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Evaluating the performance of online simulation tools for grid-connected rooftop solar systems in Baghdad, Iraq

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ABSTRACT

The main objective of the present study is to evaluate the technical performance of a 6.4kW grid-connected rooftop PV system in the capital city of Iraq. Four simulation tools, namely, PV*SOL. PVGIS, PVWatts, and RETScreen are employed to assess the potential of solar energy in the selected city. The performance of these simulations is compared by calculating the capacity factor and performance ratio. The results demonstrated that RETScreen software could be considered a reliable software and easy to use compared to other simulation tools.

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1. INTRODUCTION

The rapid growth of population and economic growth have led to an increase in the energy demand which is produced using fossil fuels [1]. Due to this increase, scientific researchers and governments start to find other energy sources such as renewable energy especially solar energy as a power source for generating electricity [2]. Solar energy is an alternative energy source and clean energy. In the literature, numerous scientific researchers have evaluated the potential of solar energy as an alternative source to generate electricity for building and so on. For instance, Kassem et al. [3] developed a 5kW grid-connected PV system to meet the energy demand of households in various locations in Libya. Çamur et al. [4] proposed a 5kW grid-connected PV system with various sun-tracking systems for generating electricity in Nahr El-Bared, Lebanon. Kassem et al. [5] designed a 6.4kW grid-connected PV system that can generate electricity for a household in three urban cities in Northern Cyprus. Kassem et al. [6] proposed a small-scale grid-connected rooftop PV system with various PV technologies and a sun-tracking system in Amman, Jordan. Kassem et al. [7] evaluated the applicability of solar PV systems with various PV technologies and sun-tracking systems for generating electricity in Baghdad, Iraq. Yadav and Bajpai [8] evaluated the performance of a 5 kW rooftop PV system at the Centre of Excellence in Renewable Energy Education and Research, University of Lucknow, India.

In Iraq, the main source of generating electricity is fossil fuels and natural gas as shown in Figure 1. Due to the civil war, Iraq remains suffering from electricity shortages. For this reason, several researchers have evaluated the performance of solar energy in various locations in Iraq [9-12]. Moreover, Iraq has high solar energy potential due to the high value of global solar irradiation (GHI) and direct normal irradiation (DNI) [13]. It can be seen that the GHI and DNI values are within the range of 4.88-5.89kWh/m2/day and 4.56-6.67 kWh/m2/day, respectively [13]. According to the solar resource classification [14], the solar resource is categorized as good and excellent.

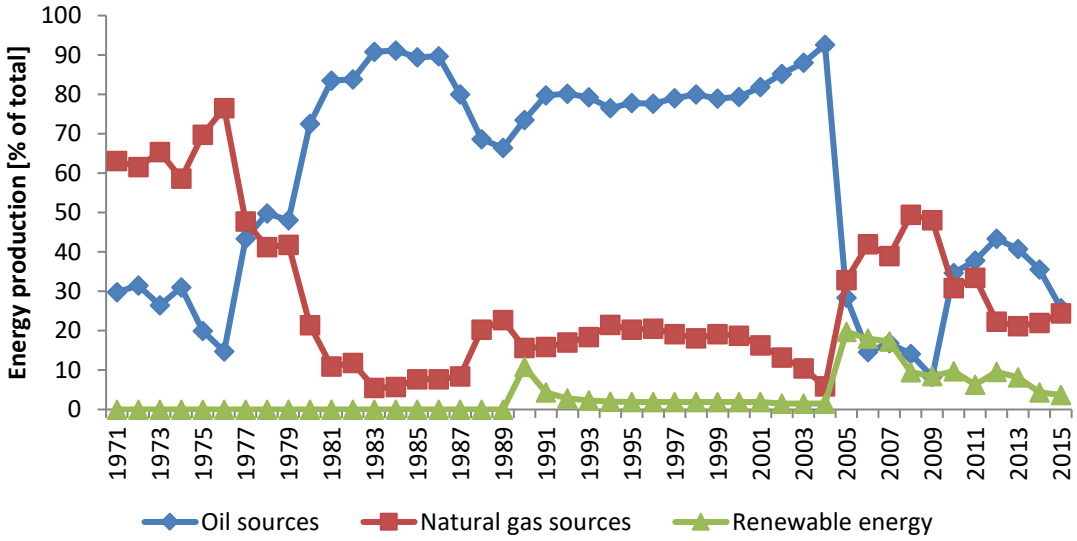

Figure 1. Electricity production from various sources in Iraq (source: World Bank 2020)

Therefore, the object of the current paper is to evaluate the performance of a 6.4 kW grid-connected rooftop PV system using various online simulation tools. PVGIS, PV*SOL, PVWatts, and RETScreen are utilized to estimate the potential of solar energy in Baghdad, Iraq. The performance of these software has been compared by calculating the annual energy yield, performance ratio, and energy yield.

2. MATERIAL AND METHODS

2.1. Details of the selected location

The details of the selected city are summarized in Table 1. Also, Figure 2 shows the location of the chosen city. A small household with a rooftop area of 70m2 is used in this study.

Table 1. Information about the selected city

City	Longitude (°E)	Latitude (°N)	Altitude [m]	Climate
Baghdad	33.34	44.40	41	Hot and dry in summer, and cold and humid in winter

2.2. System description

The description of the proposed system (6.4 kW) is listed in Table 2. The type of PV system is a fixed-tilted PV system. The main component of the grid-connected PV system (solar panel and inverters) [15]. The solar panel is the main element of solar systems. It is used to convert solar energy into electricity. It is made of semiconductor materials that absorb light from the sun. Moreover, inverters are utilized to convert the direct current output from the solar module into alternating current that can be fed into a commercial electrical grid.

Figure 2. Iraq map [7]

Table 2. Description of the developed system

System capacity	6.4 kWp
Installation type	Fixed-tilted rooftop
PV technology	Mono-Crystalline, Efficiency 14.9%
Model type	1-Soltec Inc, 1-STH 320
Model efficiency	14.9%
Orientation angles	32° (slope angle) and 0° (azimuth angle)
No. of Module (320 Wp)	20 (1-Soltec Inc, 1-STH 320)
Load Profile	2-Person household with 2-children

2.2. Online simulation tools

In the literature, various simulation tools are utilized to assess the performance of PV systems [16-20]. In this study, three simulation tools are employed to estimate the performance of rooftop PV systems in Iraq. The inputs required and specifications of the used software are shown in Figure 3.

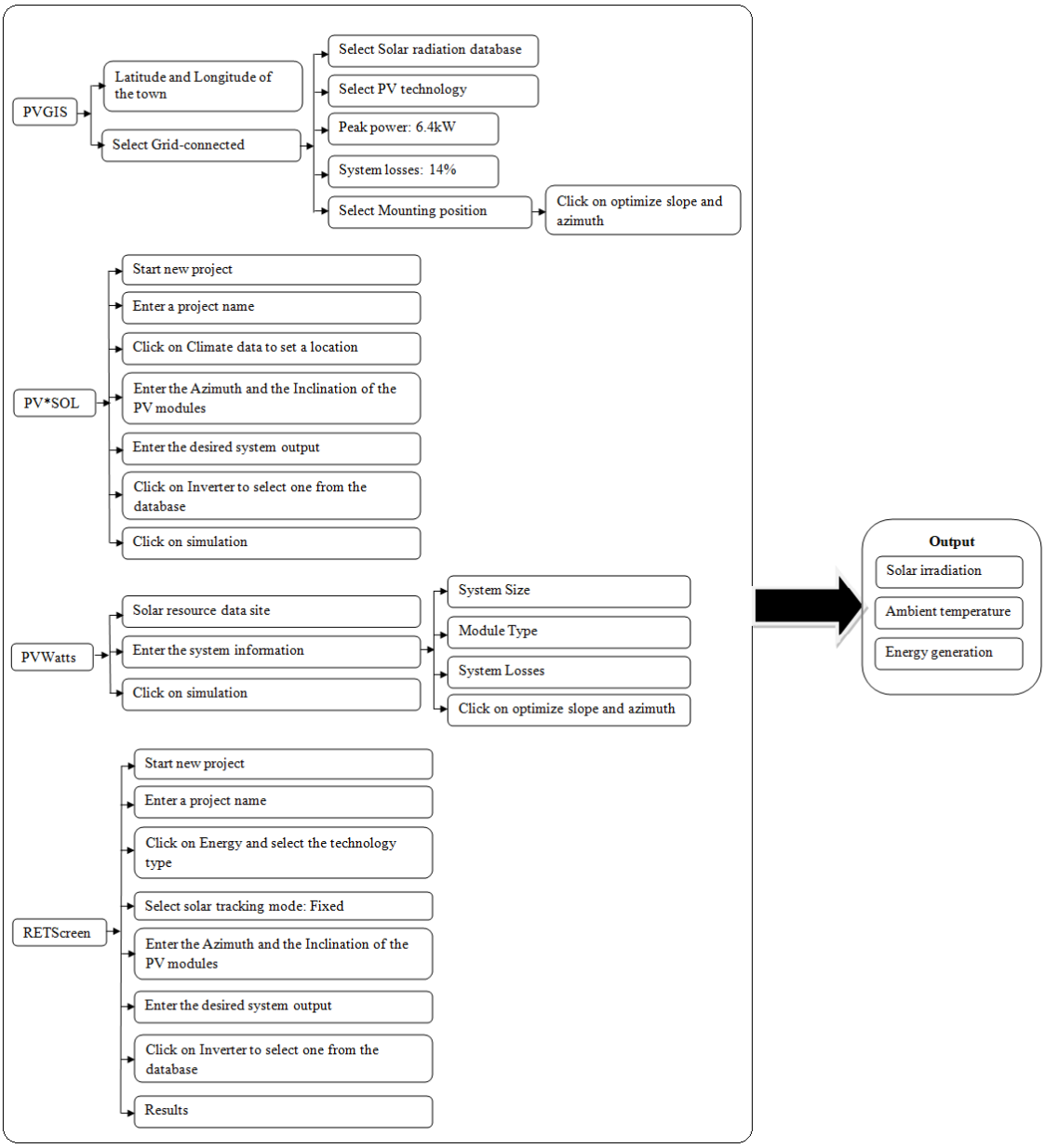

Figure 3. The input required and procedure of used simulation tools

3. RESULTS AND DISCUSSIONS

3.1. Solar radiation and air temperature data

Figure 4 illustrated the monthly variation of solar radiation (SR) and air temperature (AT), which were obtained using the PV*SOL tool. It is found that the SR and AT values are within the range of 122-230 kWh/m^2 and 13.95- 27.95℃, respectively. The maximum and minimum values of SR are recorded in July and January as shown in Figure 4.

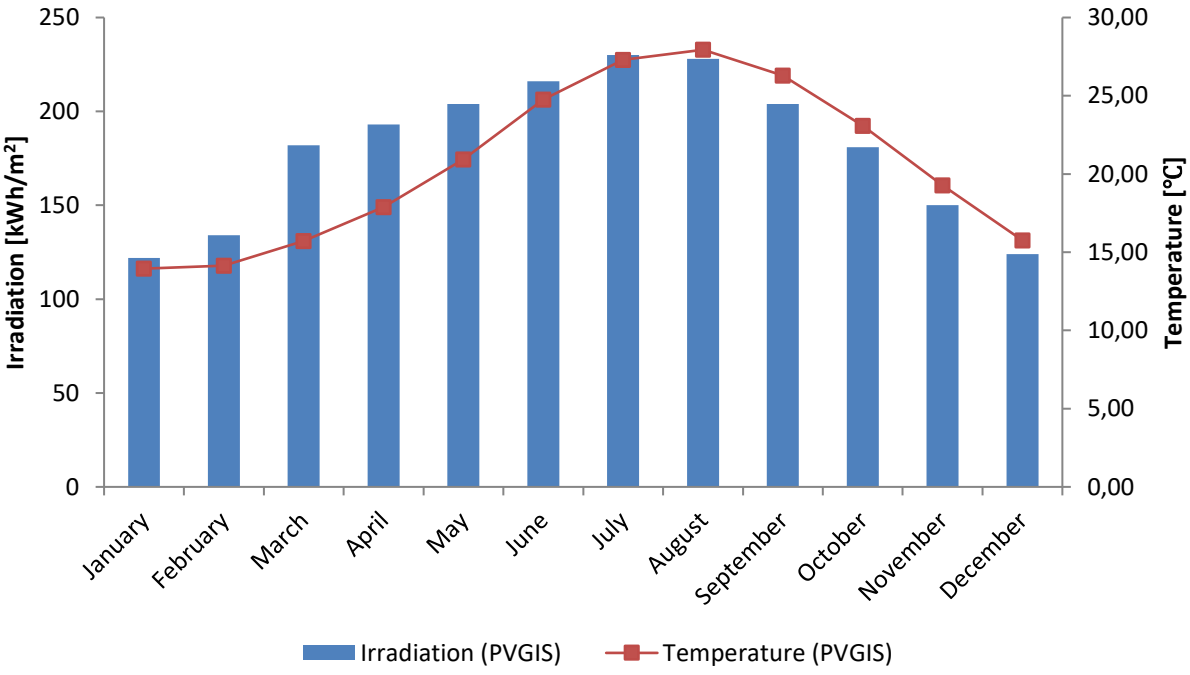

Figure 4. Monthly variation of SR and AT obtained from PVGIS

Moreover, Figure 5 shows the monthly variation of SR and AT obtained from PV*SOL. It is found that the highest value of SR is recorded in June with a value of 224 kWh/m2. Additionally, it is observed that the maximum value of AT is recorded in July and August with a value of 28℃.

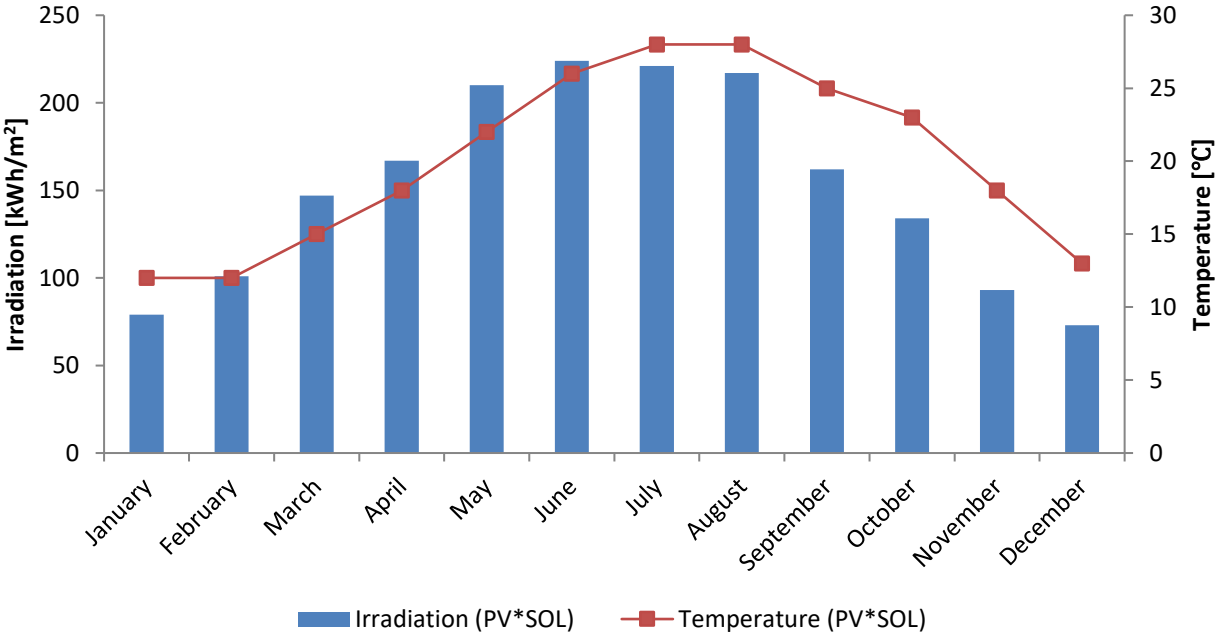

Figure 5. Monthly variation of SR and AT obtained from PV*SOL

In the PVWatts tool, it can be seen that the highest value of 201.36kWh/m^2 is recorded in June, while the minimum value of 26.25kWh/m^2 is recorded in December (Figure 6).

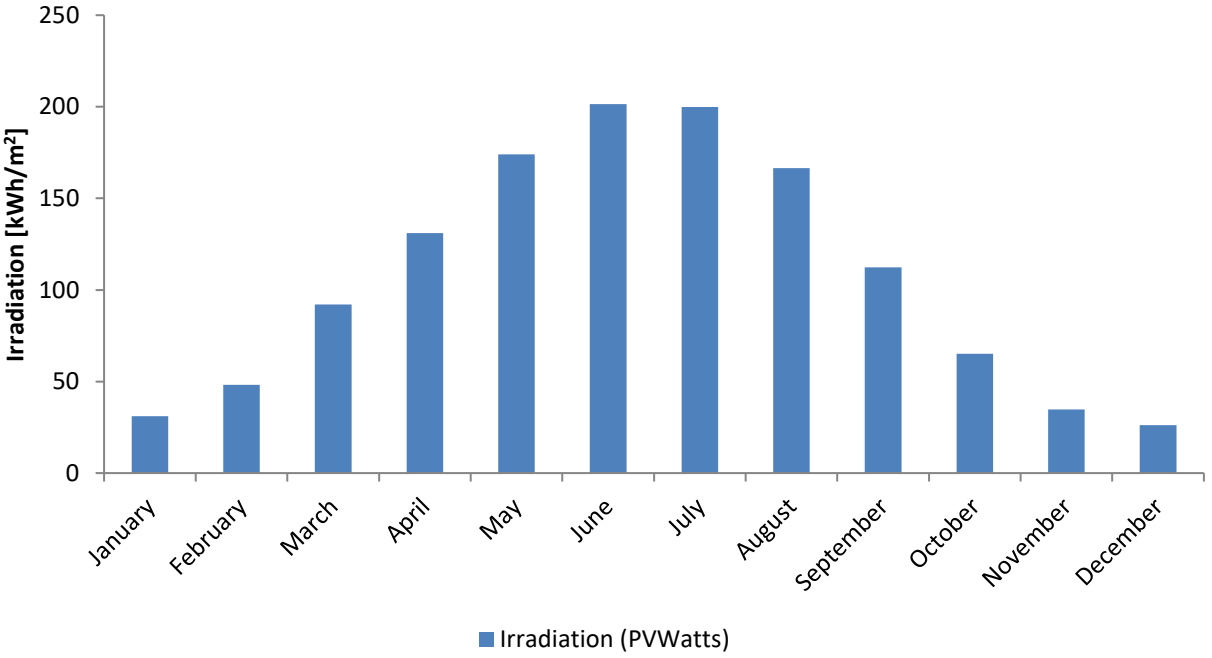

Figure 6. Monthly variation of SR obtained from PVWatts

Besides, the SR and AT data obtained from the RETScreen simulation tool are illustrated in Figure 7. It is found that the maximum value of SR and AT is obtained in July and August with a value of 245.83kWh/m^2 and 29.4℃, respectively.

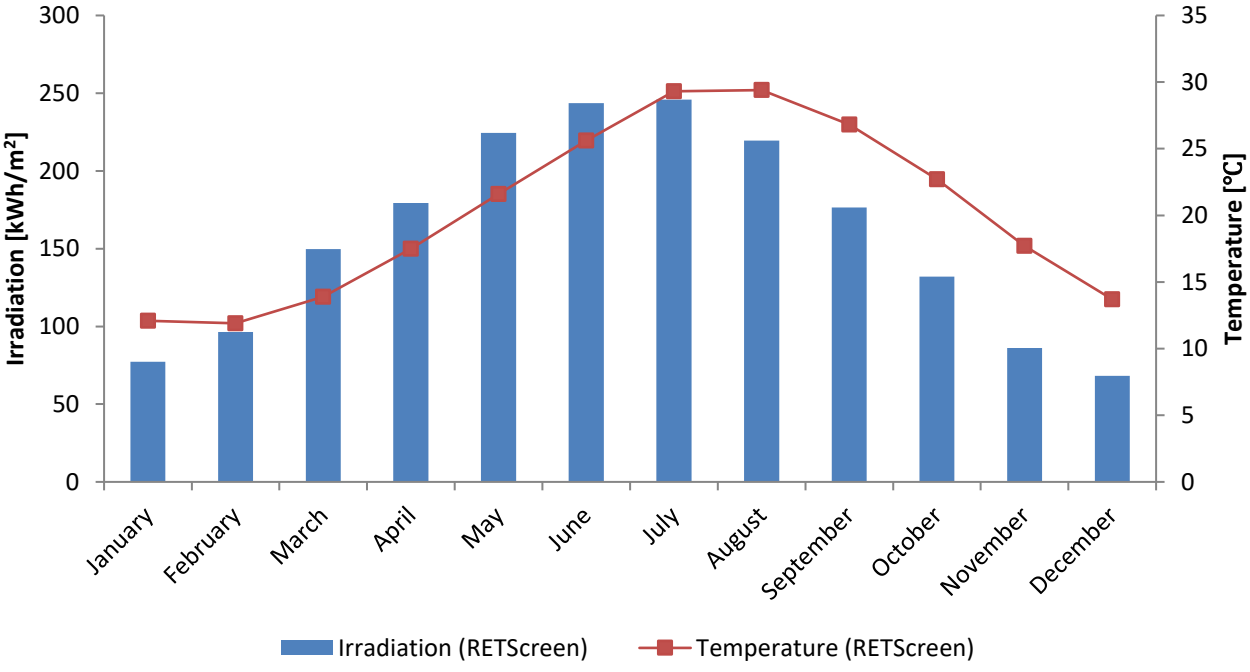

Figure 7. Monthly variation of SR and AT obtained from by RETScreen

3.2. Energy generation from various simulation tools

The mean monthly value of energy production (EP) and energy consumption (EC) using PV*SOL are illustrated in Figure 8. It is observed that the highest and lowest value of energy production is obtained in June and January, respectively. Additionally, the variation of EP obtained from PVGIS, PVWatts, and RETScreen simulation tools are shown in Figure 9. Considering the PVGIS Simulation, the highest and lowest value of EP is found in July and January with a value of 1090kWh and 641kWh, respectively.

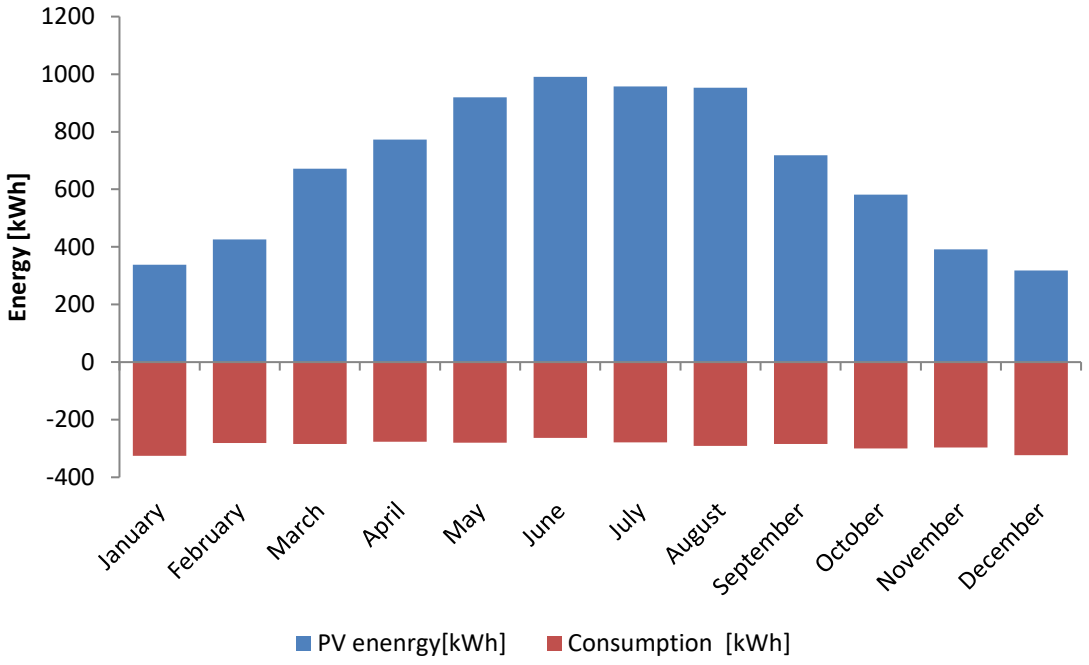

Figure 8. Monthly variation of EP and EC

Additionally, it is observed that the minimum and maximum values of EP are recorded in December and June, respectively by considering the PVWatts tool. Considering the RETScreen software, the highest value of 1064.132 kWh and lowest value of 532.836kWh are obtained in July and December, respectively.

Moreover, it is found that the total EP value is calculated to be 8040kWh (PV*SOL), 10708kWh (PVGIS), 3861 (PVWatts), and 10195.5 kWh (RETScreen). It is should be noted that the total energy demand for the selected household is estimated to be 3500kWh. Based on these findings, the amount of energy supplied by the PV system and fed into the grid is illustrated in Figure 10. For example, in PV*SOL, it is found that 39.37% of the energy demand is supplied by the PV system and 60.63% of the energy is covered by the grid. Additionally, it can be seen that 82.86% of energy is fed into the grid.

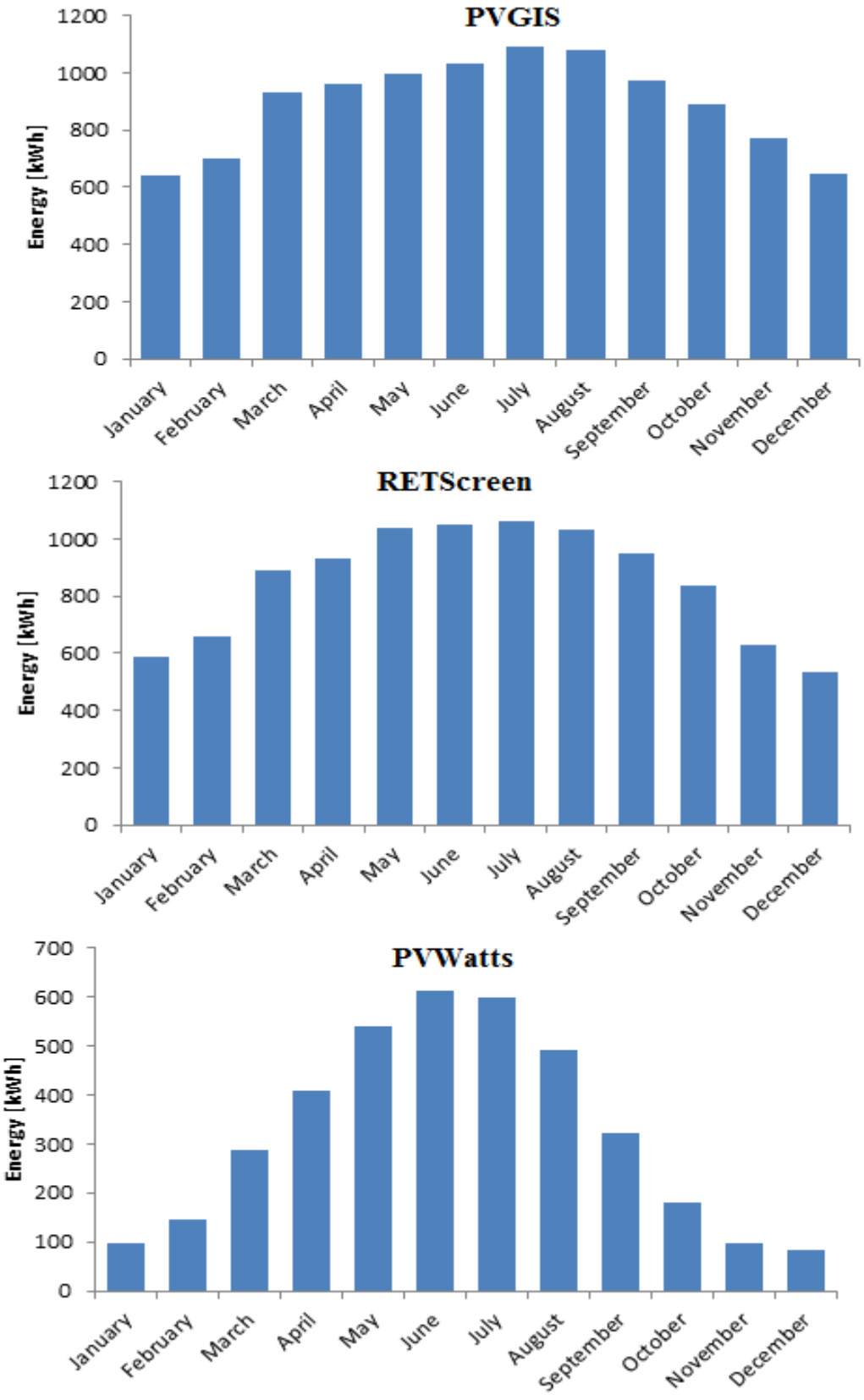

Figure 9. Monthly variation of EP value obtained from different simulation tools

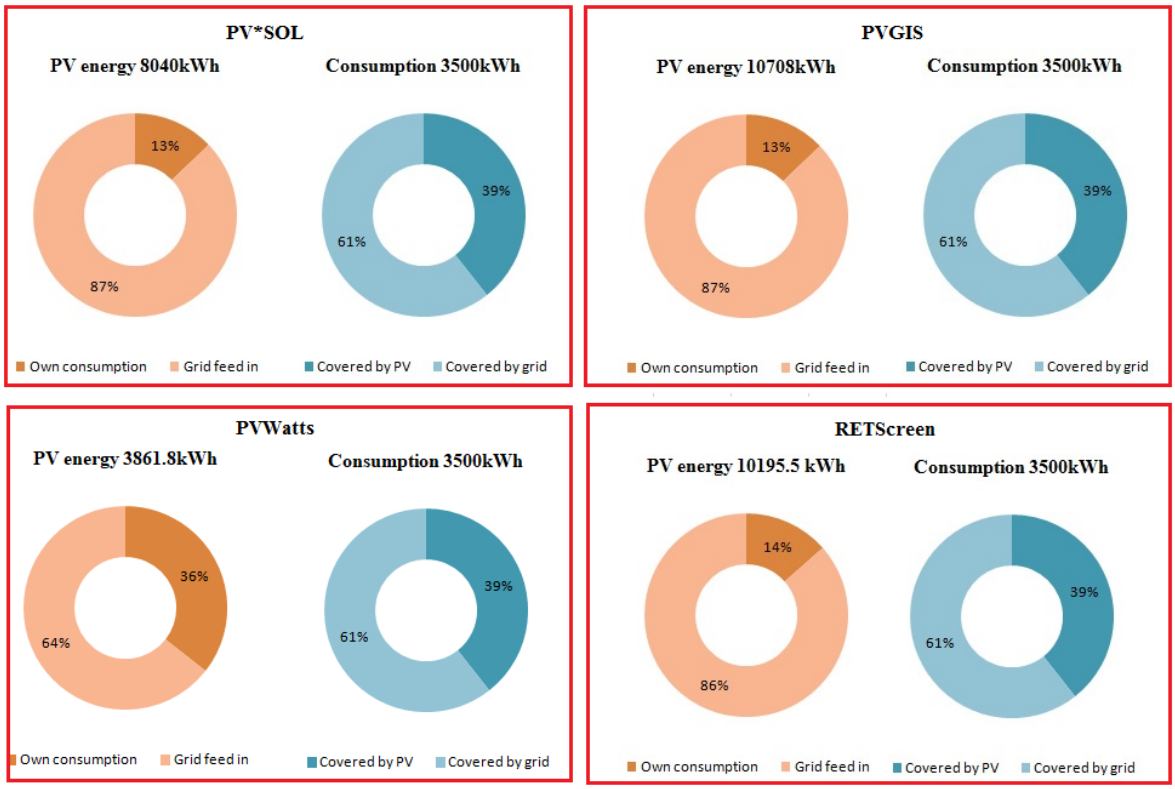

Figure 10. Power feed grid and power consumption covered by PV and grid

3.2. Performance comparison

Figure 11 illustrates the performance comparison of the developed system in the capital city of Iraq using various simulation tools. In terms of capacity factor (CF) and performance ratio (PR), it is found that RETScreen software has the highest value CF and PR compared to other simulation tools.

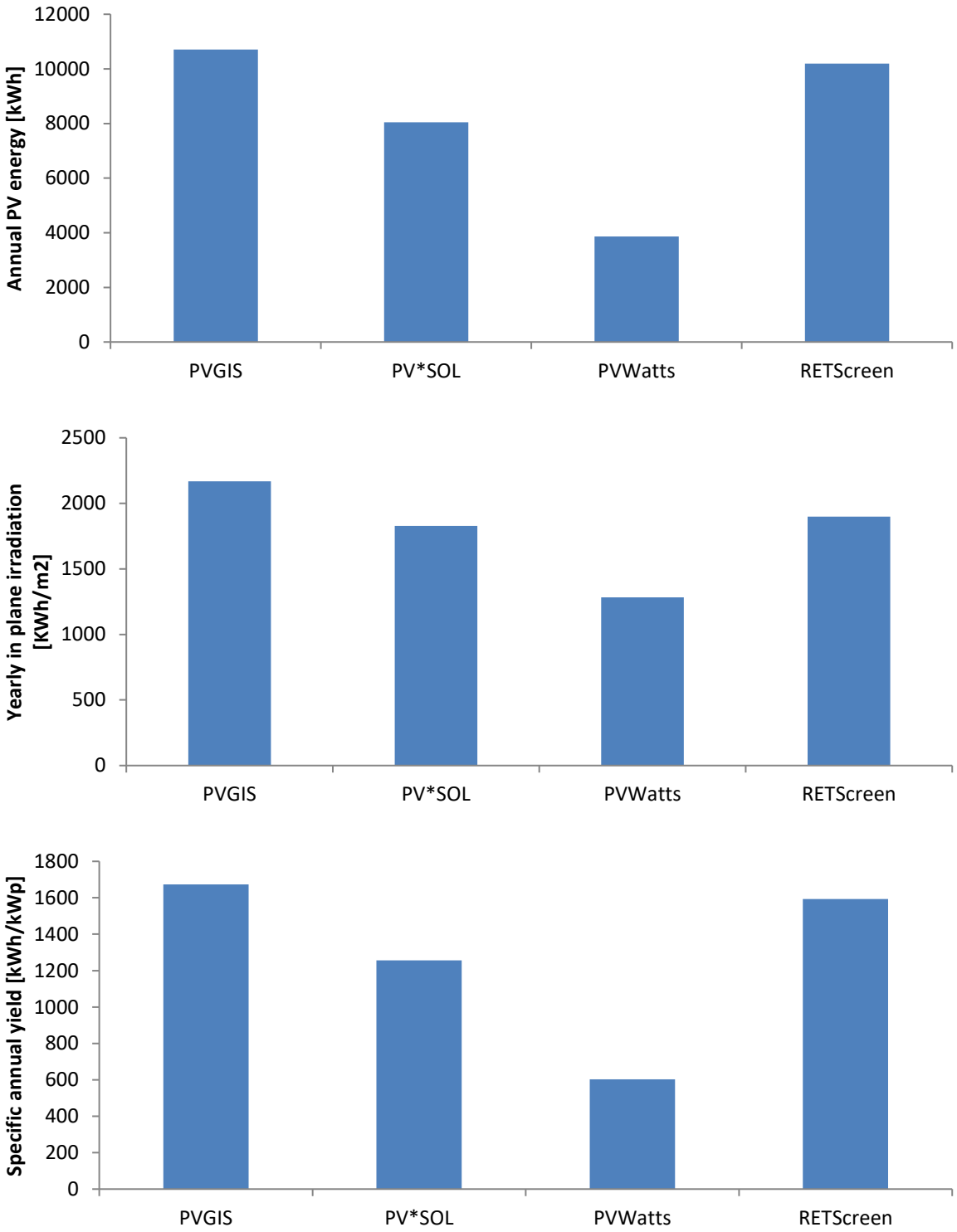

Figure 11. Performance of the proposed system using different simulation tools

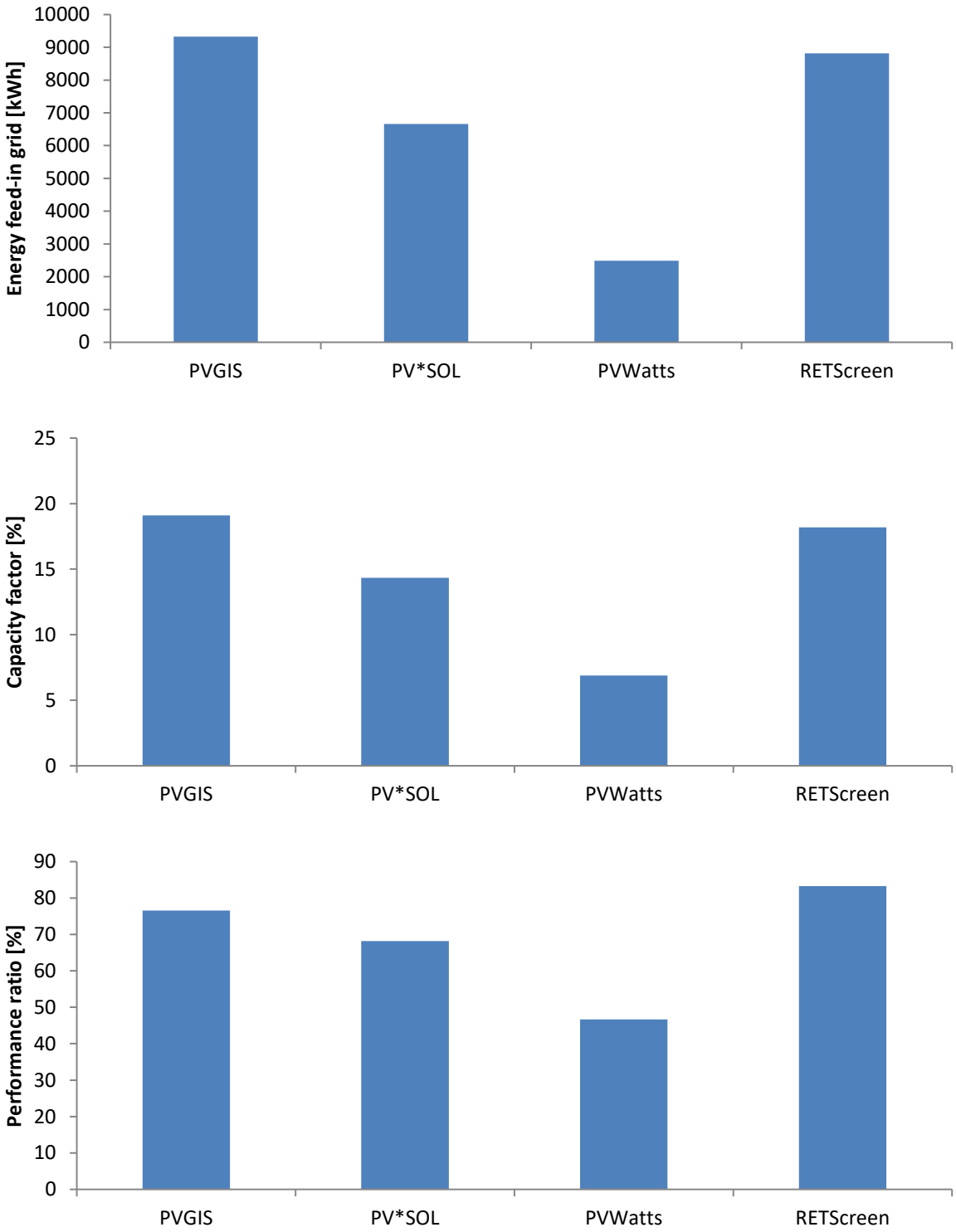

Figure 11. Continued

4. CONCLUSION

The performance of the 6.4kW grid-connected rooftop PV system was assessed using four simulation tools. Different parameters were used to evaluate the accuracy of the used simulation tools. The results indicated that the selected city has a huge value of solar radiation and it is suitable for installing a small-scale or large-scale PV system for generating electricity. Furthermore, the results demonstrated that RETScreen software could be considered reliable software and easy to use compared to other simulation

tools. Moreover, the results demonstrated that the developed system is considered a good solution for solving the electricity crisis and helping to reduce CO2 emissions in the country.

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