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Options and Opportunities for Energy Management in Malaysian Grid Systems—Putrajaya as a Case Study

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***Abstract*—**This paper presents an opportunity for energy management with an integrated photovoltaic and wind farm for the energy and economic aspects of the commercial area located in Putrajaya. The energy economy accession conforming to the wind speed, temperature, solar irradiation, and energy consumption on a daily basis is taken into consideration. Design analysis is done through the industry standard numerical tool. From the result analysis, the recommended ratio of renewable share minimizing stress to the electric grid is proposed. According to the solutions obtained from the numerical design tool, photovoltaic is recommended to be more energy efficient and economically viable in comparison of the fully crowded wind farm. From the proposed solutions, the photovoltaic is able to provide 51% of the energy consumed and it costs RM 0.365 per kW/h.

***Index Terms*—**Cost, grid, Homer Pro, photovoltaic park, wind turbine farm.

1. Introduction

In the past few years, renewable energy has experienced a huge growth area in percentage of over 30% per year compared to other energy resources such as coal and lignite energy[1]-[3]. Since it is growing rapidly, renewable energy has addressed the huge demand for electricity consumption. Among all the viable renewable options, photovoltaic and wind energy are the most popular for researchers being promising due to the considerable time available from nature[4]-[7]. Therefore, this increases the amount of photovoltaic parks and wind turbine farms worldwide[8], making them a kind of energy resources for the commercial purpose. In this context, the aim of this paper is to compare photovoltaic and wind turbine for energy and economic analysis of the proposed renewable

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options. By using the industry standard numerical tool, the design parameters for both the solar photovoltaic and the wind farms are identified. Homer Pro chooses the selection between the photovoltaic and wind farms according to the simulated results.

The vicinity of the site connected to the grid shown in Fig. 1, Putrajaya, is the business capital of Malaysia, 25 km south of Kuala Lumpur which serves as the federal administrative centre of Malaysia. Its geographical location is 2°55.6' north, 101°41' east and the time zone is GMT +08:00. The rationale for choosing Putrajaya is that it hosts most of the government buildings and one of the major initiatives by the Government of Malaysia is to make them energy resourceful contributing to the "Sustainable Energy Developmental Plan and Strategy 2018-2022".

Fig. 1. Putrajaya map.

The meteorology (wind) data is taken from the NASA energy database automatically with the built-in plug-in from the numerical tool for the input coordinates. The wind data acquired is synthesized using the numerical tool for study characteristics analysis of the wind flow within the vicinity[9]. Fig. 2 shows the wind speed for various months of the year. Also, the average temperature data is collected for determining the feasibility of solar farm through the analysis of solar irradiation available within the vicinity. Fig. 3 presents the monthly average temperature data. The

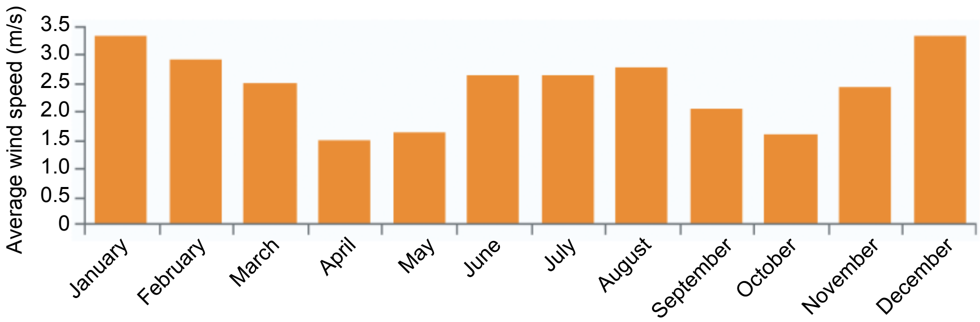
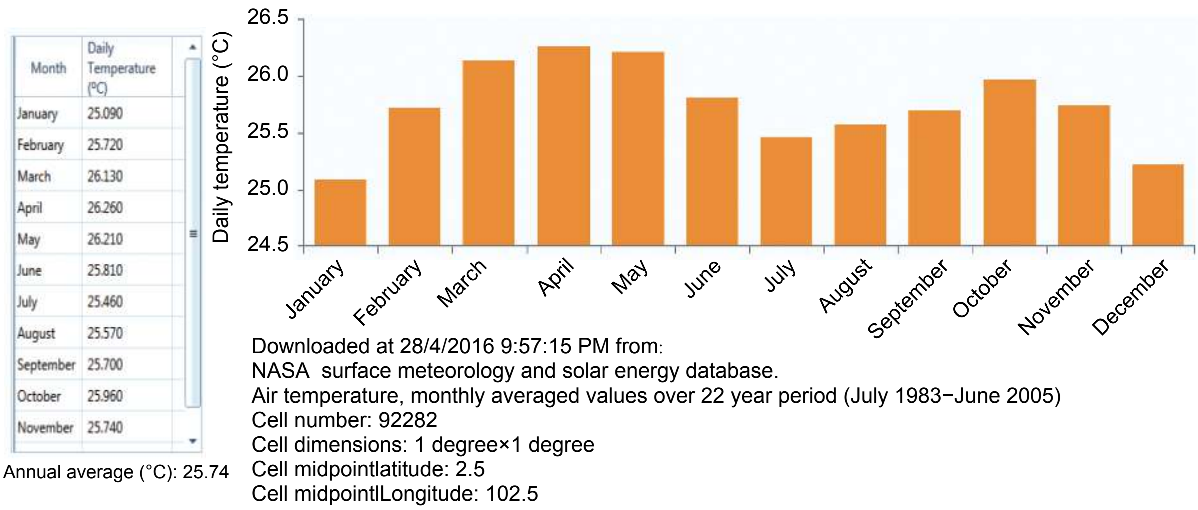


Fig. 2. Wind speed deviations across various months.



Month	Daily Temperature (°C)
January	25.090
February	25.720
March	26.130
April	26.260
May	26.210
June	25.810
July	25.460
August	25.570
September	25.700
October	25.960
November	25.740

Fig. 3. Monthly average temperature data.

average temperature data is collected in order to determine the irradiation variation typically helpful to identify how far solar is efficient on a typical day. Fig. 4 shows the 2-month temperature variations[4].

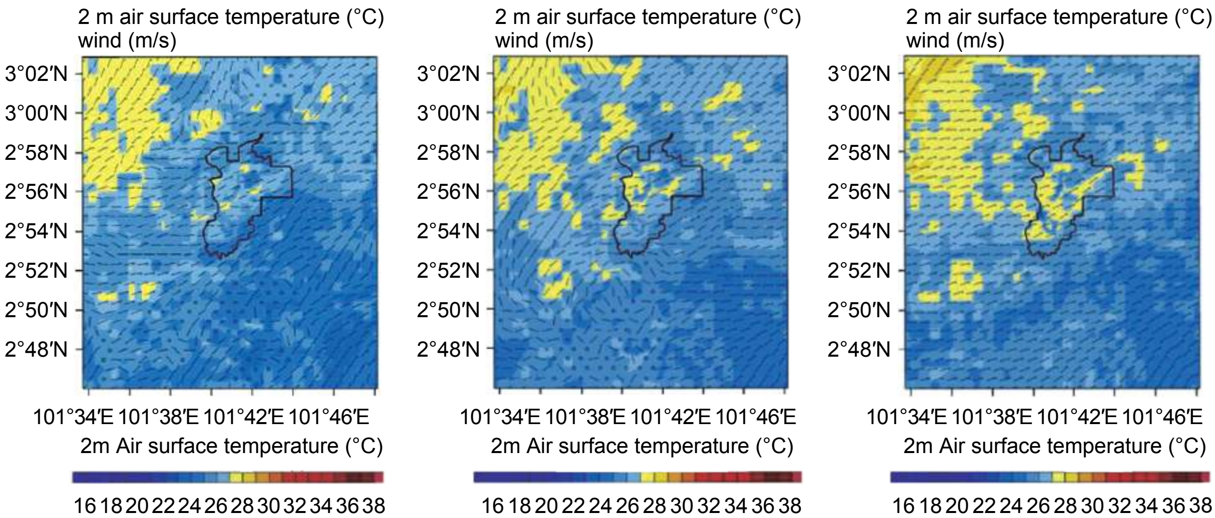


Fig. 4. 2-month temperature for the year 1999.

The energy usage per hour of a commercial area (Putrajaya) is recorded for the analysis using the numerical tool. As shown in Fig. 5, the electrical energy consumption is the highest from 9:00 am to 5:00 pm due to the office working hour and operation of the government departments. The energy consumption decreases after the working hour and it is the least during midnight to 7:00 am. Therefore, the maximum power needed to contribute for the application site can be resolved and the load and demand for electrical energy still fluctuate concurrently. According to the simulation results, a solution is given and derived for energy management. In this study, the combination of solar and wind is chosen as the viable solution primarily because of the availability of the resources over a considerable period towards power generation and storage options. However, the wind power generation is challenged by the continuously controlled power generation hence the proposed solution is putting a larger share of solar than that of the wind[10].

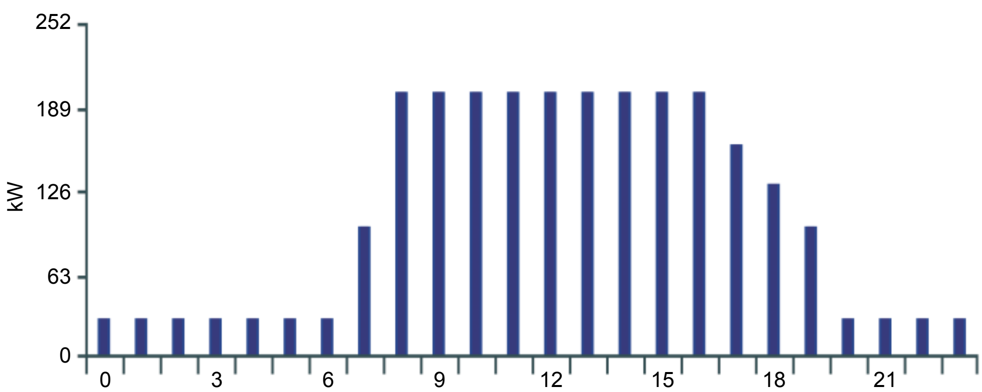
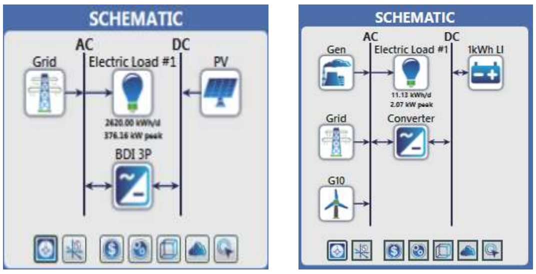


Fig. 5. Daily commercial load curve.

2. System Modeling

Homer Pro is the numerical tool used in the study for the energy systems either for decentralized capability and/or by connecting it to the power grid[11]. A comparison of the two-power conversion system is made. The photovoltaic park and wind turbine farm based on an induction generator that is doubly excited are connected to the grid as shown in Figs. 6(a) and (b) with any overproduction injected back to the grid. The selection and optimization of the chosen system involve the data from the meteorological data and the variations in the load factor, costing etc.[12]. In Malaysia, the electric tariff is fixed at a flat rate throughout the day by the government to reduce the complication on the bill calculation. In this simulation, the price rates for buying and selling electricity to the grid inserted to the numerical tool to enable a more accurate simulation of the actual cost need to implement this renewable energy plant.



(a) (b)

Fig. 6. Schematics from design tool: (a) photovoltaic park and (b) wind turbine farm schematics.

The price of the electricity per kWh is obtained from Tenaga National Berhad (TNB), a local electric utility company at the rate of 0.45 sen/kWh[13],[14]. The rate of the selling price of the electricity of the renewable plan is obtained from SEDA (Sustainable Energy Development Authority Malaysia) portal that is 0.416 sen/kWh. With above information, the calculation of the cost is conducted. The system builds from the numerical design models and represents the state of energy demand, namely peak, off-peak, and normal load operations. Besides that, it represents the demand response and the energy state of the grid in a much easier way. The system allows a more understandable figure that could present the duration of the demand peak. The demand and energy cost of both systems are required to be defined during each period. The price is provided from the specific list given by TNB, which plays a role in monitoring the electricity supply for the entire country in terms of selling and buying prices. Table 1 illustrates the costs required for the number of a wind turbine, with 1.5 MW that can be integrated into the facility with the capital and operational costs for a maximum of 10 units. The photovoltaic system is tuned to the required ratings with series-parallel connections of the systems[15]. The output increases when irradiation goes up while the power decreases when the temperature reduces[16]. The design constraints for generators are crucial in determining the efficiency of the generator. The methods applied for designing the photovoltaic cells are twofold[16] namely photovoltaic modular design through the operational characteristic of the photovoltaic modules and the selection of the power electronic control systems. Table 2 presents the costs chart with the different power panels that are integrated into the facility for the sizing of up to 2500 kW. A converter is a device used to convert an alternating current or voltage into continuous. The power electronic converter as a string inverter architecture is the most appropriate for the system[15]. From Table 3, it shows the different power converters and the size of the converters for both the photovoltaic and wind conversion systems.

Table 1: Economic analysis for wind farm

Capacity value (kW)	Capital investment (RM)	Replacement cost (RM)	Maintenance value (RM)	Units
13.00	512967.00	175809.00	137618.00	0 to 10

Table 2: Economic analysis of photovoltaic

Capacity value (kW)	Capital investment (RM)	Maintenance value (RM)	Sizing (kW)
7840.60	103133182.00	1051737.00	0 to 2500

Table 3: Economic analysis of inverter systems

Inverter cost	Capacity value (kW)	Capital investment (RM)	Maintenance value (RM)	Sizing (kW)
For the photovoltaic conversion system	1.89	819.34	0.00	0 to 2500
For wind turbine conversion system	2.79	720.00	0.00	0 to 2500

3. Energy and Economic System Modeling

The energy and economic system modeling is to identify the required electrical supply to the demand for the commercial site within the chosen area, typically that connected to the grid. In order to obtain the required target, the results obtained by the photovoltaic and wind turbine systems are analyzed according to the energy and economic options[16]-[19]. Fig. 7 presents the load profile for a typical month. During the day, it is a high level of electrical consumption for all the building located in Putrajaya. The consumption drops during the night as most of the citizens have finished their work and went back to the residential area. Figs. 8 and 9 show the rate of production for the photovoltaic and wind turbine systems, respectively. From the result, it is seen that the production of energy from photovoltaic is far better than that from the wind farm. From Figs. 8 and 9, the production of photovoltaic energy is for 12 hours with slight improved variations in the summer. Meanwhile, the wind farm graph shows a poor result with few months that have almost zero energy production[20]. Comparing the results, it is noticeable that the photovoltaic energy conversion system provides electrification for a limited period, which is from 6:00 am to 6:00 pm daily; in return, the wind energy conversion system only covers for a few months and provides a very low amount of electrification due to limited wind kinetic energy[21]. The efficiency ratio between the conversion systems is significant to its participation in load sharing and the excess generation to be fed into the grid. Undeniably, the photovoltaic system has excess production in comparison to wind farm system. However, the excess production from photovoltaic is only a little during midnight and a slight hike after 6:00 pm. The wind turbine system has almost no excess production[22]. To conclude based on the result obtained from the tool; it is noticeable that the photovoltaic energy conversion system is ideally suited for the chosen system. In the current case, the costs of the installation for both photovoltaic park and wind farm are illustrated in Table 4. It can be seen that the wind farm has a higher installation cost than the photovoltaic park.

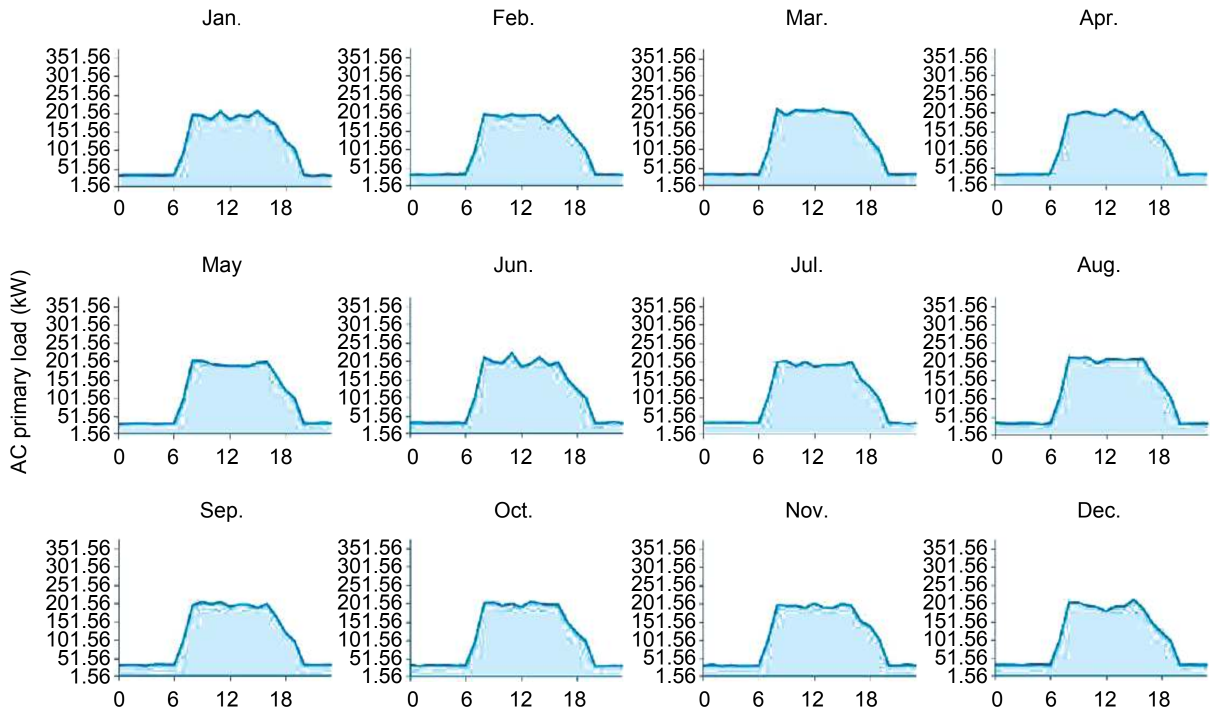


Fig. 7. AC primary daily load profile.

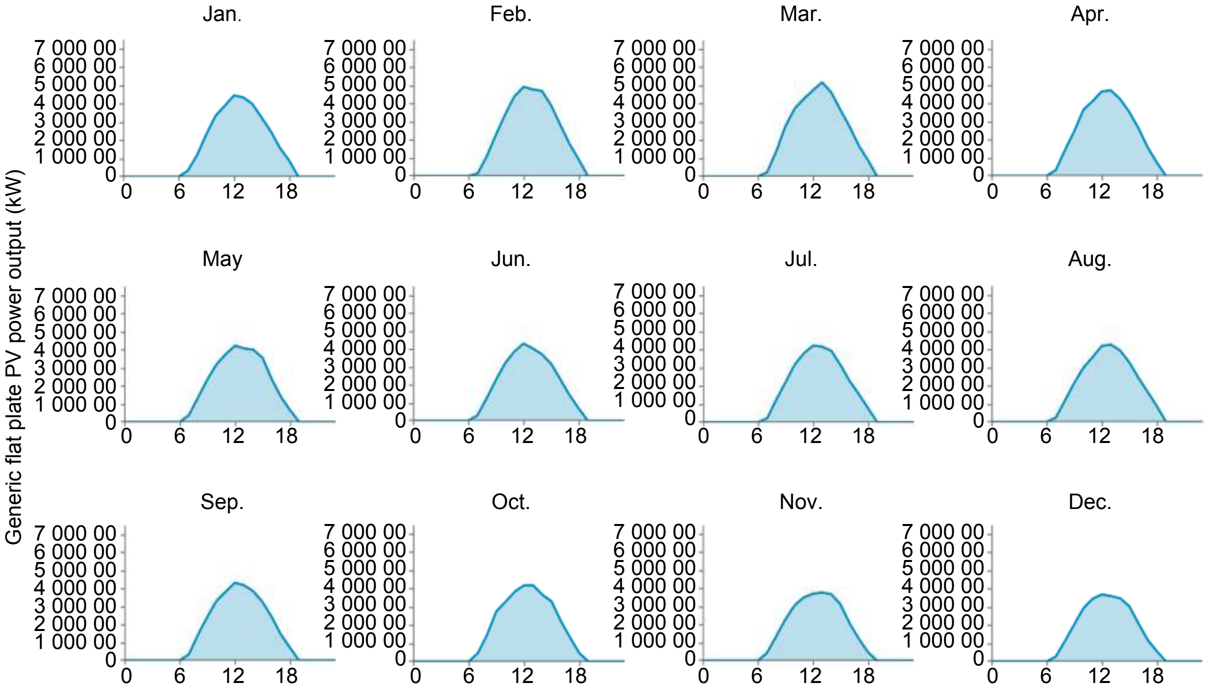


Fig. 8. Rate of energy production from renewable sources photovoltaic system.

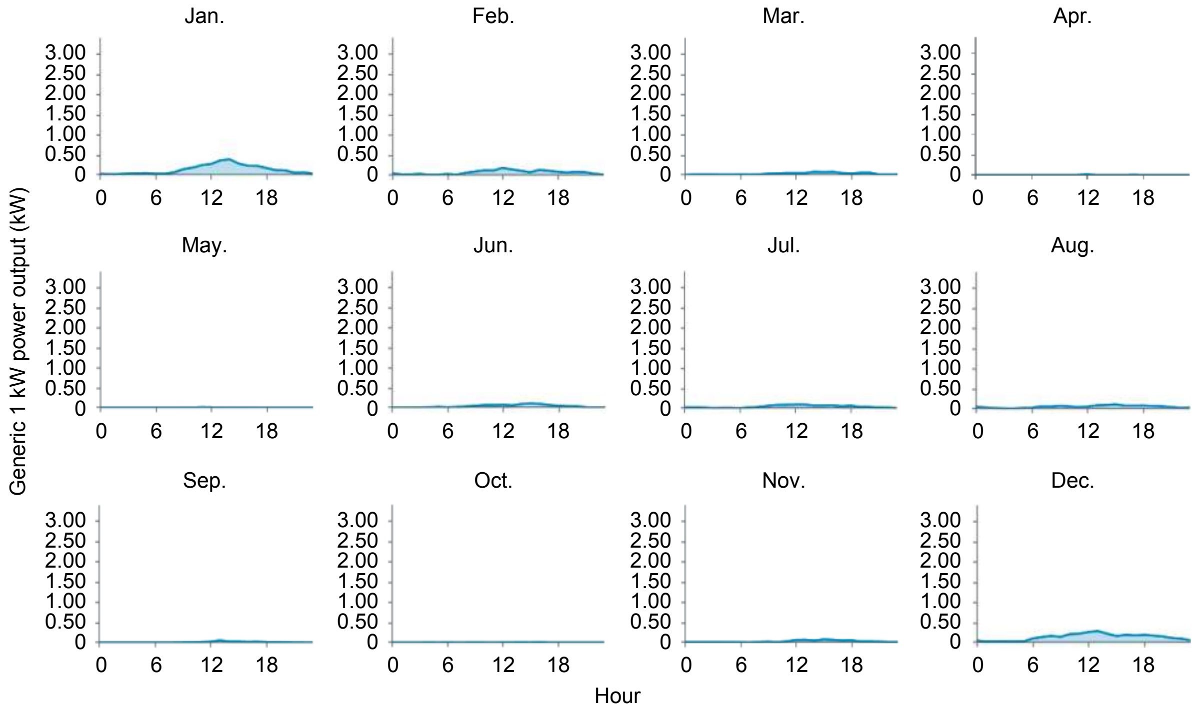


Fig. 9. Rate of energy production from renewable sources of wind turbine system.

4. Conclusions

In conclusion, two sources of energy options were studied through the numerical tool as an opportunity for the sourcing for energy and economic viability. Both the conversion systems were proposed to be integrated into the grid for the chosen area. The focus on the parameters of the conversion system was the speed of the wind,

Table 4: Net costing comparison of solar photovoltaic and wind farm systems

	Device	Capital cost (RM)	Replacement cost(RM)	Maintenance cost (RM)	Salvages (RM)	Total (RM)
Solar photovoltaic system	Flat plate photovoltaic	103130696.00	0.00	1051737.00	0.00	104182432.00
	Electric network	0.00	0.00	114528984.00	0.00	114528984.00
	Converter	565.87	254.00	0.00	50.00	770.00
	System	103156184.00	2486.00	113418232.00	486.00	10260035.00
Wind power system	Wind farm	512967.00	175809.00	137618.00	100888.00	725506.00
	Electric network	0.00	0.00	29176922.00	0.00	29176922.00
	System	748727.00	1761557.00	27499700.00	124052.00	13757086.00

temperature, profile load, and solar irradiation of the researched area. Looking towards the sustainable pathway, the design of the conversion system is required to make more competitive. As a brief, based on the results computed through the numerical tool, the photovoltaic conversion system connected to the grid exhibited better overall efficiency of the energy produced, when compared to the wind energy conversion system within the chosen area. Besides, in terms of economic cost, the energy produced by the photovoltaic had better outcomes compared to the wind turbine for the region.

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