes: Assessment of the CMSAF databases, ASR and ERAS. Solar Energy 2019, 182, 397–411.
91. Ineichen, P. Long term satellite global, beam and diffuse irradiance validation. Energy Procedia 2014, 48, 1586–1596.
92. IRENA. Renewable Power Generation Costs in 2019. 2019. Available online: https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019 (9 September 2021).
93. Al Awadi, N.N.; Moomuni, Y.; Khodary, A. Sizing of a Car Parking Photovoltaic System: An Economic Analysis. In Proceedings of the 2019 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates, 26 March–10 April 2019; IEEE: Manhattan, NY, USA, 2019; pp. 1–4.
94. Mehmood, A.; Shaikh, F.A.; Waqas, A. Modeling of the solar photovoltaic systems to fulfill the energy demand of the domestic sector of Pakistan using RETSCREEN software. In Proceedings of the 2014 International Conference and Utility Exhibition on Green Energy for Sustainable Development (ICUE); IEEE: Manhattan, NY, USA, 2014; pp. 1–7.
95. Khandelwal, A.; Shrivastava, V. Viability of grid-connected solar PV system for a village of rajasthan. In Proceedings of the 2017 International Conference on Information, Communication, Instrumentation and Control (ICICIC), Indore, India, 17–19 August 2017; IEEE: Manhattan, NY, USA, 2017; pp. 1–6.
96. Osman, Y.Y. An investigation on the performances– of domestic hot water systems in Turkish Republic of Northern Cyprus. Master’s Thesis, Near East University, Mersin, Turkey, 2016.
97. Abdallah, R.; Natbhe, E.; Juaidi, A.; Samara, S.; Manzano-Agugliaro, F. A Multi-Level World Comprehensive Neural Network Model for Maximum Annual Solar Irradiation on a Flat Surface. Energies 2020, 13, 6422.
98. Bailek, N.; Bouchouicha, K.; Aoun, N.; Mohamed, E.S.; Jamil, B.; Mostaei, A. Optimized fixed tilt for incident solar energy maximization on flat surfaces located in the Algerian Big South. Sustain. Energy Technol. Assess. 2018, 28, 96–102.
99. Çamur, H.; Kassem, Y.; Alessi, E. A Techno-Economic Comparative Study of a Grid-Connected Residential Rooftop PV Panel: The Case Study of Nahr El-Bared, Lebanon. *Eng. Technol. Appl. Sci. Res.* 2021, 11, 6956-6964.

100. Kazem, H.A.; Khatib, T. Techno-economical assessment of grid connected photovoltaic power systems productivity in Sohar, Oman. *Sustain. Energy Technol. Assess.* 2013, 3, 61-65.

101. Obeng, M.; Gyamfi, S.; Derkyi, N.S.; Kabo-bah, A.T.; Peprah, F. Technical and economic feasibility of a 50 MW grid-connected solar PV at UENR Nsoatre Campus. *J. Clean. Prod.* 2020, 247, 119159.

102. Abd-ur-Rehman, H.M.; Al-Sulaiman, F.A. Optimum selection of solar water heating (SWH) systems based on their comparative techno-economic feasibility study for the domestic sector of Saudi Arabia. *Renew. Sustain. Energy Rev.* 2016, 62, 336-349.