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SIZING PHOTOVOLTAIC SYSTEM IN DUHOK PROVINCE, KURDISTAN REGION OF IRAQ

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ABSTRACT:

Using clean energy sources instead of traditional methods of energy production is important to tackle global warming and climate change. As in the rest cities of the Kurdistan Region and Iraq, the national electricity outage crisis continues in Duhok Governorate and the production of energy via different sources is still needed.

This paper studies the simulation of two different types of solar energy systems on school roofs using the Homer Pro software. The first is a grid-connected system and the second, is an off-grid system for six different regions of Duhok Governorate, using the solar radiation data for each site.

Our findings confirm the preference for on-grid PV over an off-grid PV system at all sites. As the cost of energy in USD per kWh in both grid-tied and stand-alone models varies from one region to another, which is as follows: Amedi (0.089, 0.339), Kani Masi (0.091, 0.0338), Bamarni (0.093, 0.338), Mangesh (0.095, 0.349), Semel (0.107, 0.341), and Akre (0.127, 0.347).

The net present cost NPC in both grid-connected and grid-independent for 160 kW PV systems is as follows: Kani Masi ($217303, $260504), Amedi ($217621, $260710), Bamarni ($219007, $260587), Mangesh ($220167, $261239), Semel ($227566, $261222), and finally Akre ($238671, $262203).

KEYWORDS: Cost of Energy, Homer Pro Software, Net Present Cost, Photovoltaic System, Solar Energy.

1. INTRODUCTION

The rapid population growth and technological advancements have increased energy consumption in the last few years, particularly in the electricity sector. Furthermore, many rural and distant locations, especially in developing countries, are without electricity. Electricity generation should be boosted to address these issues. Fossil fuel resources provide a significant portion of the world's electricity. However, we must take into consideration that these traditional sources are finite and are rapidly depleting, threatening the global energy balance in terms of demand and export, and their emissions of greenhouse gasses have a significant impact on global warming and climate change (Shaahid & Elhadidy, 2007). It is thought that man-made climate change has increased the frequency of daily temperatures and contributed to the widespread intensification of extreme precipitation (Kannan, 2016). Sudan suffered from severe floods according to the Sudan Emergency Response Plan (ERP), on the other hand, these heatwaves caused droughts, as the drying up of important rivers such as (the Rhine and Po) in Europe (Dahlmann et al., 2022), and the Yangtze in China (Jiang et al., 2022) affected the commercial movement and the generation of hydraulic power.

Therefore, turning to green energy such as solar energy is a crucial way to reduce the impacts of such severe climatic conditions, since its more available, clean, and environmentally friendly (Rizwan et al., 2017). One of the renewable technologies capable of producing reliable, clean, scalable, and affordable energy is photovoltaic (PV) technology (Tyagi et al., 2013), which is a direct conversion of solar radiation to electrical energy. PV systems come in two types: grid-connected (on-grid) and standalone (off-grid) systems (Ramoliya, 2020). On-grid PV systems supply the electricity directly to the utility grid, working parallel with the traditional energy sources. These systems produce clean electricity close to the point of use without the need for batteries or distribution and transmission losses. However, in this paper, battery storage is used in both stand-alone PV systems and On-grid PV systems since Duhok Province suffers from electricity shortages.

In a stand-alone PV system, the generated electricity just feeds the intended load because there is no connection with the utility grid. If the PV array is unable to supply a load directly, a storage device, primarily a battery, is required (Ramoliya, 2020; Rekhashree & Rajashekar, 2018). When the power supplied by the PV panels exceeds the load requirement, the battery bank stores the excess energy and distributes it when the PV supply is not sufficient. This off-grid PV energy generation will be used to electrify a building or a household (Kandasamy et al., 2013). Another significant advantage of this type of PV system is to supply electricity to houses and farms in remote areas, where there are no electricity transmission lines (Aziz et al., 2019; Nag & Sarkar, 2018). Recently, interest in the PV system as a form of renewable energy has grown. In several studies, the ability of PV systems to produce energy has been assessed in terms of cost analysis, annual income, and Co_2 emissions for certain regions (Thotakura et al., 2020). When comparing the real-time monitored performance of a 1 MW grid-tied Photovoltaic system with the operational performance produced by the simulation software, the analysis shows that the differences between the operational data recorded for one year, and the evaluated energy calculated by the Photovoltaic Geographic Information System (PVGIS) software, the actual PV watts, and the PV system software were, respectively, 5.33%, 12.33%, and

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30.64% (Thotakura et al., 2020). The techno-economic feasibility analysis of installing a photovoltaic system for a clinic in a remote area of Iraq has conducted by (Al-Karaghouli & Kazmerski, 2010), the findings revealed that the net present cost (NPC) was $60,375 and, the optimal system cost was $50,700. (Hussein et al.,2013) systems over one year. Aziz et al. (2020) analyzed the environmental and techno-economic performance of a 5-kW residential solar PV microgrid system in Iraq using Homer Pro software, a house in Baghdad was chosen. Bamisile et al. (2019) studied data for a ten-megawatt PV plant based on economic variables for three different sites in Kurdistan Region was simulated and examined using RETScreen software. Saman Mirza Abdullah (2015) suggested a 200 kW PV system in Erbil. According to the study, installing PV systems nearby can drastically cut Co_2 emissions. Majeed et al. (2019) performed a techno-economic analysis of a two-MW grid-tied PV system in Chavy Land, Sulaymaniyah City. According to the simulation results provided developed a photovoltaic system design (PVSD) software, using Visual Basic, which is compatible with the climatic conditions of Iraq. The Ministry of Science and Technology has put a project into action that was developed utilizing this software. It calculates the results for a system, based on data collected from current

by the system advisor model software (SAM), the system made a major contribution to supplying the region with electricity and lowering the demand on the national grid. Below in Tables (1) and (2) are the values of energy costs in USD ($) per kWh and net present costs in ($) in both off-grid PV systems and grid-connected PV systems in several studies conducted in different sites in Iraq and other countries as well. It is well known that these values are affected by geographic locations due to the change in metrological data such as solar radiation, temperature, wind speed, etc., and technological developments such as efficiency and lifetime of the items of the PV system (PV panels, batteries, and inverters).

Table 1. COE and NPC of some studies conducted on stand-alone PV systems.

Study Area	COE $/kWh	NPC $	Reference
Erbil, Iraq	0.425	346,779	(Rasool et al., 2022)
Diyala, Iraq	0.51	32,194	(Hassan et al., 2016)
Baghdad, Iraq	0.903	32,015	(Al-Hamdani et al., 2016)
Tehran, Iran	0.796	321 m	(Hossein Jahangir et al., 2022)
Salalah, Oman	0.467	857,092	(Chaichan et al., n.d.)
Odisha, India	0.299	286166	(Pradhan et al., 2017)
Kedah, Malaysia	0.45	-	(Mansur et al., 2018)
Mubi, Nigeria	0.312	21,148	(Raji et al., 2021)

Table 2. COE and NPC of some studies conducted on grid-connected PV systems.

Study Area	COE $/kWh	NPC $	Reference
Baghdad, Iraq	0.165	29,713	(Aziz et al., 2020)
Makkah, Saudi Arabia	0.11	1.6 m	(Seedahmed et al., 2022)
Al baha, Saudi Arabia	0..0688	260,812	(Tazay, 2021)
Ouargla, Algeria	0.076	2.396 m	(Mokhtara et al., 2021)
Khulna, Bangladesh	0.0429	7,050	(Podder et al., 2018)
Bandung, Indonesia	0.043	2422.35	(Aprillia & Rigoursyah, 2020)
Kunming, China	0.116	179,876	(Li et al., 2018)

The electricity outage crisis in Duhok Governorate continues. According to the data obtained from the Duhok Electricity Directorate (*Directorate of Electricity \Duhok*, 2022), in 2021, it supplied the governorate with 637.44 MW on average, and the average demanded load reached 1500 MW in January. This means that it needs 862.56 MW more to avoid these continuous shortages. It is worth noting that the supplied electricity comes from the burning of fossil fuels process, which leads to environmental and health impacts. Despite the high potential of solar energy in Duhok Province as indicated in studies conducted on solar radiation in the Duhok Governorate as the global solar radiation is about 4.559 kWh/m^2/day (Kabao & Omar, 2022) with an average of 2778 hours of sunshine annually (Omar, 2010). However, the province has not exploited this advantage yet. This study aims to design a grid-connected photovoltaic system and off-grid photovoltaic system for a typical school, with a fixed load profile at different sites in Duhok Governorate. Depending on the meteorological data analyzed in our previous study (Kabao & Omar, 2022). The Homer Pro software, which is an abbreviation for "hybrid optimization models of multiple electricity renewables" (HOMER pro - microgrid software for designing optimized hybrid microgrids, 2022), is utilized for this purpose. The importance of this paper is to raise awareness of relying on clean energy among students, which are an important group in society, reducing the pressure on the national electricity grid, as well as benefit from the excess electricity in other projects. Since the working hours in schools do not excess entailed eight hours a day, in addition to closing schools for more than 100 days annually (holidays). Finally, benefit from the roofs of schools instead of using other lands that may be used for agriculture or other purposes.

2. MATERIALS AND METHOD

The software used in this study is Homer Pro, which is employed typically for designing, analyzing, and optimizing hybrid power systems in both cases either grid-tied (on-grid) systems or stand-alone (off-grid) systems. To run the software, the electric load profile, prices and components details (lifetime, capacity, etc.,), and meteorological data (global horizontal irradiance and temperature), have been inserted. Using the Homer library, which contains numerous components of renewable energy systems (RESs) and their specifications, the software enables adding non-existent components to its library as well.

The proposed designs are illustrated both grid-connected and off-grid systems in schematic diagrams (1 and 2). In these two figures, the short names of the components were used during the simulation, for the solar panel its Trina Vertex, for the inverter its ABB-MGS, and Iron2100 for the battery. Due to the outages in the utility grid, the advanced grid option is chosen for the proposed On-grid PV system (Figure 1), with assuming the schedule outages in Figure (3). The cost of electricity obtained from the national grid is assumed \$0.056/ kWh to buy and \$0.028 /kWh to sell back to the utility grid.

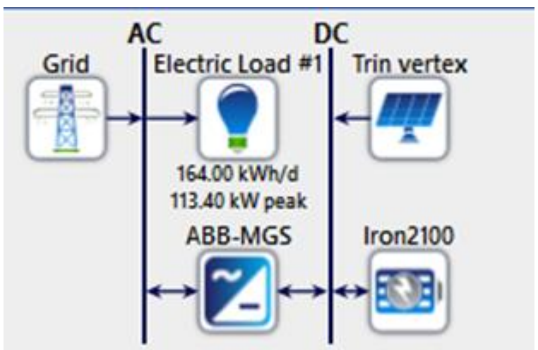

Figure 1. Schematic diagram of the grid-connected PV system.

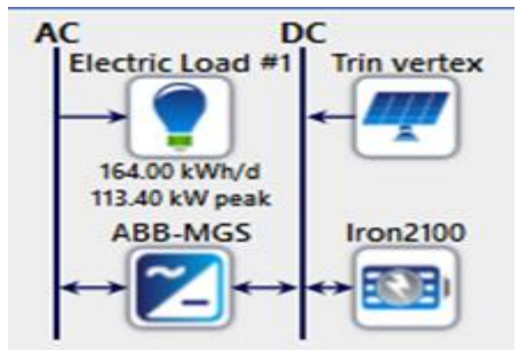

Figure 2. Schematic diagram of stand-alone PV system.

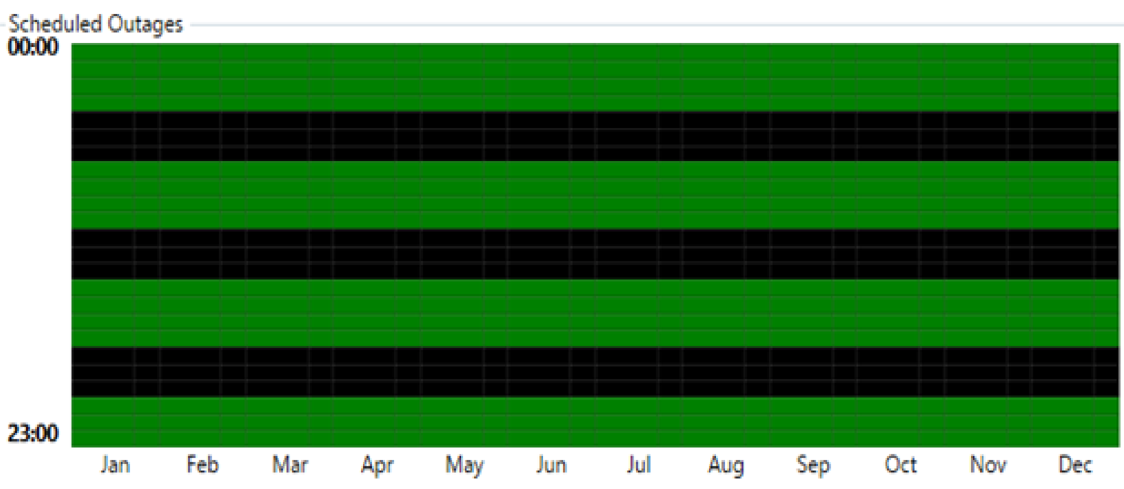

Figure 3. Scheduled outages of the proposed system.

Based on the information taken from the Duhok Electricity Directorate, daily, seasonal, and yearly electrical load profiles of the system are shown in Figure 4 (a, b, and c). As it is clear from Figure 4 (a), the peak load demand is working hours only. Figure 4 (b) presents the extent to which the load varies during the seasons of the year, and Figure 4 (c) shows the change in the load in an entire year. The technical data and economic details of the utilized components in the designed systems are shown below in Tables (3) and (4) respectively. Where the capital cost is the total installed cost of the component at the starting of the project. And replacement cost can be defined as the cost of replacing an item at the end of its lifetime; whereas, operating and maintenance costs (O and M) is the yearly value of operating and maintenance costs of the component (*HOMER*, 2022).

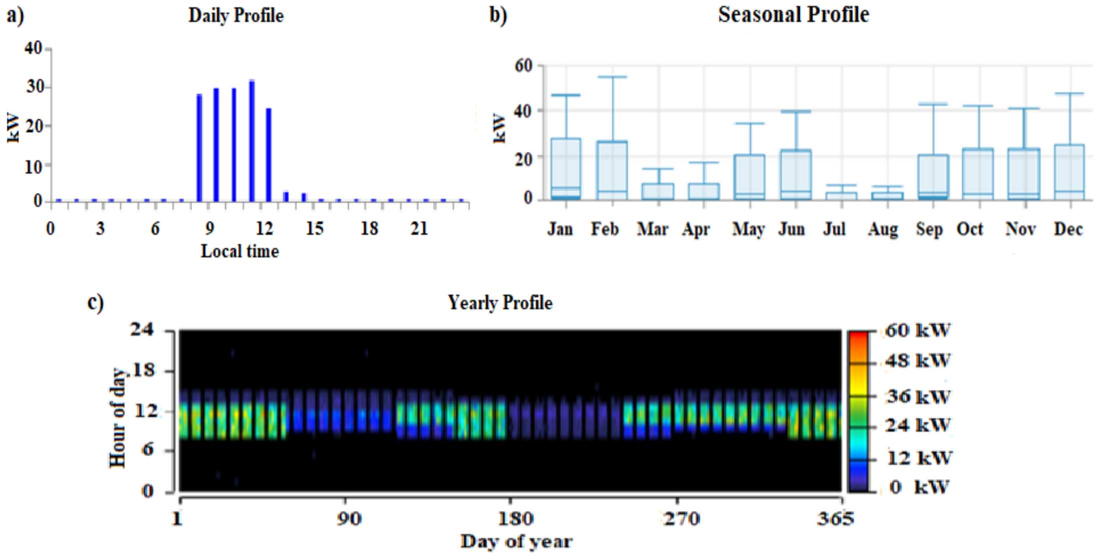

Figure 4. Load profile of the system; a) Daily profile, b) seasonal profile, and c) yearly profile.

Table 3. Specifications of the components used in the designed systems.

Components	Parameters	Values
1-PV Datasheet link (https://www.enfsolar.com/pv/panel-datasheet/crystalline/47840)	Model Panel type Lifetime Efficiency Operating Temperature	Trina Solar Vertex Flat plate 25 years 21.6% 43 C°
2-Battery Datasheet link (https://www.solar-electric.com/lib/wind-sun/Iron_Edison_Lithium_Iron_Manual.pdf)	Model Nominal Voltage Nominal Capacity Max. Capacity Roundtrip efficiency	Iron Edison LFP 2100Ah 48 volt 101 kWh 2100 Ah 95%
3-Inverter Datasheet link (https://www.fimer.com/microgrid-solutions/mgs100)	Model Capacity Lifetime Inverter Efficiency Rectifier Efficiency	ABB MGS100 60 kW 15 years 95% 95%

Table 4. Capital cost, replacement cost and operating and maintenance cost of RESs components

Components	Capital Cost ($)	Replacement cost ($)	O & M cost ($)
Trina Solar-Vertex TSM-DE21 670w	200	0	10
ABB MGS100	7199.83	5760	600
Iron Edison LFP 2100A	20000	16000	600

To study and compare the economic details of the designed systems in each site, the measured data of temperature and global solar radiation of the six stations (Amedi, Kani Masi, Bamarni, Mangesh, Akre, and Semel) are inserted into the software. To show the effect of meteorological data on economic factors in each site, the simulation is done using the search space option with a PV capacity of 160 kW, 6 batteries, and an inverter capacity of 120 kW with an initial capital cost of $182,161. The two main economic criteria used to rate different system configurations are net present cost (NPC) and cost of energy (COE). The COE determines the average cost per kWh of electrical energy in the system per year, whereas the NPC computes the present cost of installing and operating the entire system during the project lifetime minus the present income. The NPC and COE can be calculated from the following equations (Beitelmal et al., 2020; El-houari et al., 2021).

$$NPC = \frac{C_{(ann,tot)}}{CRF_{(i,N)}} \quad (1)$$

Where $C_{(ann,tot)}$ is the total annualized cost, CRF is the capital recovery factor, i and N are the yearly discount rate, and the lifetime of the project respectively.

$$COE = \frac{C_{ann,tot}}{E_{served}} \quad (2)$$

Where E_{served} is the annual electrical energy kWh used to feed the load.

3. RESULTS AND DISCUSSION

The simulation results obtained from the two proposed models PV/grid system and standalone PV system differ from one site to another, despite the fixed initial capital cost in both models. It is clear from the results that COE, NPC, and operating cost in the first model are lower than in the second one, as shown in Figures 5, 6, and 7, respectively. This is due to the electrical energy sale to the utility grid in sell-back process in the first model. Taking advantage of the smart meters, which are recently installed on the national grid in most regions of Kurdistan Region of Iraq, in contrast to the Off-grid model, which cannot benefit from excess electrical energy generated by photovoltaic panels. On the other hand, in the second model, the energy consumption is relying on photovoltaic technology and storage batteries only with 100% renewable energy fraction, while in the first model the renewable energy fraction varies from one site to another due to the solar resources of each site. Figure (5) presents the variation in the cost of energy of the six studied sites, in the On-grid model. The lowest COE is in Amedi \$0.089/kWh, which is close to the COE \$0.076/kWh obtained in a study conducted in Ouargla, Algeria by Mokhtara et al. (2021). The highest COE in Duhok Province is in Akre site with \$0.127/kWh. This value is comparable to the results presented in Table (2). Its lower than the COE of Baghdad \$0.165/kWh in a study conducted by Aziz et al. (2020) and higher than the rest results within the Table (2). The second lowest COE was in Kani Masi followed by Bamarni, Mangesh, and Semel at \$0.091/kWh, \$0.093/kWh, \$0.095/kWh, and \$0.107/kWh respectively. It is clear that these values are in the acceptable ranges too. In the stand-alone model, the lowest cost of energy is \$0.338/kWh in both Kani Masi and Bamarni. It is lower than the COE of Erbil, Diyala, and Baghdad \$0.425/kWh, \$0.51/kWh, and \$0.903/kWh as declared in studies by Rasool et al. (2022), Hassan et al. (2016), and Al-Hamdani et al. (2016) respectively. The COE in Amedi, Semel, Akre, and Mangesh is as follows: \$0.339/kWh, \$0.341/kWh, \$0.347/kWh, and \$0.349/kWh respectively. These values of COE are comparable to the COE values of the rest studies presented in Table (1).

NPC variation in both models is shown in Figure (6) below. Overall, the differences that occurred from one site to another especially, between Amedi, Kani Masi, and Bamarni are very slight due to their close geographic location to each other. In the grid-connected model, Kani Masi has the lowest NPC with \$217621 followed by Amedi with \$217621, Bamarni with \$219007, Mangesh with \$223733, Semel with \$227566, and finally Akre with \$238671, which is the highest NPC among the six sites. In the Off-grid model, the NPC in Kani Masi, Bamarni, and Amedi is as follows: \$260504, \$260587, and \$260710 respectively. In the remaining three sites, i.e., Mangesh, Semel, and Akre, the NPC is as follows: \$261239, \$261222, and \$262203.

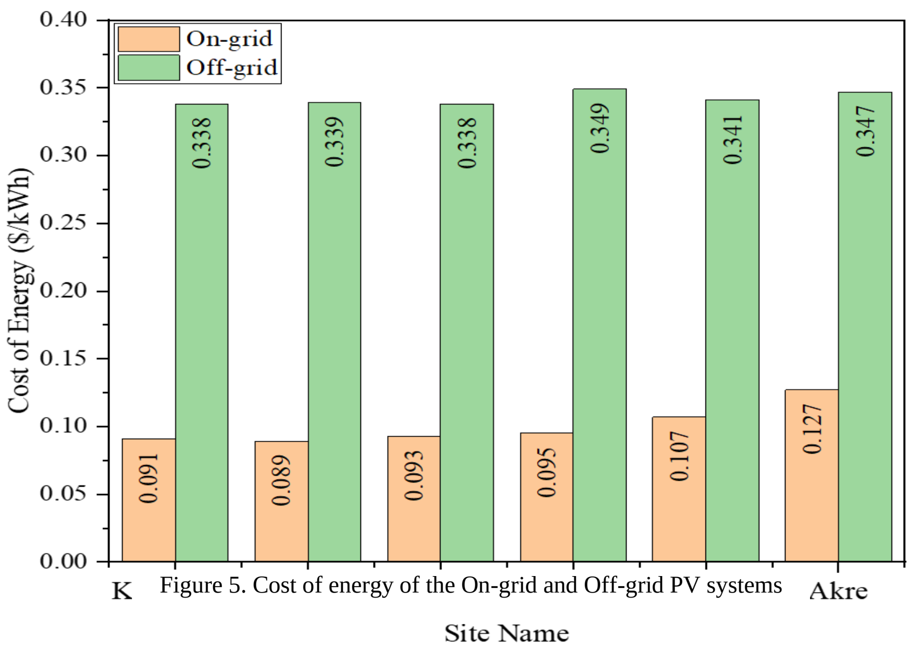

Figure 5. Cost of energy of the On-grid and Off-grid PV systems

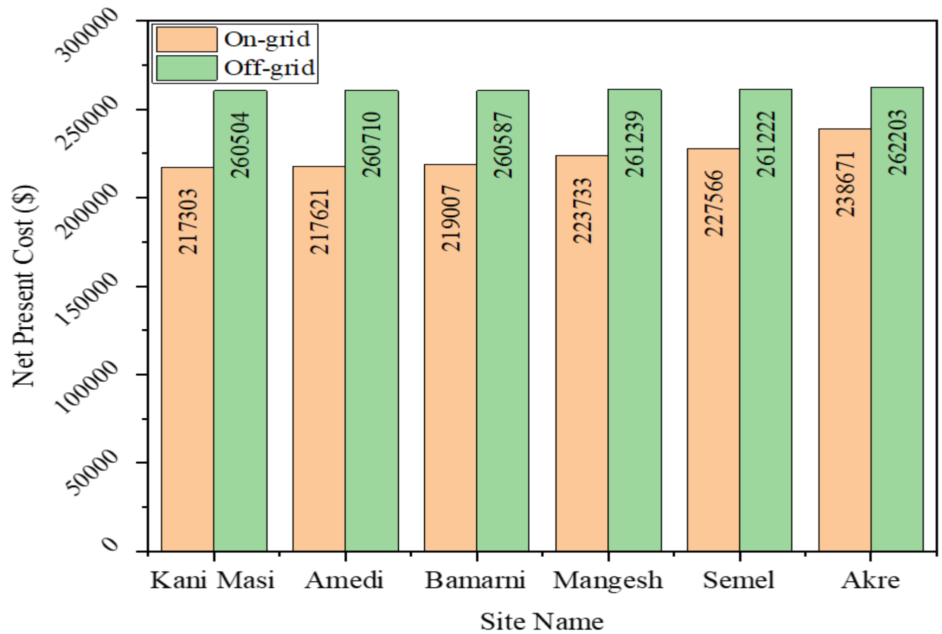

Figure 5. The net present cost of the On-grid and Off-grid PV systems.

The operating cost of the two systems is illustrated in Figure (7) below. In both scenarios, the operating cost experienced slight changes in the four sites Kani Masi, Amedi, Bamarni, and Mangesh. For the grid-connected model, the operating cost is as follows: $2719, $2743, $2850, and $3216, $3512, and $4371 for Kani Masi, Bamarni, Amedi, Mangesh, Semel, and Akre respectively. In the second scenario, it is clear that the difference in operating cost is not much between the different locations, as it is between $6067 for each of Kani Masi and Bamarni and $6192 for Akre. For the three other regions, Amedi, Semel, and Mangesh it is as follows: $6076, $6116, and $6117 respectively.

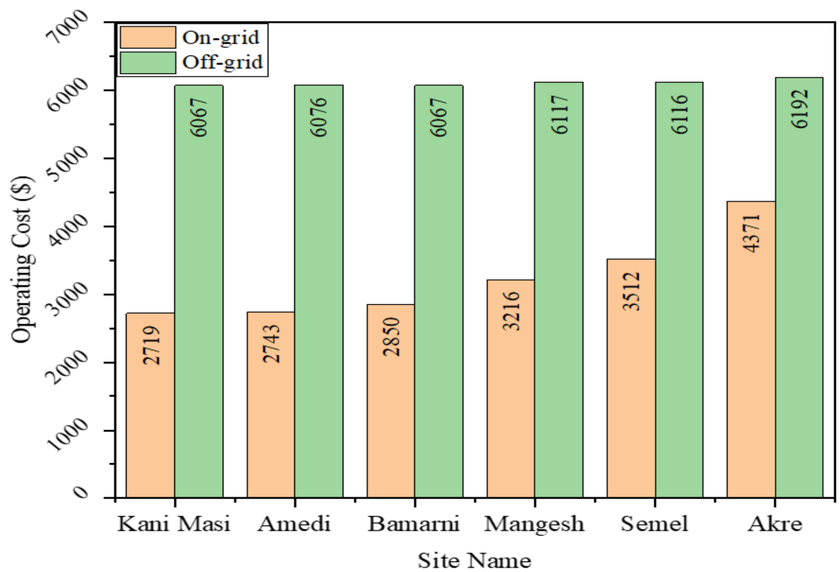

Figure 7. Operating cost of the On-grid and Off-grid PV systems

The results obtained through the search space simulation for the two different PV systems in the six different locations of Duhok Province confirm the preference for the grid-connected model over the stand-alone model economically, while the stand-alone PV system produces pure energy with a 100% renewable fraction in contrast to the On-grid PV system in which the renewable fraction varies from site to another as in Figure (8) bellow.

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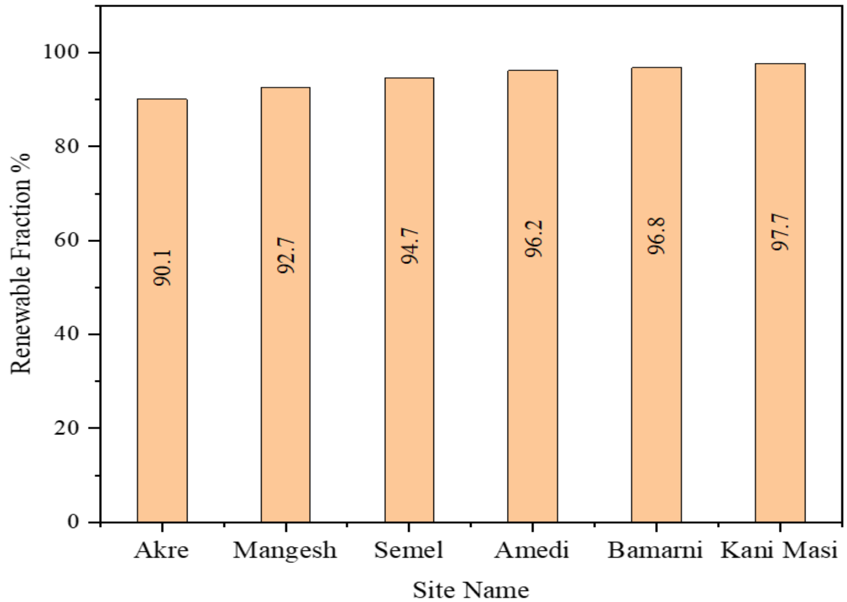

Figure 8. Renewable Fraction of the six studied sites.

The annual energy purchased from the grid and the energy sold to the grid in grid-connected PV systems for the studied sites is shown in Figure (9) bellow. As indicated in the graph, these values vary from one site to another due to the difference in their global solar radiation data (Kabao & Omar, 2022). That is why, a high fraction of energy can be sold to the grid during the school's summer holidays when global solar radiation has the highest values in sites (Amedi, Kani Masi, Bamarni, and Mangesh), which have noticeably higher energy fractions than Semel and Akre sites. This is due to the fact that those sites have lower global solar radiation (Kabao & Omar, 2022).

The purchased and sold energy values are as follow: Akre (14411, 85291) kWh/yr., Mangesh (13279, 122904) kWh/yr., Semel (8812, 105254) kWh/yr., Amedi (7197, 128971) kWh/yr., Bamarni (5863, 122797) kWh/yr., and finally Kani Masi (4296, 125254) kWh/yr.

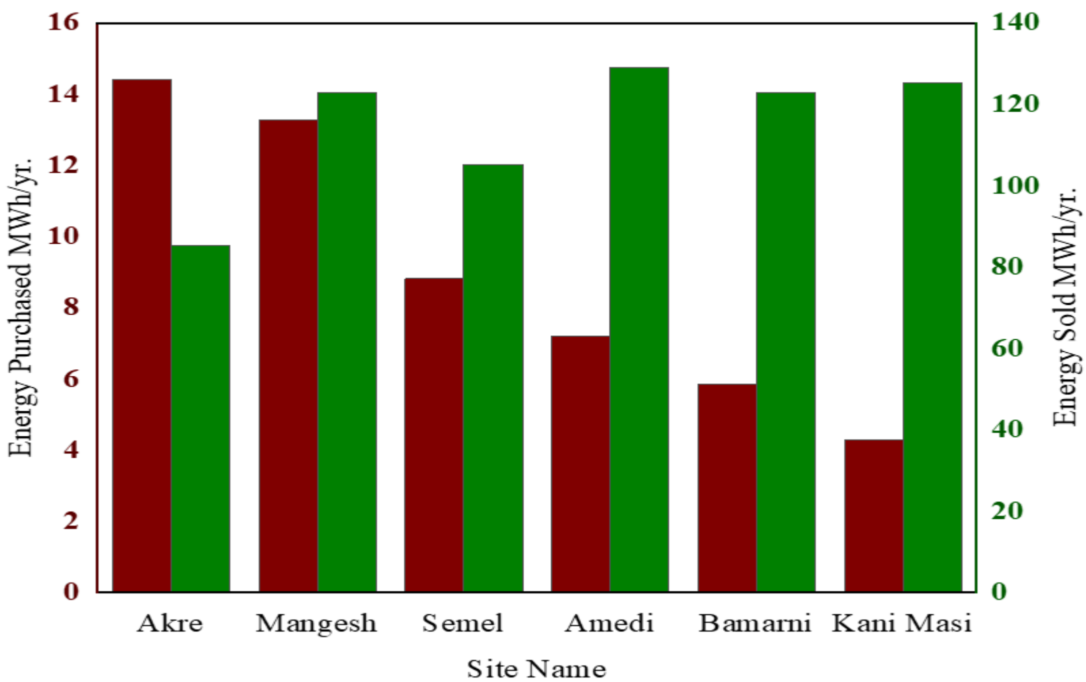

Figure 9. Purchased and Sold Energy in the studied areas.

4. CONCLUSION

This paper presents the simulated results of both On-grid and Off-grid PV systems on the roofs of schools in eight regions of Duhok Province. The simulation occurred based on real data of solar energy resources of these sites. Since each site has different solar resources, the power production of each location has changed accordingly. It is clear from the optimized results that the grid-connected model is more suitable than the off-grid model for the region, this is due to the low energy cost in the On-grid model compared to the off-grid model. The minimum energy cost in $/kWh in the grid-connected was in Amedi 0.089, which is slightly lower than in Kani Masi, Bamarni, and Mangesh, while the highest value of COE was in Akre 0.127 $/kWh followed by Semel. In the Off-grid PV systems Kani Masi, Amedi, and Bamarni have the lowest values of COE, respectively and Mangesh has the highest energy cost again. In both systems, the NPC values of the Kani Masi, Amedi, and Bamarni locations are lower than Mangesh, Semel, and Akre, respectively. Regarding the environment, both models have positive aspects for preserving the ecosystem. Although the national grid is involved in feeding the system in the second scenario when there is insufficient electricity from solar panels.

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5. REFERENCES

Al-Hamdani, A. H., Dawood, A. F., Abdullah, K. N., & Mousaui, S. M. (2016). Optimal sizing of photovoltaic systems using HOMER for Baghdad. *International Journal of Computation and Applied Sciences*, *1*(2), 1–6.

Al-Karaghouli, A., & Kazmerski, L. L. (2010). Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software. *Solar Energy*, *84*(4), 710–714.

Aprillia, B. S., & Rigoursyah, M. A. F. (2020). Design On-Grid Solar Power System for 450 VA Conventional Housing using HOMER Software. In *IOP Conference Series: Materials Science and Engineering* (Vol. 771, Issue 1, p. 012011). https://doi.org/10.1088/1757899x/771/1/012011

Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., Azmi, A., & Ramli, M. A. M. (2019). Optimization and sensitivity analysis of standalone hybrid energy systems for rural electrification: A case study of Iraq. *Renewable Energy*, *138*, 775–792.

Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., Mohammed, M. F., & Ramli, M. A. M. (2020). Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. *Energy*, *191*, 116591.

Bamisile, Olubiyo, Dagbasi, & Adun. (2019). Economic Analysis and Performance of PV Plants: An Application in Kurdistan Region of Iraq. *Int. Journal of Renewable Energy Development*, *8*(3), 293–301.

Beitelmal, W. H., Okonkwo, P. C., Al Housni, F., Alruqi, W., & Alruwaythi, O. (2020). Accessibility and Sustainability of Hybrid Energy Systems for a Cement Factory in Oman. *Sustainability: Science Practice and Policy*, *13*(1), 93.

Chaichan, M. T., Kazem, H. A., Mahdy, A. M., & Al-Waeely, A. A. (2016). Optimal sizing of a hybrid system of renewable energy for lighting street in Salalah-Oman using Homer software. *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, *2*(5), 157-164.

Dahlmann, H., Stephan, R., & Stahl, K. (2022). *Upstream-downstream asymmetries of drought impacts in major river basins of the European Alps* (No. EGU22-5841). EGU General Assembly 2022. Copernicus Meetings. https://doi.org/10.5194/egusphere-egu22-5841

Directorate of Electricity \ Duhok .(2022) .http://duhok province.com/ directorate of electricity duhok/

El-houari, H., Allouhi, A., Salameh, T., Kousksou., T., Jamil, A., & El Amrani, B. (2021). Energy, Economic, Environment (3E) analysis of WT-PV-Battery autonomous hybrid power plants in climatically varying regions. *Sustainable Energy Technologies and Assessments*, *43*, 100961.

Hassan, Q., Jaszczur, M., Mohamed, M., Styszko, K., Szramowiat, K., & Gołaś, J. (2016). Off-grid photovoltaic systems as a solution for the ambient pollution avoidance and Iraq's rural areas electrification. *E3S Web of Conferences*, *10*, 00093.

HOMER. (2022). https://www.homerenergy.com/products/pro/docs/latest/index.html

HOMER (2022). Microgrid software for designing optimized hybridmicrogrids. https://www.homerenergy.com/products/pro/index.html

Hossein Jahangir, M., Bazdar, E., & Kargarzadeh, A. (2022). Techno-economic and environmental assessment of low carbon hybrid renewable electric systems for urban energy planning: Tehran-Iran. *City and Environment Interactions*, *16*, 100085.

Hussein, B. N., Essa, I. A., & Hussein, D. J. (2013). Introducing a PV Design Program Compatible with Iraq Conditions. *Energy Procedia*, *36*, 852–861.

Jiang, W., Niu, Z., Wang, L., Yao, R., Gui, X., Xiang, F., & Ji, Y. (2022). Impacts of Drought and Climatic Factors on Vegetation Dynamics in the Yellow River Basin and Yangtze River Basin, China. *Remote Sensing*, *14*(4), 930.

Kabao, F. K., & Omar, O. S. (2022). Study of Global Solar Radiation in Duhok Province. *Science Journal of University of Zakho*, *10*(3), 93–97.

Kandasamy, C. P., Prabu, P., & Niruba, K. (2013). Solar potential assessment using PVSYST software. *2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE)*, 667–672.

Kannan. (2016). Solar energy for future world: - A review. *Renewable and Sustainable Energy Reviews*, *62*, 1092–1105.

Li, C., Zhou, D., & Zheng, Y. (2018). Techno-economic comparative study of grid-connected PV power systems in five climate zones, China. *Energy*. https://www.sciencedirect.com/science/article/pii/S0360544218320528

Majeed, A. R., Al Kez, D., & Ali, P. M. (2019). A techno economic analysis of 2MW on-grid solar power plant for tourist city Chavy–land. *Journal of Zankoy Sulaimani*, 105-114.

Mansur, T. M. N., Baharudin, N. H., & Ali, R. (2018). Sizing and Cost Analysis of Self-Consumed Solar PV DC System Compared with AC System for Residential House. *Indonesian Journal of Electrical Engineering and Computer Science*, *10*(1), 10–18.

Mokhtara, C., Negrou, B., Settou, N., Bouferrouk, A., & Yao, Y. (2021). Optimal design of grid-connected rooftop PV systems: An overview and a new approach with application to educational buildings in arid climates. *Sustainable Energy Technologies and Assessments*, *47*, 101468.

Nag, A. K., & Sarkar, S. (2018). Modeling of hybrid energy system for futuristic energy demand of an Indian rural area and their optimal and sensitivity analysis. *Renewable Energy*, *118*, 477–488.

Omar, O. S. (2010). *Estimation Of Global Solar Radiation In Duhok City And Characterization Of Two Types Of Silicon Solar Cells* [MSc]. Dohok University.

Podder, A. K., Hasan, M. R., Roy, N. K., & Komol, M. M. R. (2018). Economic Analysis of a Grid Connected PV Systems: A Case Study in Khulna. *European Journal of Engineering and Technology Research*, *3*(7), 16–21.

Pradhan, A. K., Mohanty, M. K., & Kar, S. K. (2017). Techno-economic evaluation of stand-alone hybrid renewable energy system for remote village using HOMER-pro software. *International Journal of Applied Power Engineering (IJAPE)*, *6*(2), 73.

Raji, L., Zhigilla, & Wadai. (2021). Using homer software for cost analysis of stand-alone power generation for small scale industry in Nigeria: A case study lumatec Aluminium products. *Current Journal: International Journal Applied Technology Research*, *2*(2), 90–102.

Ramoliya. (2020). Performance evaluation of grid-connected solar photovoltaic plant using PVSYST software. *Journal of Emerging Technologies in Accounting*, *9*(10), 71–97.

Rasool, N. M., Abbasoğlu, S., & Hashemipour, M. (2022). Analysis and optimizes of hybrid wind and solar photovoltaic generation system for off-grid small village. *Journal of Energy Systems*, 176–187.

Rekhashree, & Rajashekar. (2018). Study on design and performance analysis of solar PV rooftop standalone and on grid system using PVSYST. *International Research Journal of Engineering and Technology*, *5*(7), 41–48.

Rizwan, M., Shaikh, S., Waghmare, S. B., Labade, S. S., & Tekale, A. (2017). *A Review Paper on Electricity Generation from Solar Energy*. *887*(5). https://doi.org/10.22214/ijraset.2017.9272

Saman Mirza Abdullah, A. A. A. A. (2015). Economical Environmental and Performance Analysis for a 200 KW Ground Mounted Photovoltaic System: Koya City, Kurdistan of Iraq. *Journal of Engineering and Applied Sciences*, *3*(3), 72–84.

Seedahmed, M. M. A., Ramli, M. A. M., Bouchekara, H. R. E. H., Milyani, A. H., Rawa, M., Nur Budiman, F., Firmansyah Muktiadji, R., & Mahboob Ul Hassan, S. (2022). Optimal sizing of grid-connected photovoltaic system for a large commercial load in Saudi Arabia. *Alexandria Engineering Journal*, *61*(8), 6523–6540.

Shaahid, S. M., & Elhadidy, M. A. (2007). Technical and economic assessment of grid-independent hybrid photovoltaic–diesel–battery power systems for commercial loads in desert environments. In *Renewable and Sustainable Energy Reviews* (Vol. 11, Issue 8, pp. 1794–1810). https://doi.org/10.1016/j.rser.2006.03.001

Tazay, A. (2021). Techno-Economic Feasibility Analysis of a Hybrid Renewable Energy Supply Options for University Buildings in Saudi Arabia. *Open Engineering*, *11*(1), 39–55.

Thotakura, S., Chandan Kondamudi, S., Xavier, J. F., Quanjin, M., Reddy, G. R., Gangwar, P., & Davuluri, S. L. (2020). Operational performance of megawatt-scale grid integrated rooftop solar PV system in tropical wet and dry climates of India. *Case Studies in Thermal Engineering*, *18*, 100602.

Tyagi, V. V., Rahim, N. A. A., Rahim, N. A., & Selvaraj, J. A. /L. (2013). Progress in solar PV technology: Research and achievement. *Renewable and Sustainable Energy Reviews*, *20*, 443–461.