Capacity Utilization Factor (CUF) of the 70kW on-grid solar station in the dry climate of Termez

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Abstract. The aim of the present study was to assess the installed capacity utilization factor and the suitability of a 70kW photovoltaic plant placed on the roof of a dormitory located at Termez city (Termez state university). We can report the energy to production directly through mobile devices. CUF is one of the quantities that shows the performance quality of each power generating station. The results of our research cover two months autumn and winter. Through this, the theoretically estimated minimum values of CUF on the least sunny days have also been proven in real values. It is estimated that the annual result of this value will be around 15%-20%. Because in the winter months, the value of individual CUF on open days increases by 20%. An estimated 15.68 mln kg of CO2 was avoided due to the generation of 22.4MWh of energy. This is a small improvement in the environment and energy sector.

1 Introduction

In the case of the background of the development of our world, the energy demand is increasing day by day. The first reason for this is the growing population, and the second reason is the widespread use of various electronic devices and equipment. It is very important to obtain electricity using renewable energy sources to meet the demand for electricity and care for the environment [1-3]. The fact that Uzbekistan pays special attention to the field of renewable energy is also a very good indicator. In this regard, the large-scale use of solar plants is much more convenient and efficient than other types of renewable energy sources. The country aims to deploy 8 GW of solar by 2030 [4]. According to the International Renewable Energy Agency (IRENA), the country had only installed 104 MW of solar by the end of 2021.

In addition to the energy problem, the problem of climate change is becoming very important all over the world. Effective use of solar energy is one of the main solutions to these problems. In this regard, the construction and use of Solar stations (SS) of various sizes around the world are in full swing. Reduction of CO_2 gas emission into the

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atmosphere due to the energy obtained from photovoltaic (PV) and its analysis are considered in works [5,6]. Each kW·h of electrical energy fed by PV modules reduces emissions by 0.70 kg of CO2 into the atmosphere. We plan to analyze the daily, and monthly power generation and CUF of our 70kW plant under investigation.

Effective implementation of a suitable solar PV system for a particular application in a given location involves knowledge of their operational performance. Different studies have been conducted on the performance of PV systems real case studies, under different geographical locations and climatic conditions. The performance of the PV system depends on technical and environmental parameters. The performance of the PV system depends on technical and environmental parameters. PV cell efficiency, system component compatibility, inverter technology, solar radiation, such as shade, humidity, orientation, and wind speed [7, 8].

There are many dimensions that characterize the solar station. Based on our system, we analyze its monthly and daily energy production and the coefficient of use of the installed capacity using its 5-month results. Scientists such as Muyiwa S. A., Emil E.T. analyzed the PV plant in Norway and obtained a value of 10.58% for the annual CUF [9]. In addition, the annual average daily PV module efficiency, system efficiency, and inverter efficiency were 12.7%, 11.6%, and 88.8%, respectively. Ramesh Chaudhary and Pratiksinh Chavda have reviewed the influence of climatic factors on CUF in their article [10]. In this case, the strong dependence of CUF on radiation was mentioned in the conclusion and varied between the values of 16.96% and 22.41%. Quantities related to the energy produced by the PV system, and system losses [11-15] were considered in detail in the works. Various economic indicators of SS were also analyzed.

Many articles analyze the energy produced by the solar plant and the quantities related to it. In our article, we analyze the monitoring results of 70kW QS installed on the territory of Termez State University in Termez. Here we analyze the results of the station CUF for 5 months. The fact that the city of Termez is located in the southernmost part of the territory of Uzbekistan and there are a lot of sunny days is very suitable for our research. The fact that the use of renewable energy ensures the reduction of carbon dioxide released into the environment is also a basis for supporting this direction.

2 Material and methods

2.1. Study location

The 70kW solar plant in our study is located on the territory of Termez State University (longitude of 37° 13'57"N, latitude of 67° 17'8" E) (Figure 1). Termez is a city located in the southernmost part of the Republic of Uzbekistan, the climate here is very hot in summer and short and cold in winter.

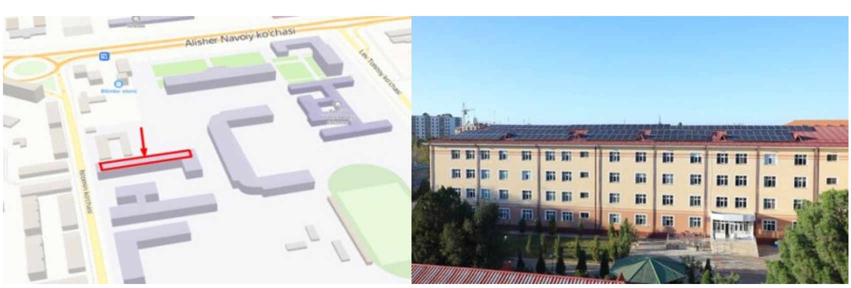


Fig. 1. Location of on-grid solar system

Termez is one of the cities with the most open sunny days and the largest annual solar radiation, as it is located in the southernmost part of our country. Based on the geographical and climatic conditions of Termiz, we can conclude that it has a huge potential for renewable solar energy Figure 2.

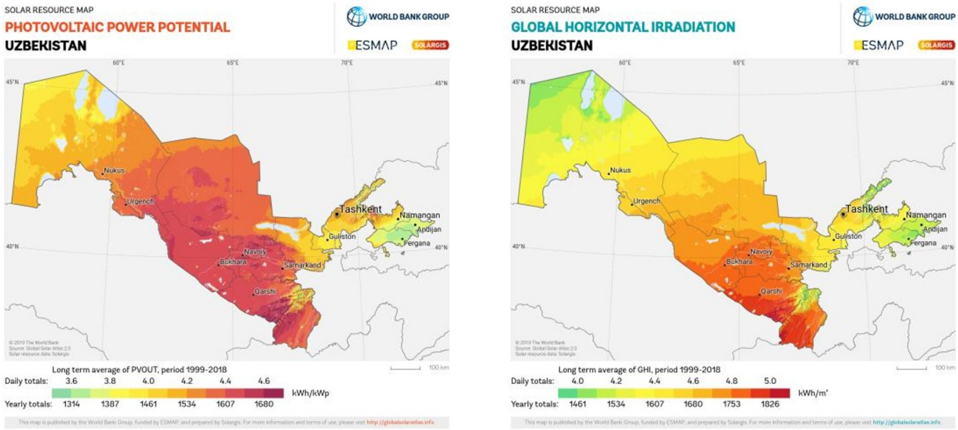


Fig. 2. Photovoltaic power potential in Uzbekistan.

The duration of annual solar sunshine exceeds 3000 hours per year. Termez has a high solar energy potential, which indicates that it can become one of the future green energy areas for the installation of photovoltaic energy systems. You can get information about the average sunshine hours in months and years from table 1 below.

Table 1.

Month	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean monthly sunshine hours	139.5	144.1	189.1	246.0	334.8	375.0	384.4	362.7	315.0	257.3	195.0	139.5	3,082.4
Mean daily sunshine hours	4.5	5.1	6.1	8.2	10.8	12.5	12.4	11.7	10.5	8.3	6.5	4.5	8.4

2.2 PV system description and system description

In our study, the installed power utilization coefficient of the 70kW on-grid solar plant installed on the territory of Termez State University was analyzed. This system is installed on the roof of one of the university dormitories facing south. 450W and 540W monocrystalline panels were used in the on-grid solar system, and their electrical characteristics are given in Table 2.

Table 2.

Model Type	LS450HC	LS540BF
Peak Power (P_{max})	450W	540W
Module Efficiency	20.6%	20.95%
Maximum Power Voltage (Vmp)	41.00V	41.55V
Maximum Power Current (Imp)	10.98A	13.00A
Open Circuit (Voc)	49.60V	49.5V
Short Circuit Current (Isc)	11.53A	13.81A
Power Tolerance	± 3 %	± 3 %
Maximum System Voltage Nominal	1500V	1500V
Maximum Series Fuse Rating	20A	25A

The system consists of 540W and 450W monocrystalline panels. SS has been working since October 17.

2.3 On - grid solar system description

In this solar system, solar panels will generate DC electricity by absorbing sunlight and the solar inverter will convert the same DC electricity into AC electricity which can then be used directly at home or business. If the system will produce more power than is being consumed, the surplus is fed into the main electrical grid via solar net metering. The diagram of the 70kW on-grid solar plant we installed is shown in Figure 3. In this case, the inverter is connected to the Internet via Wi-Fi, and it is possible to monitor the daily energy produced by the system, the energy produced, and its consumption at any time of the day. The system uses a SUN2000-100KTL-M1 inverter and it is nowadays modern equipment for solar energy areas. We can get full reports of daily, and monthly power produced by the system, and daily weather information through the site https://region02eu5.fusionsolar.huawei.com using mobile phones or computers. We used this information directly in our article.

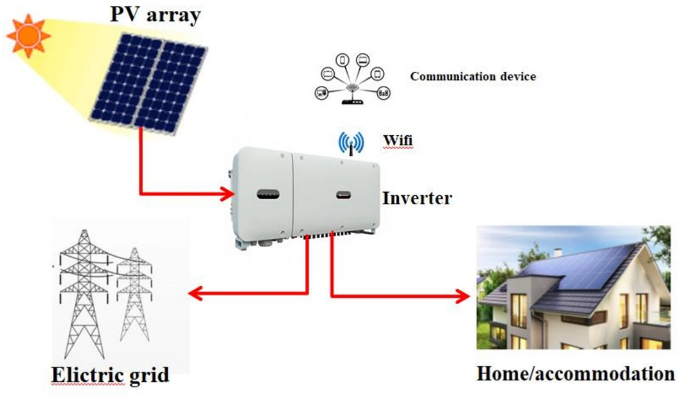


Fig. 3. Schematic block circuit diagram of the PV array.

2.4 Capacity Utilization Factor

The CUF is defined as the ratio of the AC's actual energy output to the amount of energy that the PV system would generate if it operated at nominal power [16,17]. Another definition is to determine how long an electrical system will operate at 100 percent capacity. The coefficients calculated in small time intervals differ sharply from each other, and therefore the results obtained in the calculations for a week, month, or year become more accurate as time increases.

$$\eta_{CUF} = \frac{E_{yield}}{P_{PV,rated} \cdot Time_{Fixed}} \quad (1)$$

Where E_{yield} is SS's total energy produced for a fixed time, $P_{PV,rated}$ is the installed power of SS. $Time_{Fixed}$ is the exact time taken for SS to produce E_{yield} energy.

3 Results and discussion

The collected data from 17 October 2022 to 24 February 2023 used to study the photovoltaic plant's performance were carried out at the Termez State University.

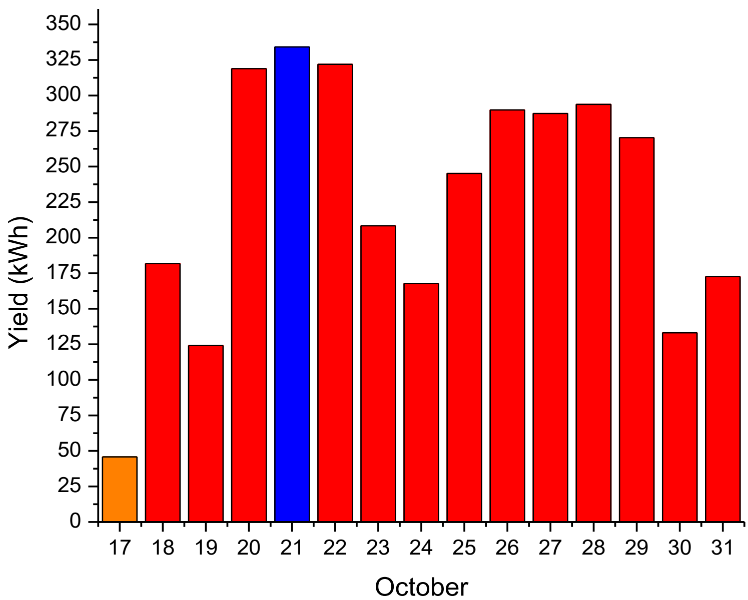


Fig. 4. The energy produced in October

You can see the daily energy report for October in Figure 4. This month, the total produced energy was 3.4MWh, and the date of the largest energy produced, was October 21. The energy distribution over time this day is given in Figure 5.

 https://doi.org/10.1051/e3sconf/202340102059

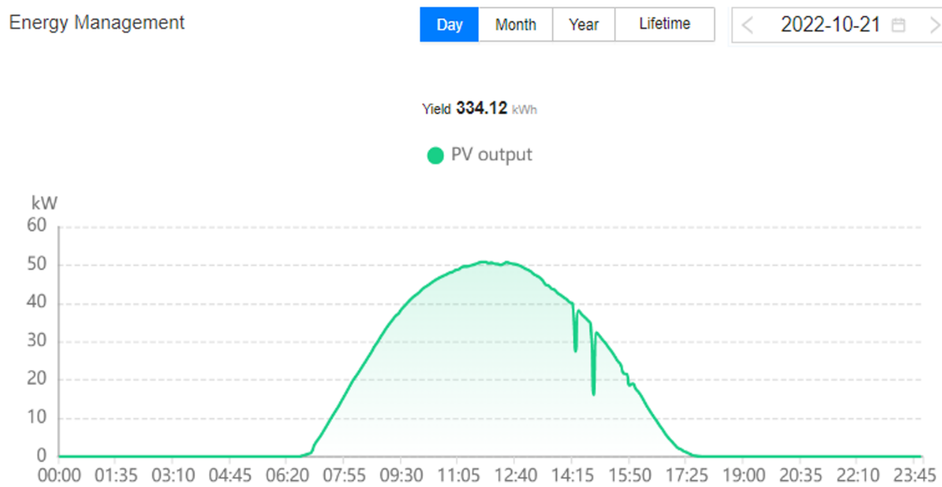


Fig. 5. The energy distribution over time October 21

October 21 was sunny, with some clouds in the afternoon, resulting in a loss of smoothness in the graph. Continuing this analysis, we can see the energy distribution under the influence of a cloudy day on October 30 from Figure 6.

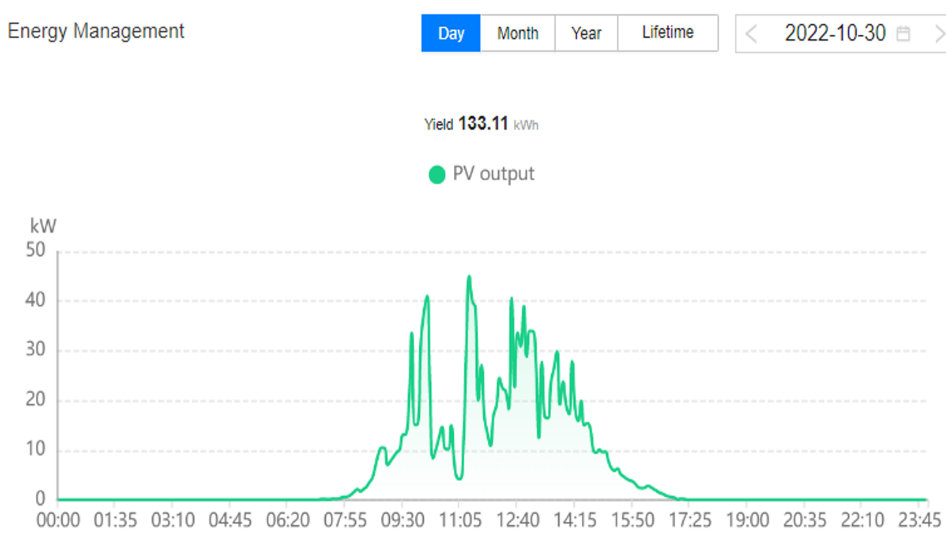
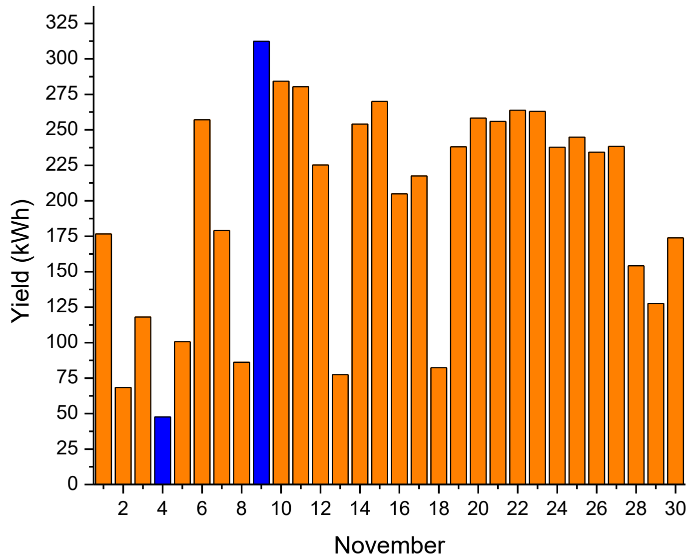
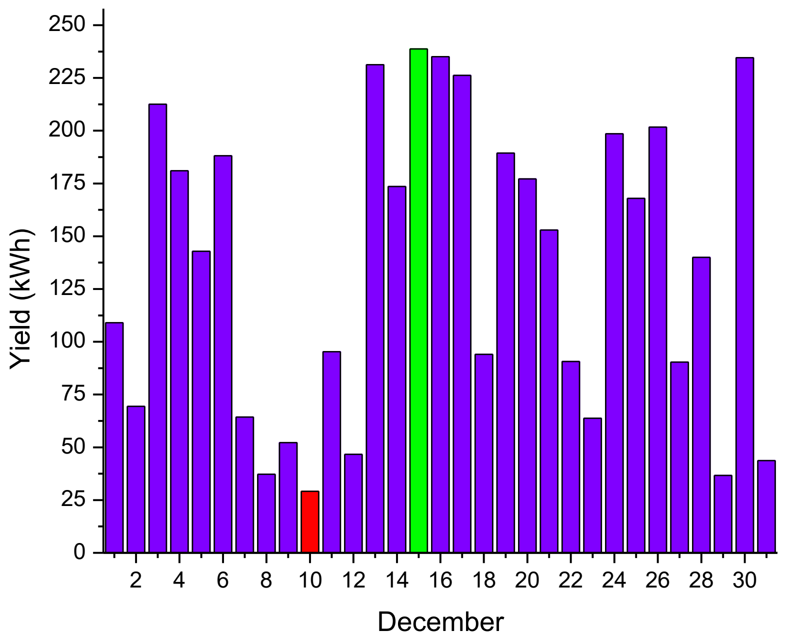
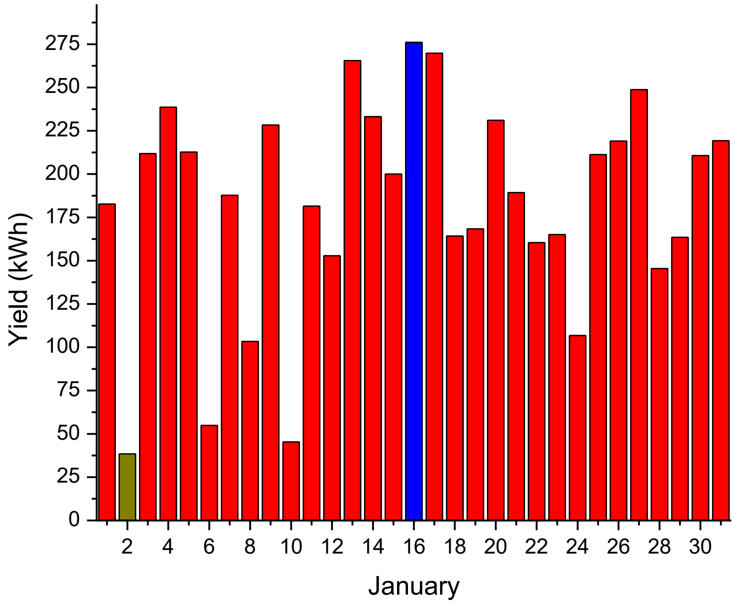


Fig. 6 The energy distribution over time October 30

You can see the daily energy reports produced in November and the months of winter in Figure 7.


Yield (kWh)
November


Yield (kWh)
December



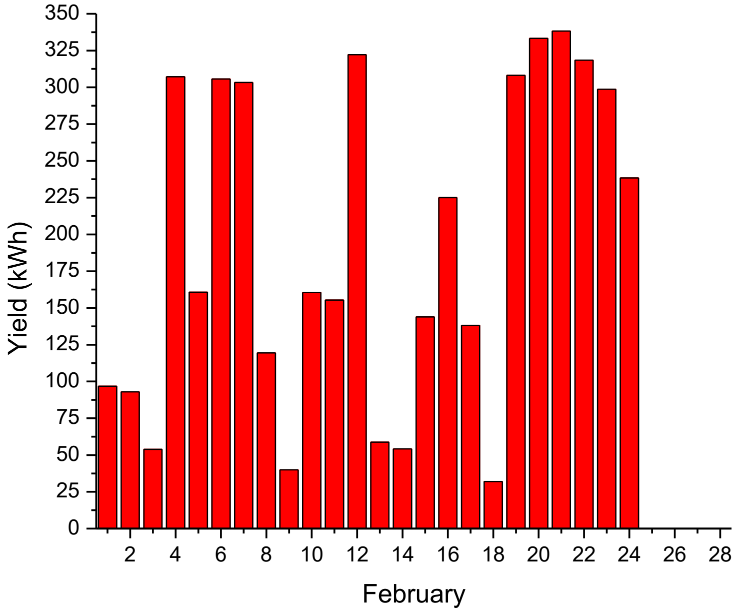


Fig. 7. The daily energy reports produced in November and the months of winter

The total energy manufactured in these months is in Figure 8. We have to consider that 15 and 24 days of results were obtained in October and February respectively.

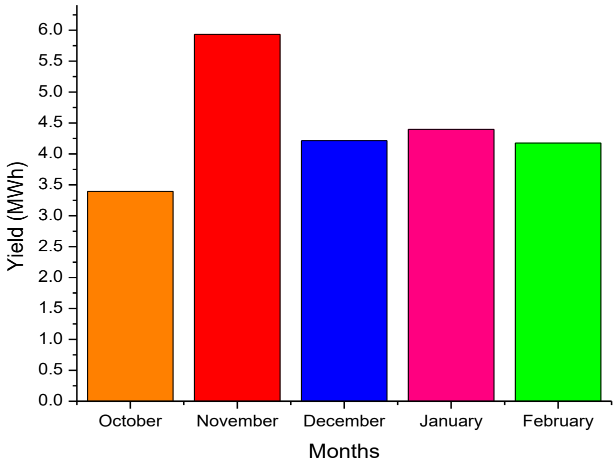


Fig. 8. The total energy manufactured in these months

We present the results of calculations of months and total CUF in Figure 9. So, while the CUF for the autumn month is 13.5% and 11.8%, this indicator is 8.1%, 8.4%, and 11%, respectively, in the winter months. The total value was 10.15%. The shortness of the days in the winter months and the fact that many days are cloudy and snowy are the reasons for the low productivity in the winter months.

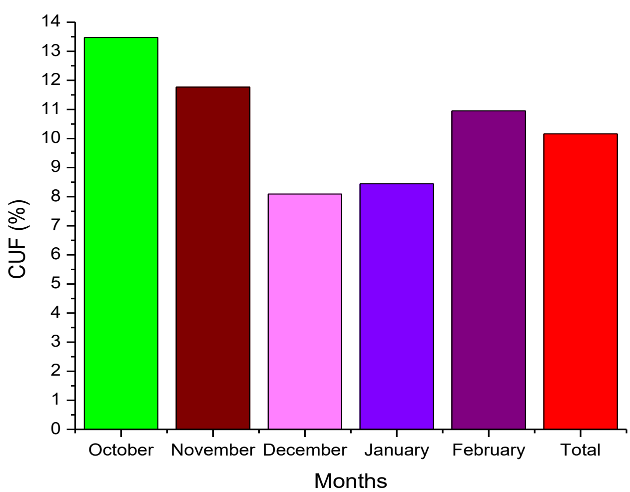


Fig. 9. CUF in months and total

With the increase of sunny days, the CUF will definitely increase. From the above table, it can be estimated that the average duration of sunshine in winter is 4.7 hours, and this value increases to 8.3 hours in spring and 12.2 hours in summer. But it should also be noted that as the temperature of the panel increases, the power loss also increases [18-20]. In this case, it is necessary to take into account the stationarity of the panels and the degree of dusting. But our goal is to research the CUF of SS and we have reviewed these pointers in detail above.

4 Conclusions

The study of the CUF of stationary SS in the dry climate of Termez is one of our first works in this direction, which includes a five-month analysis of this value. It is estimated that the annual result of this value will be around 15%-20%. Because in the winter months, the value of individual CUF on open days increases by 20%. We can predict this, knowing that most of the spring and summer months will be sunny days. The study of CUF data gives us detailed information about SS and is the first of real work results in this area. Since the climatic conditions of the region are highly dependent on this coefficient, it is necessary to study the climatic data of the region in detail before building the SS. In addition, 15.68mln kg of CO_2 gas has been prevented from being released into the environment as a result of 22.4MWh of energy produced to date.

Acknowledgments

We would like to express our gratitude to Termiz State University, which greatly supports the field of renewable energy sources and scientific work.

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