Analysis of the efficiency of 300 kw grid-connected solar photovoltaic systems at Bukhara state university

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Abstract. Uzbekistan has a great potential for solar radiation in its vast regions, averaging from 5.9 kWh/m^2. In order to increase the contribution of solar energy to the national grid, it is extremely important to evaluate the performance of existing solar photovoltaic systems and further assistance in the design and installation of new power plants. This study presents an analysis of the technical characteristics of a 300 kW solar photovoltaic system at Bukhara State University, which was monitored during the year from February to October 2023. An economic analysis of the solar photovoltaic system is carried out. In the study period of 2023, this solar power plant produced 486.8 MWh. According to the economic analysis, the cost of energy (LCOE) is 0.099 kW·h and the payback period is 9.7 years, respectively. The study shows that the performance of the Bukhara State University system is similar to the characteristics of other solar power plants around the world

1 Introdaction

The growth of the population, the construction of new buildings and the development of the economy due to rapid industrialization lead to a regular increase in the demand for energy in Uzbekistan. If we pay attention to the latest published statistics, electricity in Uzbekistan is produced mainly from natural gas, and its share in the total production balance is 87.79% (Fig. 1) [1]. As a result, reserves of renewable energy resources are sharply decreasing, and the amount of greenhouse gas emissions, harmful to the environment, is increasing.

In order to solve these problems, a number of works are being carried out in Uzbekistan, including on July 17, 2020 "On amendments and additions to the Law of the Republic of Uzbekistan "On the rational use of energy"" The Law of the Republic of Uzbekistan No. 628 was adopted [2]. Also, in more than 30 decrees and decisions issued by the President of the Republic of Uzbekistan in 2017-2023, measures that need to be implemented on the effective use of alternative energy sources have been determined [3]. In order to fulfill the tasks of the decision PQ-57 of the President of the Republic of Uzbekistan "On measures to accelerate the introduction of renewable energy sources and energy-saving technologies in 2023", in February-October 2023, 1300 kW power installed at the Bukhara State University. A solar photoelectric plant has been put into operation [4].

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2 Solar photovoltaic system of Bukhara state university

Bukhara State University is located in the center of Bukhara city. Solar PV system is located at N39°45`43` and E064°25`21` latitude and longitude, 223.93 m above sea level. Location latitude is very important for obtaining meteorological data. Fig.2 shows the geographical location of the Bukhara State University solar photovoltaic plant project (Google Earth, 2022) [5].

3 Description of solar photovoltaic system

Bukhara State University's 300 kW solar photovoltaic system connected to a single transformer. The photovoltaic system consists of 546 solar panels, each with a capacity of 550 W, distributed across three university buildings and covering an area of 3554.1 m^2. In addition, there are 6 solar inverters with a total capacity of 300 kW. Solar inverters coordinate the voltage, current and output of the panels using solar optimizers connected to the modules. Fig.3 shows an image of a grid-connected solar photovoltaic system on the roof of the Bukhara State University building. Bukhara State University's grid-connected solar photovoltaic system is connected to a single 380V transformer.
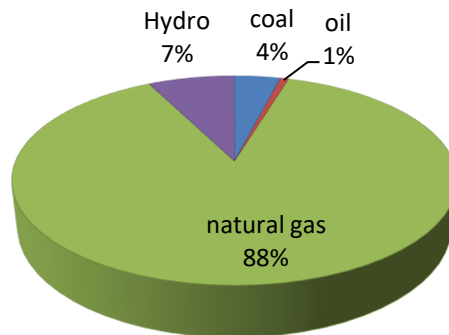

Fig.1. Share of electricity production in Uzbekistan in 2020 (iea.org, 2020).

4 Technical characteristics

Solar photovoltaic cells of Bukhara State University consist of 550 W Ipvisola monocrystalline cells. Technical characteristics are presented in Tables 1 and 2.

Fig. 2. Geographical location of Bukhara State University (Google Earth, 2023).

Fig. 3. Solar photovoltaic system in the building of Bukhara state university.

5 Data collection and monitoring

The ambient temperature and solar radiation required in this study were obtained from the NASA-SSE database. The location coordinates of Bukhara State University served as boundary conditions for obtaining accurate NASA ambient temperature and solar radiation data. The output power data was obtained from the monitoring system installed in the facility. The solar inverters are connected to the local network, which transmits data to the gateway, which transmits the data to the servers of the solar energy monitoring system. This information is carried out remotely through the Ipvisola online portal in real time. Electricity efficiency data is available hourly, daily, monthly or yearly on the solar monitoring portal. The monitoring unit provides real-time financial and technical data on the operation of the solar power plant.

Table 1. Technical details of the existing system

Designation	Photoelectric system on the roof of Bukhara State University
Power	300 kW
Total area	3554.1 (1209.5)* m²
Tracking system (Single/Dual axis)	No tracking system
Tilt	30°-32° SW 208°

Type of installation	Silicon monocrystalline
Number of inverters	6
Number of modules	468
* area of solar panels	

6 Performance analysis

The properties of a grid-connected solar photovoltaic system were analyzed using the 1998 IEC 61724 standard (International Electrotechnical Commission, 1998) [6, 7]. The performance indicators presented in this standard are very important to evaluate the performance of photovoltaic systems and to determine the losses shown by the systems [8]. The evaluated parameters are the performance factor, energy output, system collection losses, final output and power utilization factor.

Table 2. Features of the photovoltaic module

Parameter	STC Value
Maximum power rating	550 W·p
Open circuit voltage	42.10 V
Short circuit current	13.9±3 A
Rated voltage at maximum power	42.10 V
Rated current at maximum power	13.06 A
Module efficiency	21 %
Weight	28.4 kg
Dimensions	2279x1134x35 mm
Maximum system voltage	50.1±3 V
Operating temperature	45±2 0C
Maximum and nominal values of storage	Class A
Fixed power	1500 VDC
Temperature coefficients	-40°C +85°C
Nominal operating temperature of the element	25°C
Cell type silicon monocrystalline	Mono Si
Number of cells	144
Module type	YH550W-36MH
Company	Ipvisola

7 Economic analysis

The cost of Bukhara State University 300 kW Solar Photoelectric Plant is 293396.14 USD. In November 2023, the exchange rate was 1 US dollar = 12270.1 Uzbek soums [9]. Thus, the investment cost of this project was approximately 3,600,000,000 Uzbek soums. According to the agreement on the purchase of electricity between the university and the Ministry of Energy of Uzbekistan and in accordance with the relevant regulations, the price of 0.081 USD per kilowatt-hour of solar energy supplied to the electric grid is set. The payback period and quoted cost of energy (LCOE) were used to calculate and analyze the economic performance during the installation years. The quoted energy cost is used to compare power generation technologies despite differences in project size, location, system characteristics, and even lifetime. LCOE is calculated by dividing the total investment costs (life cycle costs) associated with the project by the energy produced during its lifetime [10]. The delivered energy value is determined as follows:

$$LCOE = \frac{CRF*C_1+C_{O\&M}}{E_A} \quad \frac{cost}{kWh} \tag{1}$$

here, C_1-investment capital; $C_{O\&M}$ - annual operation and maintenance costs; E_A-annual electricity production; and CRF -permanent annuity to the present value of receiving this annuity over a certain period of time

$$CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n - 1}$$

The payback period is defined as the time required for the cash flows of the project to cover the investment capital costs [11]. The reimbursement period is determined as follows:

$$SPP = \frac{IC_0}{CF_1} \qquad (2)$$

where IC_0 is the value of invested capital; CF_1 is the project's annual cash flow.

8 Saving greenhouse gases

The advantage of solar photovoltaic systems is that they do not emit greenhouse gases (GHG) during their entire operation [12]. In the period from 2019 to 2020, the average emission factor for solar PV systems in Uzbekistan was 0.4087 tons of CO2/kW·h [13]. The grid emission factor usually calculates the amount of carbon dioxide that can be avoided by generating electricity using solar photovoltaic systems. Using this network emission factor, the reduction of greenhouse gas emissions into the atmosphere is calculated using the following formula:

$$(CO_2)_a = 0.4087 \cdot E_A \qquad (3)$$

where E_A is the energy produced during the specified period, a

9 Results and discussion

Ambient temperature and solar radiation data for Bukhara State University were obtained from NASA-ESS. The average annual ambient temperature in this place is 17.5°C, and the average annual solar radiation is 5.9 kW/m^2. Figure 4 shows the ambient temperature and solar radiation in the region in 2019-2023. The highest temperature was 31°C in July, and the lowest recorded ambient temperature was 0.7°C in December. On the other hand, the highest average solar radiation value of 7.76 kW/m^2 was recorded in June, while the lowest solar radiation value was observed in December with 1.45 kW/m^2.
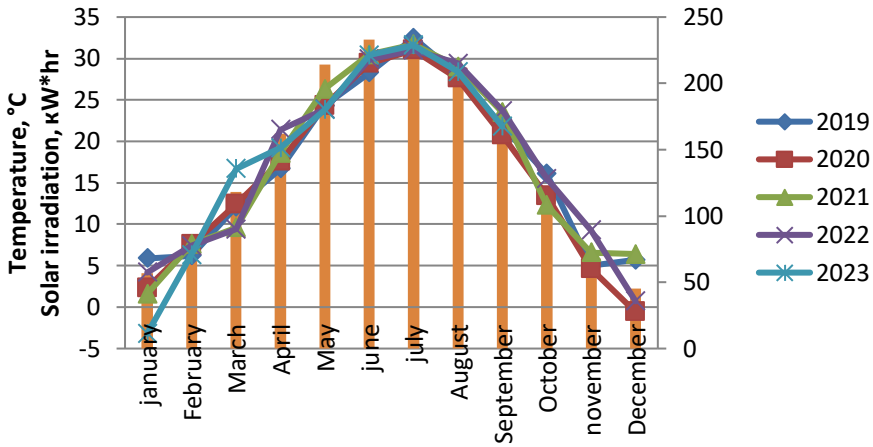
Fig. 4. Monthly changes of ambient temperature and solar radiation in Bukhara region in 2019-2023.

10 Analysis of solar photovoltaic plant performance

Figure 5 shows the monthly change of the energy and power utilization coefficient that can be produced by the 300 kW solar power plant at Bukhara State University during the year. The highest production of electricity was observed in November, and the lowest in June. In addition, the energy produced in November and June was 0.482 MW·h and 0.451 MW·h, respectively. In 2023, the total annual electricity production will be 5.6 MW·h.

11 Economic indicators

Economic calculations were calculated based on equation (1) using the energy cost method. According to calculations, the change in the value of energy brought by the change in the discount rate is shown in Figure 6. Accordingly, when the discount rate increases from 2 percent to 14 percent, the quoted energy value changes from $0.014 to $0.099.

The payback period is determined using formula (2). Calculations show that the average period of reimbursement of costs under the given conditions is 9.7 years.

12 Reducing greenhouse gas emissions

Fig. 7 shows the amount of greenhouse gas reduction in the months of the considered system. Calculations were made using equation (3). The annual reduced amount of greenhouse gases is 1112.15 tons.
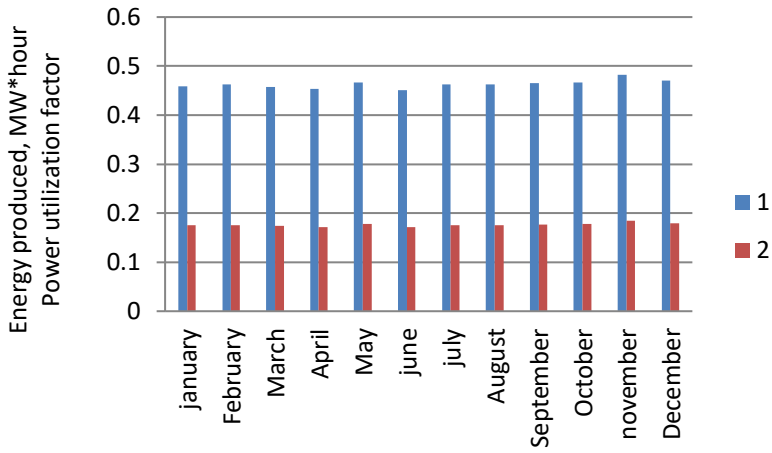
Fig. 5. Generated energy and monthly capacity utilization factor: generated power (1), capacity utilization factor (2).
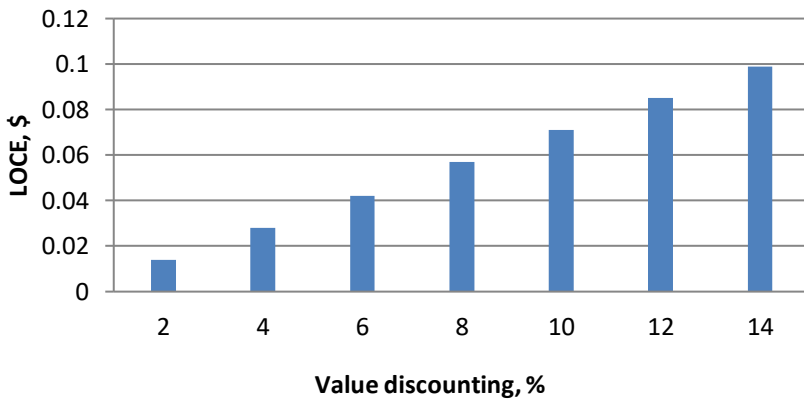

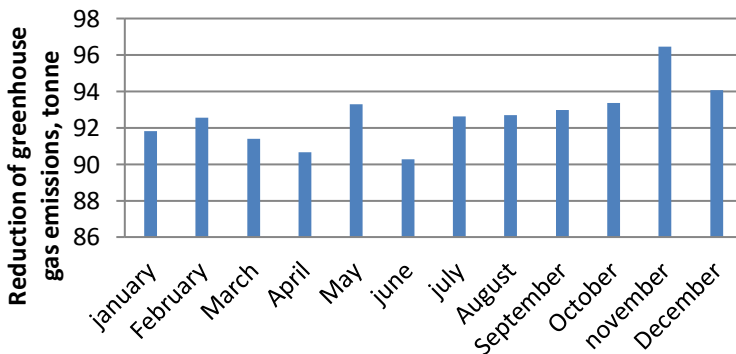**Fig. 6.** Dependence of current value of electricity on discount rates

Fig.7. Reduction of greenhouse gas emissions

13 Conclusion

In this work, the analysis of the efficiency, economic and environmental indicators of the solar photovoltaic system connected to the grid with a capacity of 300 kW at the Bukhara State University was carried out. The cost of energy (LCOE) method was used in the analysis. According to the calculations, the amount of energy produced by the solar photoelectric plant during the study period is equal to 486.8 MW·h. Economic analysis showed that the LCOE and payback period were 0.099 kW·h and 9.7 years, respectively.

References

1. https://www.iea.org
2. Law of the Republic of Uzbekistan No. ORQ-628 "On Amendments and Additions to the Law of the Republic of Uzbekistan "On Rational Use of Energy", 14.07.2020.
3. https://lex.uz/search/nat?body_id=19123&status=Y&from=01.01.2017&to=19.11.2023&query=qayta+tiklanuvchi+energiya+muqobil+energiya (19.11.2023).
4. Decision PQ-57 of the President of the Republic of Uzbekistan "On measures to accelerate the introduction of renewable energy sources and energy-saving technologies in 2023". National database of legislative information, 17.02.2023, No. 07/23/57/0093;
5. Google Earth. https://earth.google.com/web/@39.76184365,64.42172368,223.0598182a,296.08497798d,35y,359.99995618h,0t,0r/data=OgMKATA, 2023.
6. International Electrotechnical Commission, Photovoltaic System Performance Monitoring Guidelines for Measurement, Data Exchange and Analysis, IEC, 1998, 61724.
7. E. Ayora, M. Munji, K. Kaberere, B. Thomas, Performance analysis of 600 kWp grid-tied rooftop solar photovoltaic systems at strathmore university in Kenya Results in Engineering **19,** 101302 (2023)
8. S. Sathiracheewin, P. Sripadungtham, S. Kamuang, Adv. Sci. Technol. Eng. Syst. J. **5(4)**, 816–823 (2020)
9. https://bank.uz/uz/currency/archive
10. A. Kerboua, F.B. Hacene, M.F. Goosen, L.F. Ribeiro, Results in Engineering **16** 100675 (2022)
11. J.A. Qadourah, Results in Engineering **16**, 100642 (2022)
12. R. Kuldoshev, et al., E3S Web of Conferences **371**, 05069 (2023)
13. A. Hamroyev, H. Jumayeva, E3S Web of Conferences **420**, 10007 (2023)
14. M. Peyvandi, A. Hajinezhad, S.F. Moosavian, Results in Engineering **17**, 100819 (2023)
15. www.volker-quaschning.de