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Solar Potential assessment in Near East University, Northern Cyprus

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Abstract

The rises in the world population and energy demand have encouraged the scientific researchers to investigate the renewable energies' potential, practically solar energy in the world. The solar rooftop photovoltaic system is considered as a possible source for electricity generation for small households. Therefore, the aim of this study is to investigate the feasibility of on-grid photovoltaic (PV) system for Civil and Environmental Engineering faculty in Near East University. This study is focused on the use of PVGIS as simulation tool to analyze the performance of 110kW PV system and compared the performance of different PV technologies based on performance ratio, capacity factor and energy cost. Moreover, the effect of inclination angles on the performance of PV systems has been discussed. The results showed that the annual performance ratio was varied from 74.47% to 77.70% and their energy yields were ranged from 1653.64 kWh/kWp (CIS module) to 1725.45 kWh/kWp (CdTe module). Between these three types of PV systems considered here, CdTe PV system has the higher performance ratio with more than 75%. Consequently, this system can be help to reduce the green gas emissions and supply electricity to the Near East University.

Keywords: Grid-connected; Near East University; PV system; PV technologies; simulation tool

1. INTRODUCTION

Solar energy is an emission free energy source and it is considered as significant renewable source to reduce the fossil fuel consumption. The key benefit of solar energy is to avoid carbon dioxide emissions [1]. Solar system is based on converting sunlight into electricity directly using photovoltaic (PV) panels. Solar PV system is used effectively for meeting the electricity demand in many countries particularly having constant fluctuations in supply of grid electricity [2]. Solar PV energy generation is utilized by using solar modules consisting of a number of solar cells containing a photovoltaic material. The grid-connected PV systems and stand-alone PV systems are the most widely used configurations among all types of PV systems[3].

Various studies have been investigated the PV system performance. Dondariya et al., [4] examined the feasibility of on-grid rooftop PV system for small household building in India using four-simulation software. Moreover, Charfi et al., [5] studied experimentally the performance of PV system with different inclination angles. Shukla et al. [6] investigated the feasibility of on-grid rooftop PV system for residential hostel building at MANIT using Solargis PV Planner software. Lastly, Kumar et al. [7] analyzed the feasibility of developing a solar PV plant at two different campuses of University Malaysia Pahang (UMP) using PVGIS and PV Watts simulation tools.

The global energy demand is rapidly increased because of the growth in the population, along with consumption of fossil fuel [8]. Due to that reasons, the significance of using renewable energy as alternative source; particularly solar energy for electricity generation in North Cyprus to reduce greenhouse gas emissions (GHG) is increased in recent years. Numerous studies have been conducted to investigate the solar potential in North Cyprus. Kassem et al. [9] assessed the economic feasibility of 12MW on-grid wind farms and PV plants for producing electricity at Kyrenia and Nicosia in North Cyprus. It has been concluded that PV plants are the most economical option compared to wind farms for generating electricity in the selected regions. Kassem and Gökçekuş [10] conducted a techno-economic evaluation of a proposed 1MW on-grid PV power plant in the town of Lefke (Lefka). The results obtained from the analysis showed that, a PV plant could be used as a viable alternative for reducing the GHG emissions in North Cyprus and generating electricity from renewable energy sources.

In this regard, the current paper aims to describe the solar potential at Near East University in North Cyprus. In order to carry out the study, PVGIS simulation software is used to evaluate the performance of 110kW on-grid rooftop PV system for given location. In addition, three different PV technologies (crystalline silicon PV modules, Copper Indium Selenide (CIS) PV modules and Cadmium telluride (CdTe) PV modules) are compared in order to select the best photovoltaic technology for area based on the simulation results. Moreover, the effect of inclination angles on the performance of PV systems has been discussed.

2. MATERIAL AND METHOD

2.1 Location details

Cyprus is the third biggest island in the Mediterranean Sea, and the climate of Cyprus is a typical Mediterranean climate. Climate conditions on the island vary by geographical factors. Being a small Mediterranean Island, currently there is not any electrical interconnection with neighbouring countries. Therefore, the energy demands of the northern part of Cyprus need to be satisfied by a local generation of power. Education is considered as the major derivers of economic development to become more advanced by improving production processes, standards of living, efficiency levels and economic growth [11, 12]. Education, one of the most important ingredients of human capital is considered as an important determinant of sustainable economic growth [13].

According to North Cyprus State Planning Organization, there are 16 universities established in North Cyprus. In addition, Eastern Mediterranean University (1979-1980), Girne American University (1985-1986), Near East University (1988-1989) and European University of Lefke (1990-1991) are the oldest of these universities in North Cyprus. The total student numbers in these universities are shown in Figure 1.

Geographically, Near East University is located in Nicosia, which is the biggest among other universities in Nicosia, North Cyprus. Figure 2 shows the location of the studied town considered in this study. The description of the explored area in terms of longitude, latitude, and altitude is tabulated in Table 1.

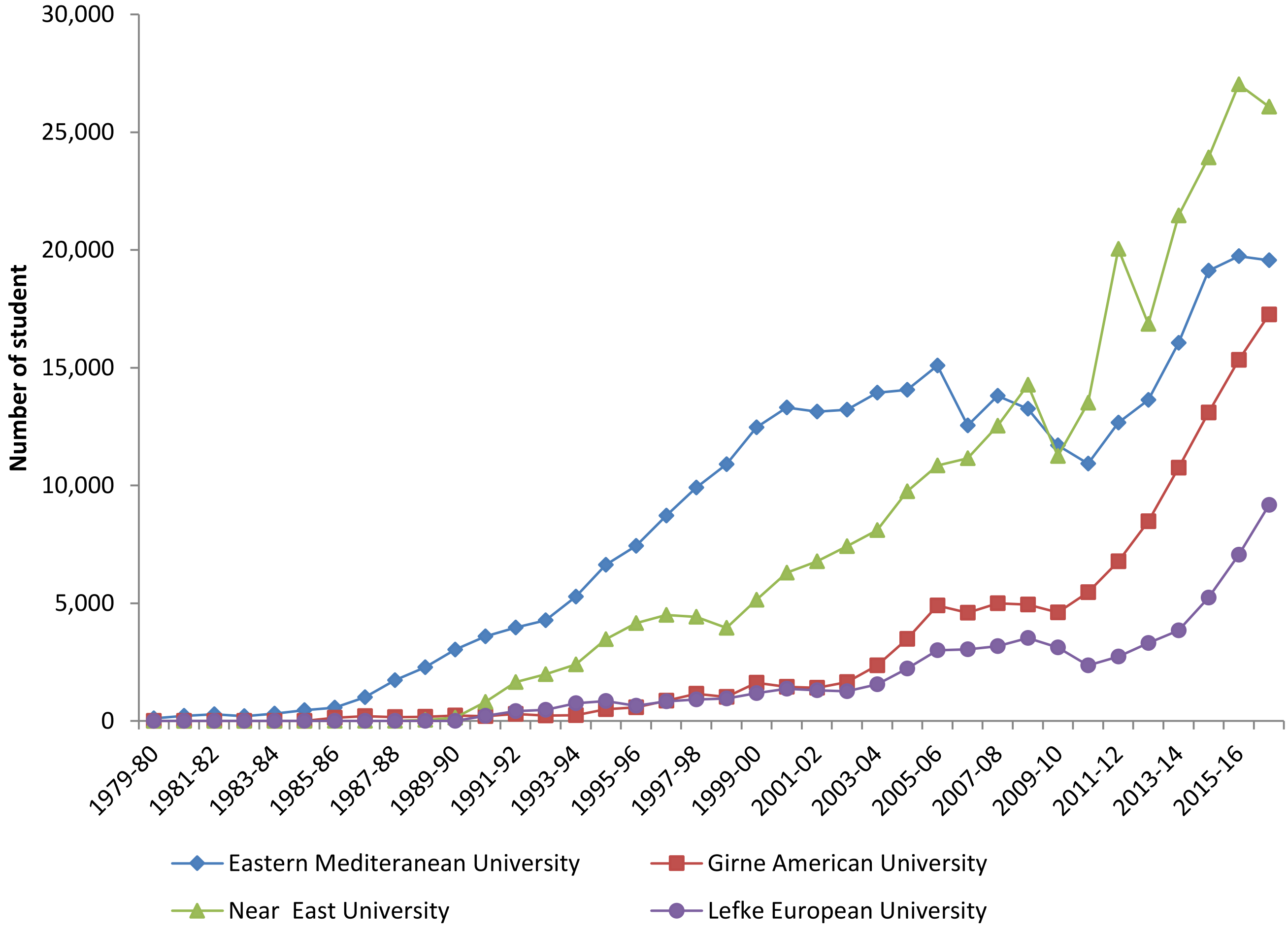

Figure 1. Number of students in the oldest universities in North Cyprus

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Figure 2. Location of the campus area adopted for the study

Table 1. Information of the studied towns

Location	Longitude (°E)	Latitude (°N)	Total number of student
Near East University	35.228	33.322	25000 students

2.2 System description

The description of the 110kW rooftop system adopted for this study is illustrated in Table 2.

The system is a fixed stand type and can be able to power for the university sufficiently. The components of the on-line solar PV plants are shown in Figure 3.

Table 2. Description of 110kW rooftop system

Installed power	110kW
Type of modules	Variable
Averaged frame PV model area	2 m^2
Mounting system	Fixed mounting, free standing
Optimum Azimuth/slope	Variable
Availability	95%
DC/AC losses	5.0% / 2.0%
Area required	800m^2

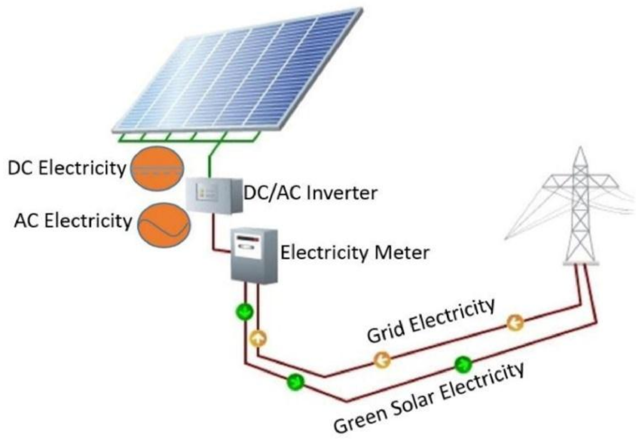

Figure 3. Components of on-grid PV system [14]

2.3 Energy yield and performance ratio

Energy yield and performance ratio of the system are the most important parameters to estimate the performance of the PV system, which depends on solar radiation and energy production under the operating conditions. They are expressed as below;

$$Energy\ Yield = \frac{E_{PV,AC}}{P_{max,G,STC}} \quad (1)$$

$$Performance\ ratio = \frac{E_{AC}}{E_{DC} \times Irradiation} \quad (2)$$

where E_{AC} is energy output, E_{DC} is the nameplate D.C power obtained in standard test condition.

3. DISCUSSION AND RESULTS

3.1 Solar irradiation and averaged temperature

The data of irradiation and temperature obtained from PVGIS are illustrated in Figure 3 and tabulated in Table 3. The global horizontal irradiation and direct normal irradiation are varied from 76.94 to 247.58 kWh/m^2 and 106.00 to 259.58 kWh/m^2, respectively. While, the maximum solar irradiation is recorded in July, the minimum global horizontal irradiation and direct normal irradiation are obtained in December and January, respectively. In addition, it is noticed that the highest and lowest averaged monthly temperature is recorded in August (27.97℃) and January (13.79℃).

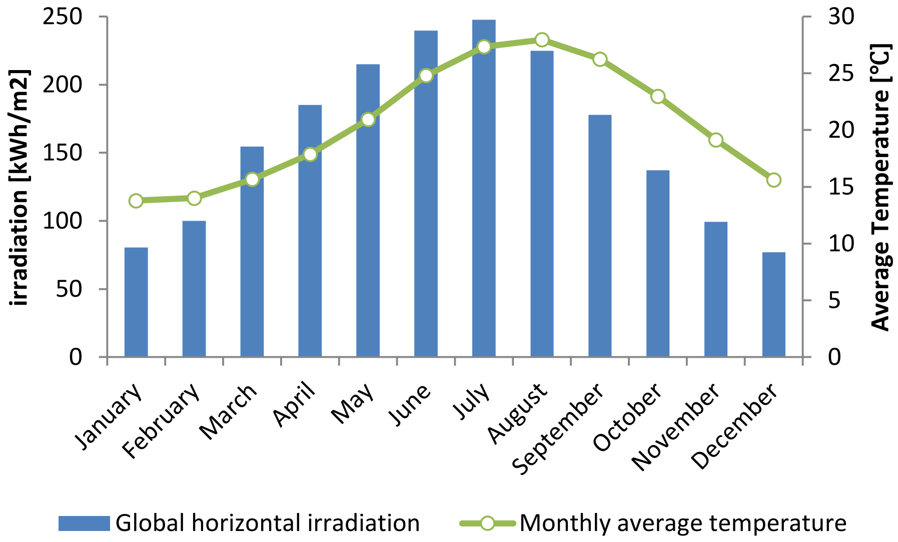

Figure 3. Monthly variation of solar irradiation and averaged temperature

Table 3. Solar irradiation in kWh/m^2 and air temperature in ℃

Month	Global horizontal irradiation	Direct Normal irradiation	Diffuse/global ratio	Monthly average temperature
January	80.608	106.000	0.442	13.792
February	100.033	115.167	0.416	14.008
March	154.583	163.000	0.365	15.667
April	185.167	176.000	0.354	17.875
May	215.083	204.333	0.322	20.942
June	239.667	244.167	0.266	24.800
July	247.583	259.583	0.247	27.342
August	224.750	242.000	0.258	27.967
September	177.917	202.333	0.283	26.250
October	137.250	167.667	0.326	22.983
November	99.425	141.500	0.350	19.142
December	76.942	110.583	0.422	15.617

3.2 Estimated energy production for different PV technologies

In general, the global solar irradiation does not depend on the PV technologies. Therefore, the global irradiation for optimum slope angle (31°) and azimuth angle (0°) at the Near East University is presented in Figure 4. It is found that the maximum and minimum solar radiation potential at the selected university is achieved in July (230 kWh/m^2) and January (122 kWh/m^2), respectively.

Furthermore, the variation of electricity production from the given system for the optimum slope and azimuth angles is illustrated in Figure 5. It is observed that the maximum electricity generated in July, which is 18600kWh (crystalline silicon and CIS PV modules) and 19600kWh (CdTe PV module). In addition, it is noticed that the monthly electricity production by CdTe PV modules is higher compared to crystalline silicon and CIS PV modules at the optimum slope angle (31°) and azimuth angle (0°).

The annual global irradiation and electricity production from the given system for different PV technologies is summarized in Table 4.

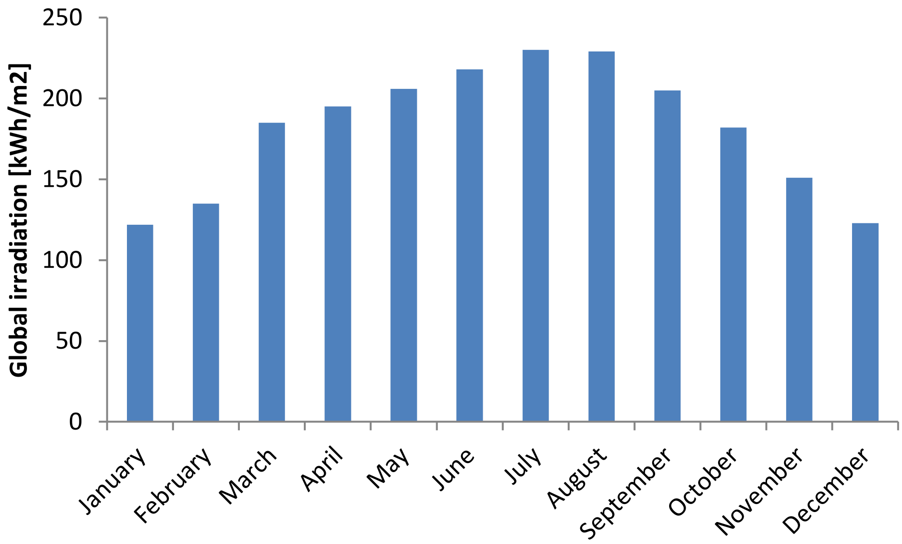

Figure 4. Monthly in-plane irradiation at Near East University

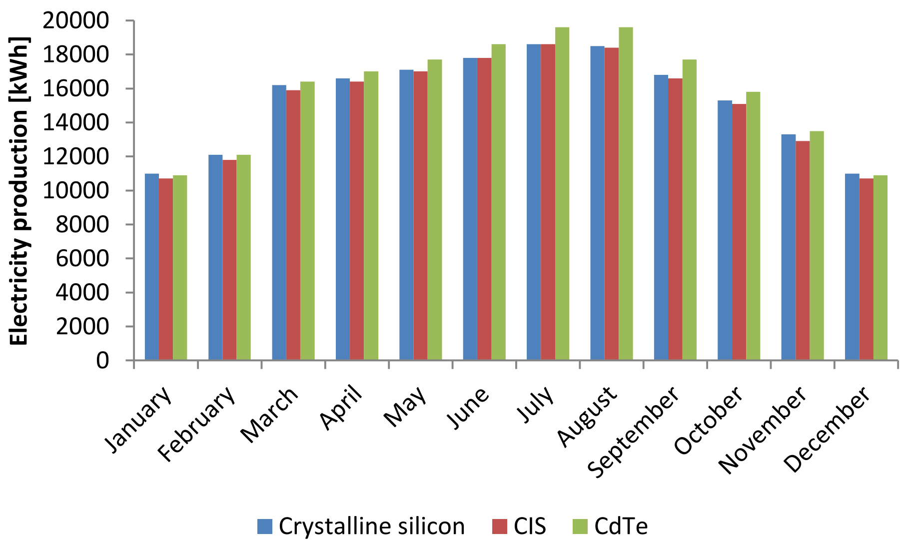

Figure 5. Monthly electricity production for different PV technologies

Table 4. Annual solar electricity generation

PV technologies	Crystalline silicon	CIS	CdTe
PV energy production [kWh]	184000	182000	1900000
in-plane irradiation [kWh/m^2]	2180	2180	2180
Changes in output due to			
Angle of incidence [%]	-2.6	-2.6	-2.6
Spectral effects [%]	0.4	0	0.7
Temperature and low irradiance [%]	-8.6	-9.5	-6.1
Total loss [%]	-23.2	24.2	20.8

3.2 Performance ratio and capacity factor

The monthly variation of energy production, performance ratio and capacity factor for three PV technologies are plotted as shown in Figure 6. Moreover, the annual energy production, energy yield, performance ratio, capacity factor and energy cost are tabulated in Table 5. It is observed that the energy yields are ranged from 1653.64 kWh/kWp (CIS module) to 1725.45 kWh/kWp (CdTe module). Additionally, the performance ratio is within the range of 74.47-77.70%. Moreover, CdTe PV technologies shows better performance in terms of annual energy production and capacity factor compared to other PV technologies. This may be due to lower temperature coefficient and capture losses of these technologies (Table 4).

3.3 Impact of tilt angle on fixed system

In this study, the effect of tilt angle on the electricity production and solar irradiation is investigated. Based on PVGIS simulation tools, the optimum tilt and azimuth angles for given system is 31° and 0°, respectively. In the current study, the tilt angle is varied from 20° to 43° in order to investigate the variation of energy production and solar irradiation for given system. Table 7 shows the variation of energy production with some selected tilt angles by PVGIS simulation tools. The results show that the annual energy production with optimum angles is 184300 kWh (Crystalline silicon module), 181900 kWh (CIS module) and 189800 kWh (CdTe module).

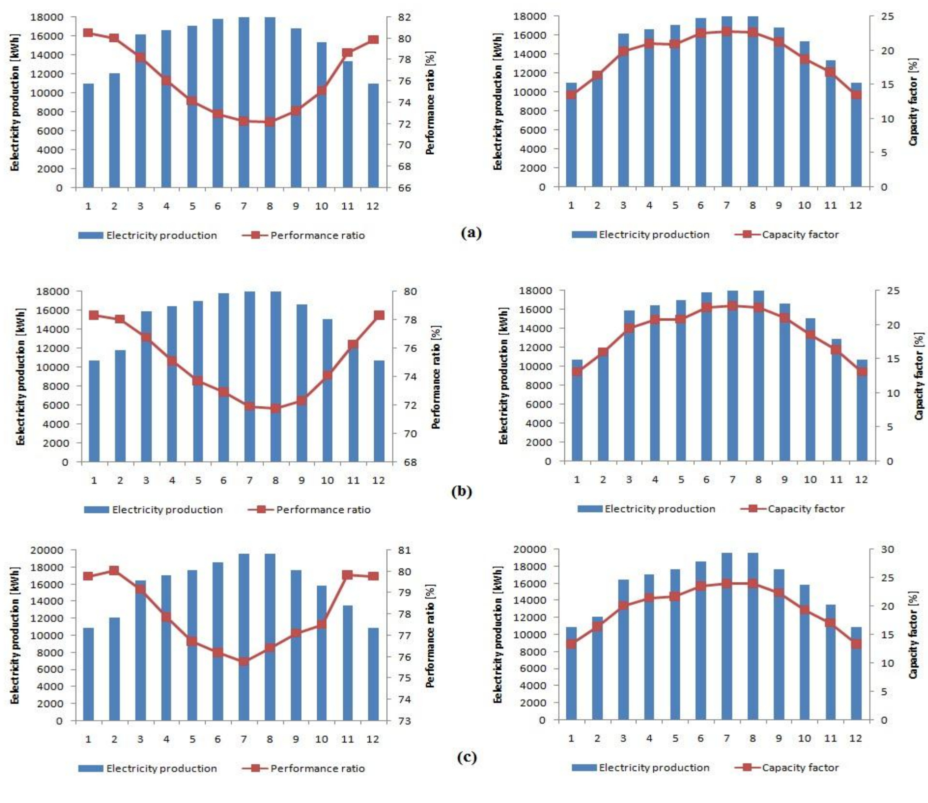

Figure 6. Variation of PV electricity production, performance ratio and capacity factor of the system for different PV technologies; (a) Crystalline silicon, (b) CIS and (c) CdTe.

Table 6. Annual average electricity production and average performance ratio at optimum tilt angle (31°)

PV technologies	Annual average electricity production (kWh)	Energy output [kWh/kWp]	Average performance ratio [%]	Average capacity factor [%]
Crystalline silicon	184300	1675.45	75.45	19.13
CIS	181900	1653.64	74.47	18.88
CdTe	189800	1725.45	77.70	19.70

Table 7. Estimated energy production by each fixed array panels with optimum tilt angle and some selected tilt angle for different PV technologies

	PV technology: Crystalline silicon module					
	22		**31**		**39**	
Month	Em	Hm	**Em**	**Hm**	Em	Hm
January	10200	112	**11000**	**122**	11600	128
February	11400	128	**12100**	**135**	12500	139
March	15800	180	**16200**	**185**	16300	186
April	16800	197	**16600**	**195**	16200	191
May	17800	213	**17100**	**206**	16300	196
June	18700	229	**17800**	**218**	16700	205
July	19400	241	**18600**	**230**	17500	218
August	18800	233	**18500**	**229**	17900	221
September	16500	202	**16800**	**205**	16700	204
October	14600	173	**15300**	**182**	15700	186
November	12200	139	**13300**	**151**	13900	159
December	10000	112	**11000**	**123**	11700	130
Annual	182200	2159	**184300**	**2181**	183000	2163
	PV technology: CIS					
	22		**31**		**39**	
Month	Em	Hm	**Em**	**Hm**	Em	Hm
January	9830	112	**10700**	**122**	11200	128
February	11100	128	**11800**	**135**	12200	139
March	15500	180	**15900**	**185**	16000	186
April	16600	197	**16400**	**195**	16100	191
May	17600	213	**17000**	**206**	16200	196
June	18700	229	**17800**	**218**	16700	205
July	19400	241	**18600**	**231**	17500	218
August	18800	233	**18400**	**229**	17800	221
September	16400	202	**16600**	**205**	16500	204
October	14400	173	**15100**	**182**	15500	186
November	11900	139	**12900**	**151**	13500	159
December	9700	112	**10700**	**122**	11300	130
Annual	179930	2159	**181900**	**2181**	180500	2163

	PV technology: CdTe					
	22		31		39	
Month	Em	Hm	**Em**	**Hm**	Em	Hm
January	10000	112	**10900**	**122**	11500	128
February	11400	128	**12100**	**135**	12500	139
March	15900	180	**16400**	**185**	16500	186
April	17200	197	**17000**	**195**	16600	191
May	18400	213	**17700**	**206**	16900	196
June	19700	229	**18600**	**218**	17400	205
July	20600	241	**19700**	**231**	18500	218
August	20000	233	**19600**	**229**	18900	221
September	17400	202	**17700**	**205**	17600	204
October	15000	173	**15800**	**182**	16200	186
November	12400	139	**13500**	**151**	14300	159
December	9910	112	**10900**	**122**	11600	130
Annual	187910	2159	**189900**	**2181**	188500	2163

4. CONCLUSION

The current study described herein had two goals. The first goal was to assess and describe the solar resource potential in the Near East University. To achieve this, PVGIS simulation tool was used in terms of collecting and analyzing data. The result demonstrated that the maximum and minimum solar radiation potential at the selected university is achieved in July (230 kWh/m^2) and January (122 kWh/m^2), respectively. The second goal of this study was to determine the best PV technologies for Near East University based on the simulation results. At this stage of the analysis, energy yield, performance ratio and capacity factor were calculated for each system. The result showed that the annual performance ratio was varied from 74.47% to 77.70% and their energy yields were ranged from 1653.64 kWh/kWp (CIS module) to 1725.45 kWh/kWp (CdTe module). Between the three types of PV systems mentioned here, CdTe PV system has the higher performance ratio than 75%. From the annual energy yield of the PV systems, it is observed that all the three technology perform satisfactory under mediterranean weather conditions. The electricity generated by PV systems can be used to sufficiently power Near East University campus area.

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REFERENCE

[1]. Shukla, A. K., Sudhakar, K., & Baredar, P. (2016). A comprehensive review on design of building integrated photovoltaic system. Energy and Buildings, 128, 99-110. doi:10.1016/j.enbuild.2016.06.077

[2]. Zeyringer, M., Pachauri, S., Schmid, E., Schmidt, J., Worrell, E., & Morawetz, U. B. (2015). Analyzing grid extension and stand-alone photovoltaic systems for the cost-effective electrification of Kenya. Energy for Sustainable Development, 25, 75-86. doi:10.1016/j.esd.2015.01.003

[3]. Menconi, M. E., Dellanna, S., Scarlato, A., & Grohmann, D. (2016). Energy sovereignty in Italian inner areas: Off-grid renewable solutions for isolated systems and rural buildings. Renewable Energy, 93, 14-26. doi:10.1016/j.renene.2016.02.034

[4]. Dondariya, C., Porwal, D., Awasthi, A., Shukla, A. K., Sudhakar, K., S.r., M. M., & Bhimte, A. (2018). Performance simulation of grid-connected rooftop solar PV system for small households: A case study of Ujjain, India. Energy Reports, 4, 546-553. doi:10.1016/j.egyr.2018.08.002

[5]. Charfi, W., Chaabane, M., Mhiri, H., & Bournot, P. (2018). Performance evaluation of a solar photovoltaic system. Energy Reports, 4, 400-406. doi:10.1016/j.egyr.2018.06.004

[6]. Shukla, A. K., Sudhakar, K., & Baredar, P. (2016). Simulation and performance analysis of 110 kWp grid-connected photovoltaic system for residential building in India: A comparative analysis of various PV technology. Energy Reports, 2, 82-88. doi:10.1016/j.egyr.2016.04.001

[7]. Kumar, N. M., Sudhakar, K., & Samykano, M. (2017). Techno-economic analysis of 1 MWp grid connected solar PV plant in Malaysia. International Journal of Ambient Energy, 40(4), 434-443. doi:10.1080/01430750.2017.1410226

[8]. Belgasim, B., Aldali, Y., Abdunnabi, M. J., Hashem, G., & Hossin, K. (2018). The potential of concentrating solar power (CSP) for electricity generation in Libya. Renewable and Sustainable Energy Reviews, 90, 1-15. doi:10.1016/j.rser.2018.03.045

[9]. Kassem, Y.; Gökçekuş, H.;Çamur, H. (2018). Economic assessment of renewable power generation based on wind speed and solar radiation in urban regions. Global J. Environ. Sci. Manage., 4(4), 465-482.

[10]. Kassem, Y., & Gökçekuş, H. (2018). GHG Emissions and Energy Performance of 1MW Grid-Connected Solar PV Plant at Lefke In Northern Cyprus: Case Study. Disaster Science and Engineering, 4(2), 90-98.

[11]. Marshall, A. (2013). Principles of economics. Basingstoke, Hampshire: Palgrave Macmillan.

[12]. Gylfason, T. (2001). Natural resources, education, and economic development. European Economic Review, 45(5), 847-859.

[13]. Afzal, M., Rehman, H., Farooq, M., & Sarwar, K. (2011). Education and economic growth in Pakistan: A cointegration and causality analysis. International Journal of Educational Research, 321-335.

[14]. Al-Najideen, M. and Alrwashdeh, S. (2017). Design of a solar photovoltaic system to cover the electricity demand for the faculty of Engineering- Mu'tah University in Jordan. Resource-Efficient Technologies, 3(4), pp.440-445.