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Optimizing Hybrid Renewable Energy Systems for Electric Vehicle Charging Stations: A Feasibility Study in Iraqi Cities

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Abstract

The transition from conventional vehicles to electric vehicles (EV) represents an important development in the field of sustainable transportation. To prevent concerns about battery drain, the use of EVs requires the establishment of sufficient charging stations (CS) to recharge vehicle batteries. In Iraq, the infrastructure of electric vehicle charging stations (EVCS) is still limited, which reduces the reliance and reliability of EVs. This study assessed the economic efficiency and feasibility of optimizing hybrid renewable energy systems (HRES) for EVCS in three cities of Iraq addressing the growing demand for renewable energy due to concerns regarding fossil fuel depletion, environmental sustainability, and escalating conventional energy expenses. Hybrid Optimization Model for Multiple Energy Resources (HOMER) program was used considering weather data, load profiles, and equipment specifications. The results indicated that the system with a capacity of 300 kW of photovoltaic (PV), 100 kW of generator (GEN), and 78 units of batteries is found to be the optimal system in all three cities, with the lowest cost of energy (COE) around 0.025 $/kw. The renewable energy fractions of the optimal system in Mosul, Baghdad, and Basrah are 53%, 52.7%, and 52.7%, respectively. This setup achieves annual energy production of 704351 kWh from PV and 509681 kWh from GEN. This arrangement keeps the battery storage at a high state of charge (SoC), guaranteeing system stability and prolonging the battery's life. The system's capacity to reliably fulfil load requirements with less dependence on the DG. These results provide valuable insights into the deployment of HRES to achieve a more sustainable environment.

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Keywords: Photovoltaic; Electric Vehicle; Charging Station; Solar Energy; Hybrid Energy; HOMER; Optimization

1. Introduction

Energy occupies a pivotal place in the development process, as it enables investments and the launch of innovations and new industries; therefore, finding solutions to address the increasing demand for energy has become necessary [1]. Transportation consumes around 26% of the total energy consumption by many countries, and the big amount of that energy is coming from the burning of fossil fuels. This indicates that transportation is a key contributor to the issue of rising energy demand and global warming [2]. To participate in reducing harmful emissions to the environment, the European Union regulation sets goals to reduce emissions from vehicles for the years 2025 and 2030. One of these goals is reducing carbon dioxide emissions by 15% for street vehicles. The use of conventional vehicles must now be limited, even though numerous technologies and studies are being conducted to develop vehicle engines that reduce emissions and the consumption of fuel. These engines, which continue to run on fossil fuels, contribute to the same issues that we are trying to avoid. At the time when the British and French governments announced that the sale of all small traditional

vehicles that operate on fossil fuels is going to be banned by 2040, there is a great trend towards the use of electric vehicles (EV) [3]. In addition to the excellent performance of EVs, they require less maintenance and can significantly reduce greenhouse gas emissions compared to the use of conventional vehicles, which contributes to a greener and more sustainable future by reducing dependence on fossil fuels. EVs are also cost-effective in term of fuel economy, as the cost of electricity is lower than that of fuel, and electricity prices are stable compared to the fluctuations in fuel prices that have risen over the past decade. The number of EVs has reached 5 million in 2018 with an increase of 63%, and this increase gives a great indication of the increase in their spread and reliability [4]. Due to the severe lack of electric vehicle charging stations (EVCS) in most countries, the majority of EV owners prefer to rely on slow charging at home before leaving for work. However, travelling to distant locations becomes more problematic, necessitating the installation of EVCS to ensure a continuous supply of electricity without straining the existing electrical grid. Ironically, EVs are environmentally friendly, but traditional methods of charging EVs currently rely on electricity generated from fossil fuels, which causes large amounts of carbon emissions. Renewable energy sources (RES) are clean, reliable, and do not harm the living organisms, nor do they pollute the environment [5]. Therefore, integrating renewable energy sources into the EV charging infrastructure has become a pivotal step toward promoting sustainability in the field of transportation. By using renewable energy sources to charge EVs, we can significantly reduce the environmental impact, demonstrate our continued commitment to greener and more sustainable transportation options, and achieve energy independence.

The transition from traditional energy to renewable energy is a goal sought by governments and large companies, but during this quest for transformation, some obstacles must be faced and some problems must emerge. Among these obstacles, facing renewable energy systems such as solar panels are the high cost and the need for a suitable climate. In an effort to solve some of these problems, researchers have developed a new system known as HRES, meaning “Hybrid Renewable Energy Systems,” which is a system that combines two or more energy sources so that they work together in an integrated manner to provide a higher energy rate and efficiency than one source working separately. HRES is the subject of several research projects that combine two or more global sources. In [6], authors studied the techno-economic analysis of an off-grid system consisting of PV/Battery for EVCS in Madrid/Spain using Hybrid Optimisation Model for Multiple Energy Resources (HOMER) software [7]. The obtained results demonstrated that the off-grid system could reduce air pollution and was considered a viable option. Temperature effects were not considered in the study. In [8][9], authors optimised a PV/WT system for CS in Turkey, finding that a 200 kW of WT and 250 kW of PV configuration was the optimal one. In [10], authors conducted a techno-economic analysis of PV/GEN/Battery to estimate the annual cost of energy (COE), CO2 emission, and the system balance of CS in the United States and China using a simulation model in different scenarios. The results showed that the use of charging systems in front of shops, malls, and car parking during working hours is economically, environmentally, and technically feasible in all locations. PV fractions of 50% and 75% are feasible in studied places, while a fraction of 100% is possible but may incur high costs. In [11], authors compared between renewable and non-renewable systems using WT, PV, GEN, and batteries using HOMER software. As a result, an optimised system could reduce the net present cost (NPC) and CO2 by around 29.65% and 16 tonnes, respectively. In [12], authors designed an off-grid system comprising PV/biogas generators/batteries for EVCS in India using HOMER Pro software to determine the lowest COE and NPC. The results showed that the minimum COE and NPC were around 0.1902 $/kWh and 68,202 $, respectively. In addition, the system could reduce the annual CO2 emissions by around 44.16% and save around 13−17 $ per month for one vehicle compared to conventional CS. In [1][13], authors conducted a study to find the technical and environmental configuration of PV/GEN/battery for EV CSs in three cities of Ethiopia. The results showed that the optimal system was found with a minimum COE of 0.18 $, 0.196 $, and 0.188 $ and NPC of 2.85 M$, 2.72 M$, and 2.97 M$, respectively. In [14], authors investigated the techno-economic optimisation of an off-grid RES to meet the required electrical demand of CS in four cities of Qatar using HOMER software. The results showed that WT/PV/electrolyser/biogenerator/battery is the optimal system for the studied places, with COE ranges between 0.285 $/kW to 0.329 $/kW and NPC ranges between 2.53 M$ to 2.92 M$. In [15], authors conducted a techno-economic evaluation of a PV/WT system for vehicle CSs at a highway at six places in India using HOMER software. The results confirmed that the correct choice of location might reduce the COE and increase electrical energy production by 70%. In [16], authors optimised an off-grid re to electrify CSs across six regions in Turkey using HOMER software. As a result, among the provinces, Manisa is the optimal location to implement an EVCS with a yearly energy production of 3,049,337 kWh. The COE and NPC are found as 0.441 $/kWh and 7.24 M$, respectively. In [17], authors evaluated a stand-alone PV/hydrogen/battery system in Pakistan, finding that the PV/hydrogen/battery with a COE of 0.379 Rs/kWh is more cost-effective than the PV/hydrogen with a COE of 0.432 Rs/kWh[18]. In [19], authors optimised PV/WT/battery HRES for EVCSs at five different locations in China. The results showed that the PV/WT/battery system is the most optimal configuration in the five regions, with energy costs varying from one region to another. It also showed that the real number of EVs could affect the design of the CS [20].

While numerous studies have explored the integration of HRES in various contexts, there is no detailed study from a technical and economic standpoint on the possibility of investing in renewable energy sources and establishing an electric CS in Iraq that relies on renewable energy sources for its energy as an alternative to stations that rely on fossil fuels. For the mentioned reasons, this study addresses these shortcomings by utilising localised meteorological data to design and optimise a RES for EVCS based on solar energy in three of the biggest cities of Iraq, which have high population density and potential for EVs.

The Key Contributions of the paper in bullet points.

1. EV Charging Infrastructure Assessment in Iraq — Points to the current limitations in Iraq's EV charging station (EVCS) infrastructure and the need for reliable, sustainable solutions.
2. Analysis of HRES for EVCS: The economic efficiency and technical feasibility of employing Hybrid Renewable Energy Systems (HRES) to power Electric Vehicle Charging Stations (EVCS) in three Iraqi cities (Mosul, Baghdad, and Basrah) is explored in this article.
3. HOMER Software Optimization: Simulates and optimizes various configurations using the Hybrid Optimization Model for Multiple Energy Resources (HOMER) software taking into account weather data, load profiles, and equipment specs.
4. Determines Optimal System Configuration: Identifies the least cost configuration as 300 kW of photovoltaic (PV) panels, 100 kW generator, and 78 units of battery storage, with resulting low cost of energy (COE) of ~$0.025/kWh.
5. Tabulated Renewable Energy Contents: Lists renewable energy share for individual cities — Mosul 53%, Baghdad and Basrah 52.7% — indicating significant utility-scale renewable penetration.
6. Advanced battery storage use: Proves that the system keeps a high SoC (State of Charge) level for batteries, ensuring system stability and operational longevity.
7. Reduced Dependence on DG: Verification of meeting energy demands at a significantly lower dependency of conventional diesel generators.
8. Complying Sustainable Energy Policy: Offers a solid foundation for evidence-based decision making on potential policies to promote renewables-based EV infrastructure in Iraq and similar areas.

2. Methodology

2.1. Status of EVs in Iraq

In a country like Iraq, some vehicle selling companies began importing EVs to the Iraqi markets after the Iraqi government enacted laws encouraging people to buy environmentally friendly vehicles, as the customs duties imposed on EVs were reduced by up to 100% in 2019, but still EV owners suffer from the problem of a lack of CS, and establishing an EVCS will provide convenience to EV owners, which will help in its spread. Comparing to other countries, Iraq has a good chance to investigate in the field of solar energy due to its distinguished position.

2.2. Sizing methodology of EVCS

The sizing methodology of EVCS needs to know the Meteorological data, load demand that the system should meet, and components are using in the proposed system, with different prices and properties. When establishing an EVCS, the place must be easily accessible and suitable for drivers, and it is preferable for the station to be on main and highway roads to achieve the greatest benefits. Therefore, in this study, three stations will be taken, which are Mosul in the northern (36.3489° N, 43.1577° E), Baghdad in the central (33.3152° N, 44.3661° E), and Basrah in the southern (30.5042° N, 47.7825° E) of Iraq as a case study. According to the load, there are several types of EVs produced by companies in the international market, including Tesla, Toyota, BMW, Renault ZOE, and Mercedes. In the western region, the prevailing types are Toyota Highlander, Renault ZOE, and BMW. It is worth noting that the battery capacity and charging time vary from one vehicle to another. Among these models, the BMW i3 has a good battery capacity of 33 kWh. Since the station is on external roads, it is expected that many vehicles will be charged at the same time. There must be additional facilities at the station, such as restaurants and shops. In this study, 2 BMW vehicles are assumed to be charged in one hour at night and 4 vehicles at daylight. 20 kW is assumed to be for additional facility load, so the system should supply 86 kWh from 7 p.m. to 6 a.m. and 156 kWh from 7 a.m. to 6 p.m. The selected regions are shown in Figure 1.

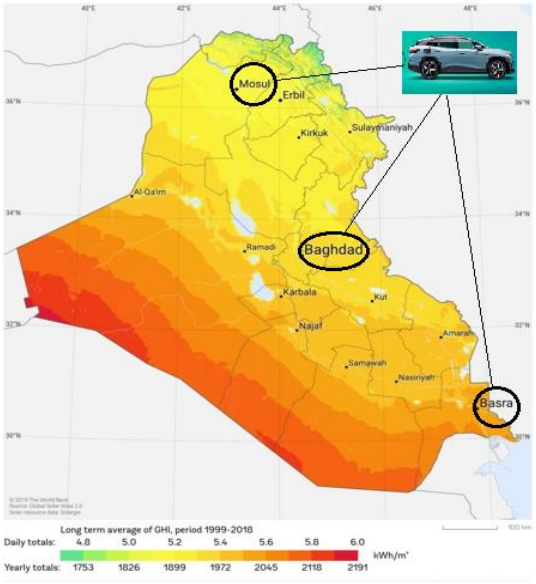


Figure 1. Selected regions in Iraq

2.3. Data collection

Iraq stands out with a high amount of radiation, with the monthly average reaching between 2.73 kWh/m^2/day and 7.57 kWh/m2/day in December and June, respectively, and this gives a good indicator for generating electrical power. The ambient temperature affects adversely the voltage output of the solar panel, so when the temperature of the solar panel increases, the efficiency of the panel decreases clearly. Figure 2 and Figure 3 show the monthly solar radiation and ambient temperature received in the studied places. These are obtained from the Ministry of Transport and Communications, General Authority for Meteorology, Climate Section of Iraq.

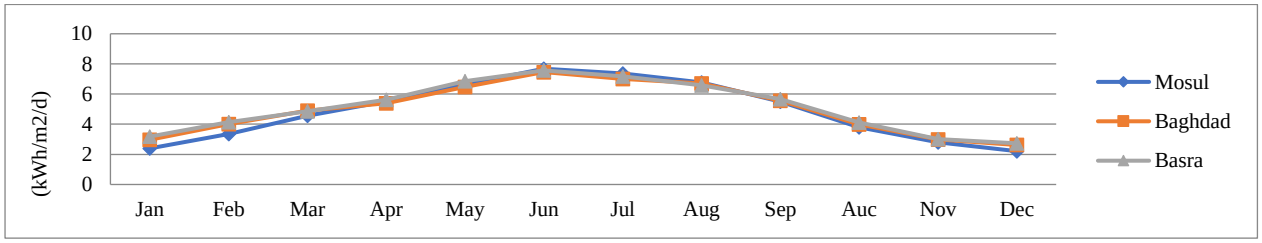


Figure 2. Solar radiation received in studied places (kWh /m2/d)

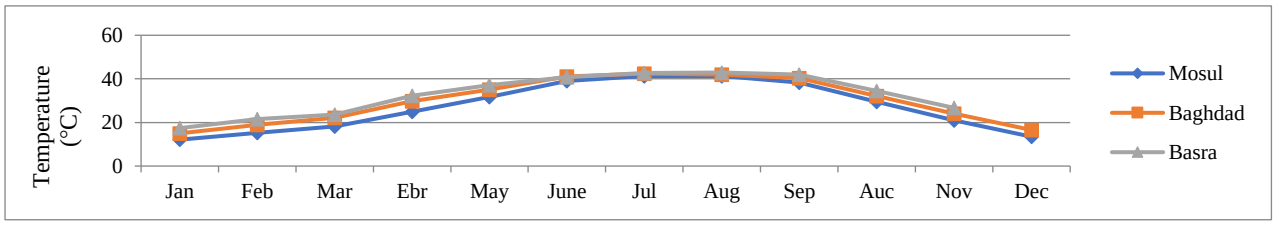


Figure 3. Monthly ambient temperature (°C)

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2.4. System configuration

The schematic diagram of the proposed system is shown in Figure 4. The specifications of parameters are presented in Tables 1 and 2.

Table 1: The system components characteristics[31]

omponent	arameters	alues
V (Generic Flat Plate PV)	Capacity (w)	1 kW
	operation temperature(°C)	45
	Temperature coefficient (%/°C)	-0.41
	Efficiency (%)	17.49
	Derating factor (%)	88
ystem converter	Efficiency (%)	90
	Lifetime (years)	15
attery	Nominal capacity (kWh)	6.91
	Round trip efficiency (%)	95
iesel generator	Fuel type	diesel
	Capacity (kW)	100
	Fuel curve intercept (L/h)	36.8
	Fuel curve slope (L/h/kW)	0.278
	Minimum load ratio (%)	20

Table 2: Costs of system components

omponent	ifetime	urchase cost	eplacement	laintenance cost
V	25 years	1000($)	-	25 $/year
EN	15000 h	40000$	40000 ($)	0.01 $/h
attery	8 years	600	500($)	0
onverter	10 years	180 ($/kW)	175 ($/kW)	0

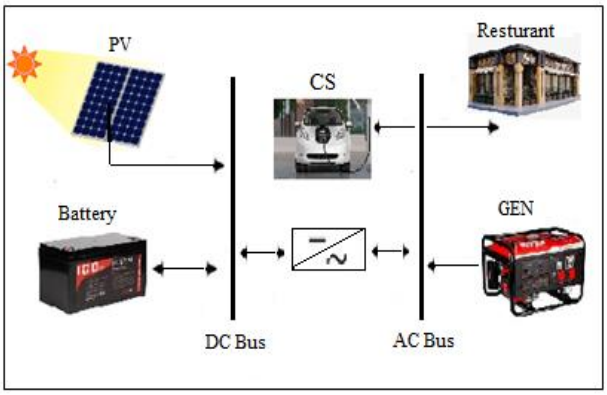


Figure 4. Schematic diagram of the system

2.5. Hybrid system modelling

2.5.1. Modelling of PV

The PV output can be calculated by Eq. (1)[21]-[22].

$$\boldsymbol{P_{pv} = Y_{pv} F_{pv} \times \frac{G}{G_{REF}} \times \left[1 + K_t\left(T_c - T_{c,STC}\right)\right]} \quad (1)$$

Where Y_{PV} is the PV rated power, F_{pv} is the derating factor, G is the solar radiation (W/m^2), G_{REF} is the reference radiation (1000 W/m^2), $T_{c,STC}$ is the reference temperature (25°C), Kt is the temperature coefficient (%/°C), and T_c is the PV surface temperature.

2.5.2. Battery model

The lifetime of the batteries, which are affected by the number of times they are charged and discharged (number of cycles), is calculated by Eq. (2) [23].

$$\boldsymbol{R_{batt} = MIN\left(\frac{N_{batt} x Q_{lifetime}}{Q_{thrpt}}, R_{batt,f}\right)} \quad (2)$$

where R_{batt} represents the lifetime of the storage (year), N_{batt} is the number of batteries, $Q_{lifetime}$ is the single storage lifetime (kWh), Q_{thrpt} is the annual storage throughput (kWh/year), and $R_{batt,f}$ is storage float life (year). The battery wear cost refers to the cost of cycling energy through the storage bank. If the storage properties indicate that the storage life is limited by throughput, the program assumes the storage bank requires replacement when its lifetime throughput equals its total throughput. Therefore, with each kWh of throughput, the storage bank approaches its required replacement. Storage wear cost is calculated by Eq. (3).

$$\boldsymbol{C_{bw} = \frac{C_{rep,batt}}{N_{batt} x Q_{lifetime} x \sqrt{\eta_{rt}}}} \quad (3)$$

where $C_{rep,batt}$ is the replacement cost of storage bank (USD), N_{batt} is storage bank number of batteries, $Q_{lifetime}$ is the single storage lifetime throughput (kWh), and η_{rt} is storage round trip efficiency (fractional).

2.5.3. Modelling of GEN

The efficiency and the hourly fuel consumption are the factories that affect the choosing of GEN in designing of HRES, as shown in Eq. (4)[24]-[25]:

$$\boldsymbol{Q(t) = a.P(t) + b.P_r} \quad (4)$$

Where Q(t) represents the GEN fuel consumption in L/h, P (t) is the GEN generated power in Kw and P_r is the GEN rated power, a and b are constants and taken as 0.246 and 0.08415, respectively, which represent the coefficients of fuel consumption.

2.5.4. COE model

The COE is the average cost of electricity per kWh. It is calculated by Eq. (5)[26]-[27].

$$\boldsymbol{COE = \frac{C_{ann,tot}}{E_{ann,tot}}} \quad (5)$$

Where $\mathbf{C_{ann,tot}}$ is the total annualised cost of the system ($/yr) and $\mathbf{E_{ann,tot}}$is the electrical served during system lifetime (kWh/year)

2.5.5. NPC model

NPC represents all expenses incurred by the system during the lifetime of the system. It can be calculated by Eq. (6) [28]-[27].

$$NPC = \frac{C_{ann,tot}}{CRF(i,R_{proj})} \quad (6)$$

$C_{ann,tot}$ represent the total annualised cost (USD/year), i is the real interest rate (%), CRF is the capital recovery factor, and R_{proj} is project lifetime (year). The capital recovery factor can be calculated by Eq. (7) [29].

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1} \quad (7)$$

where i is the real interest rate (%) and n is the number of years.

2.6. Power Management

The power management of a power system is slightly critical because the system may consist of renewable and traditional sources with a battery as a backup, so managing the power supplied from renewable energy and charge/discharge of the battery should be taken into account and chosen properly. The strategy of controlling the power is summarised in three points:

- The renewable sources supply electricity to the load, and the excess electricity is used for charging the battery.
- When renewable sources could not able to meet the load. Battery will discharge to cover the shortfall.

When the battery reaches its minimum SoC and there is a shortage, GEN will compensate for the shortfall.

2.7. HOMER pro software

The HOMER software is an important tool used in designing single-source and hybrid electrical systems by combining traditional energy sources (fossil fuels) and renewable sources (solar, wind, and hydro energies) in addition to energy storage units and inverters. This tool can be used in several applications, for example, residential homes, university campuses, communication towers, and EVCS. It was done by Modern National Laboratories/USA [30]. This tool requires several inputs to analyse the system, including climate data such as solar radiation, wind speed, and temperature, in addition to the specifications and prices of the components used in the system. It can be isolated and connected to the network systems. It can also give different configurations to obtain the optimal system in terms of the total cost of the project and the cost of energy produced.

3. Results and Discussion

In this section, the results of different system configurations were presented. After setting the initial conditions of the proposed system in Baghdad, which were: load demand is 2952 kWh/day, annual average solar radiation is 8.49 kWh /m2/day, and annual average temperature is 28.054 c. Project lifetime assumed to be 25 years. Nominal discount rate (NDR) is 6% and annual capacity shortage is zero percentage. Two systems among different configurations are analysed from technical, environmental, and economical sides, namely: GEN and PV/GEN/Battery to show the comparison between electrical sources using conventional energy generation and combining fossil fuel sources with solar energy. The sensitivity is included, which represents the effects of changing some parameters on the system's accuracy. The result of the first station (Baghdad), which is taken as a reference, is presented in the section below.

3.1. Baghdad station

3.1.1. Standalone GEN system

In this configuration, the station depends 100% on the GEN for supplying electricity. The result showed that the optimal system with the lowest cost of energy was found with two GENs, as shown in Figure 5. The first GEN has a capacity of 100 kilowatts, through which it can cover the required load during the night. The second GEN, whose capacity is 80 kilowatts, covers the load during the day in cooperation with the first GEN.

The electricity production was found to be 1077840 kWh/yr with zero unmet electric load. The COE and the capital cost are 0.03$/kWh and 1600000$, respectively. The total fuel consumption over the project period is 347616 L, and the net present cost of the project is 1350000.

		Cmns100 (kW)	CAT-100 (kW)	Dispatch	NPC ($)	COE ($)
		100	80.0	LF	$1.35M	$0.0336

Figure 5. Optimisation result of HOMER

3.1.2. PV/GEN/battery system

This configuration examines the impact of combining PV modules with GEN. Batteries are needed to store the excess energy and use it at another time when PV capacity cannot meet the load demand. The system with a capacity of 300 kW of PV, 100 kW of GEN, and 78 units of batteries is found to be the best system (the optimal system with the lowest COE and NPC as shown in Figure 6) with a total electric production of 1214032 kWh/yr and a capital cost of 17775391$.

Although the initial cost of a system that contains only diesel is lower than a hybrid system, however, during the lifetime of the project, which is 25 years, the energy production rate in the hybrid system is lower than that of a conventional energy generation system due to the long lifetime of the project, and this is an incentive for the increase in the use of renewable energy sources.

Both configurations are reliable and can meet the load demand, but since the main objective of designing a HRES is to design a reliable system with less costs and harmful gas emissions, compared with GEN and PV/GEN/battery, in this location, PV/GEN/battery is the optimal system for meeting the electrical load demand for CS requirements for the studied site.

Architecture								
	CS6U-340M (kW)	Cmns100 (kW)	PowerSafe OPzV 2500	Converter (kW)	Dispatch	NPC ($)	COE ($)
	300	100	78	172	LF	$1.02M	$0.0255

Figure 6. Optimisation result of HOMER

3.1.2.1. Power Generation

The monthly average energy generated by the optimal system, which consists of 300 kW PV, 100 kW GEN, and 78 batteries for one year, is shown in Figure 7. PV generates around 704351 kWh/year (52.7%), while GEN generates around 509681 kWh/year (47.3%) of the total production. The total electricity consumption is 1077480 kWh/year from the total electricity generation of 1214032 kWh/year.

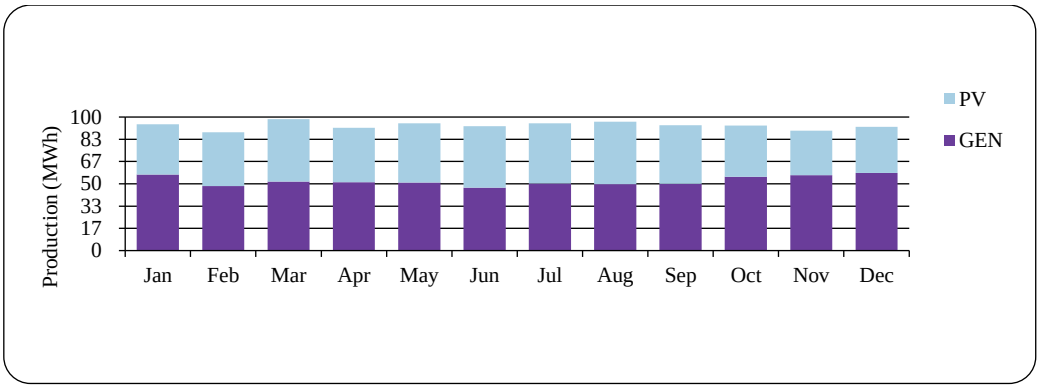


Figure 7. Monthly average energy generated

The hourly output for three days in January is shown in Figure 8 and Figure 9 showing the PV output with the load demand, SOC, and GEN outputs. It is obvious to see that at the beginning of the day, when the weather is sunny, the energy generated from the PV will cover the required load in addition to charging the batteries for use at night or when the sun is absent. In the case of dusty or cloudy weather, the energy generated from the PV may not be enough to charge the batteries or even cover the required load, and thus the battery begins to supply power to the load until it reaches the minimum SOC. In this case, the GEN will work and compensate for the loss of power, and this increases the reliability of the system by reducing the electricity shortage.

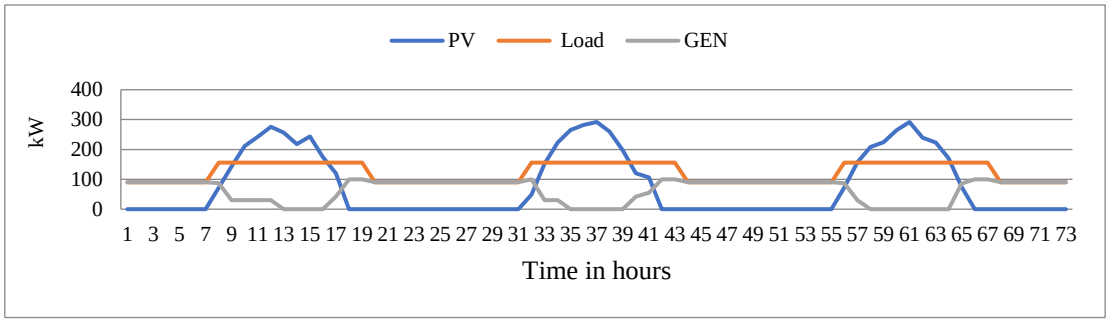


Figure 8. Hourly output of PV, GEN, and load demand

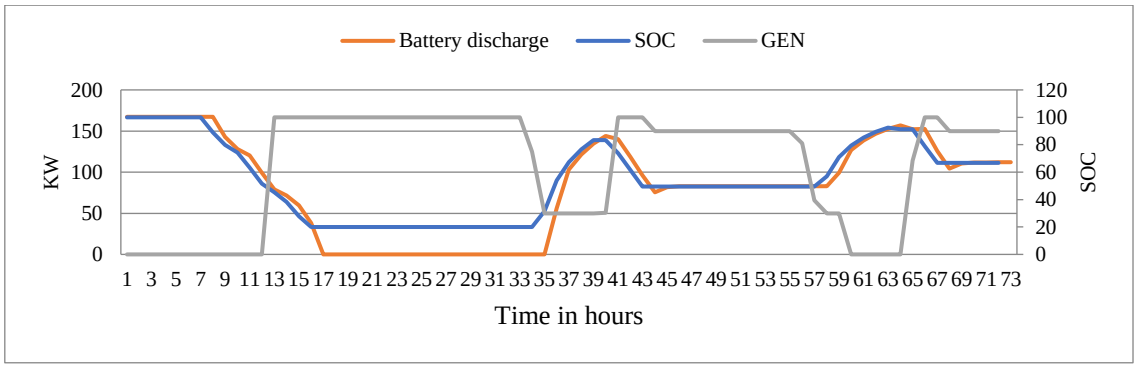


Figure 9. Hourly battery discharge, SOC, and GEN output

3.1.2.2. Economic Evaluation Results

The results showed that the proposed hybrid system, which consists of PV/GEN/Battery, was economically optimal compared to the first system, which consists of only GEN. Figure 10 shows the cost summary of the optimal system component. The results showed that the major cost of the project goes to the resource cost of fuel used during the lifetime of the project, followed by the replacement cost. The high replacement cost because the replacement parts of the system, except solar panels, are replaced according to the life span of each part. This means that the parts were replaced more than once. Next comes the capital and maintenance costs, respectively, as shown in Figure 10.

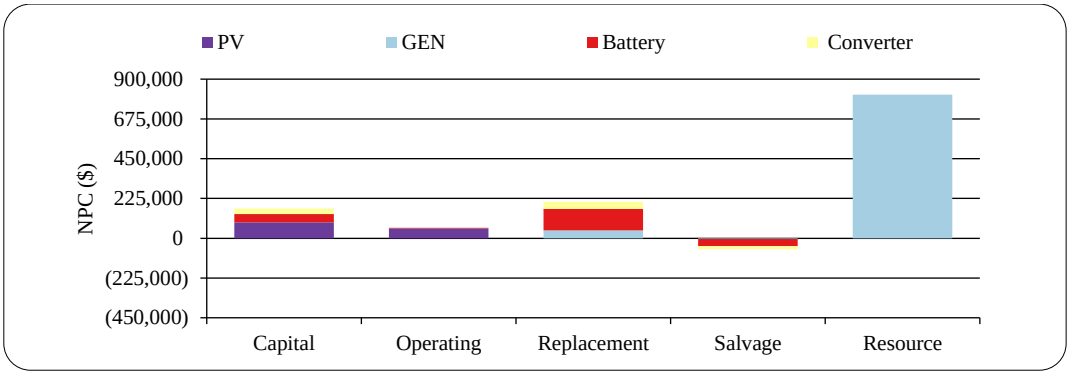


Figure 10. Cost summary of the optimal system component

At the same time, the economic and component sequential cash flow during the project lifetime is shown in Figure 11. The figure shows that the initial cost, which is in the first year, takes the largest value from the project cost, followed by the replacement cost, which occurs in successive years depending on the lifetime of each component. Parts have been replaced in more than one year, and this means that the parts have been replaced more than once. Next comes the cost of fuel, which varies relatively depending on the number of hours the GEN runs during the year. As for the operating cost, it is very low compared to the total project cost. Therefore, it appears that there are revenues from the parts that can be benefitted from after the end of the project's life, and this is what the value of the salvage explains.

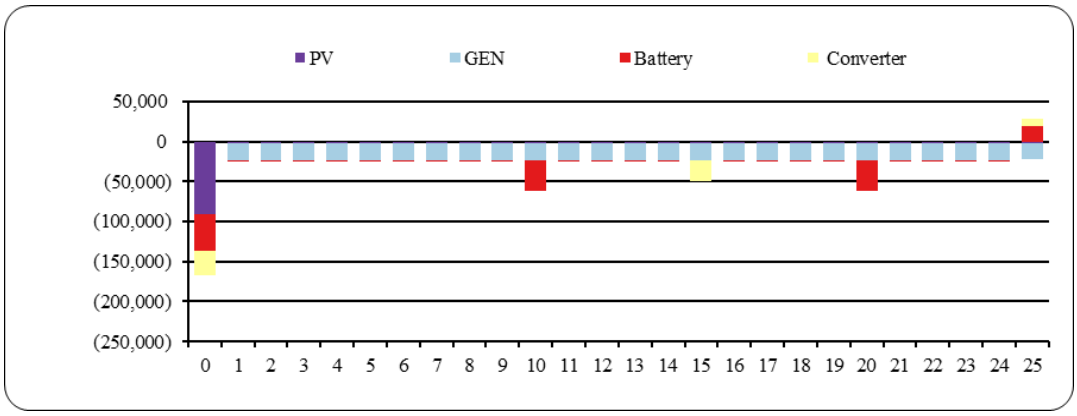


Figure 11. The economic and component chronological cash flow

3.1.2.3. Emission

As for the greenhouse emissions, their quantity changes according to the number of hours that the GEN operates. This means that the greater the reliance on renewable energy, the fewer the number of hours the GEN operates, and this will reduce harmful emissions. Therefore, increasing the amount of solar radiation in a certain place will increase the production of the resulting energy that supplies the load, which leads to reducing dependence on the GEN and thus reducing emissions. The annual emission is calculated by multiplying the emission factor by the total annual fuel consumption. Figure 12 shows different types of greenhouse emissions. It shows that the integration of solar energy with the GEN will reduce emissions.

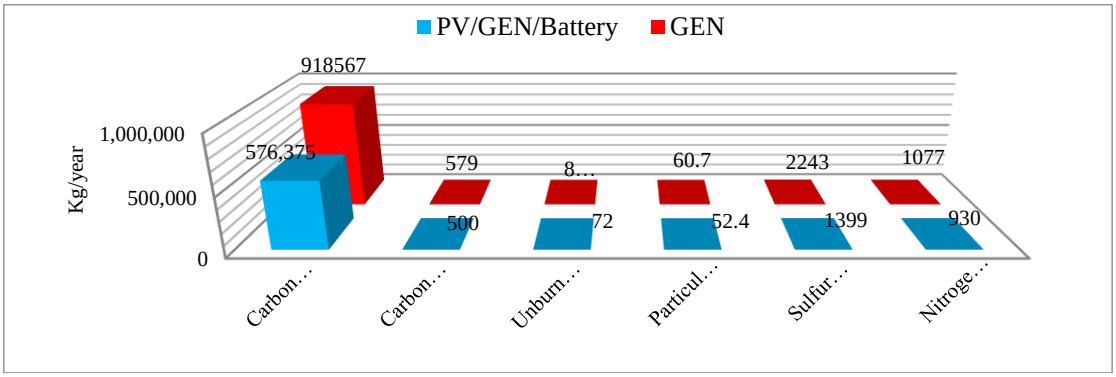


Figure 12. Greenhouse emissions in the proposed system

3.2. Mosul and Basrah

Since the first site (Baghdad station) was considered a reference for this study and the HRES was designed and the optimal system was carefully chosen, in these two regions, the same optimal system that was obtained from the first site was designed using the same inputs (technical and economical parameters) and conditions. Since solar radiation and temperature vary from one region to another, which can affect the output of the system, the solar radiation and temperature available in those two regions were taken into account. The optimal systems obtained in these sites are shown in Table 3. The results show that the optimal system in Mosul contributes 53% renewable energy, and in Basra, renewable energy contributes 52.7%. Despite the small difference in the percentage of solar energy participation, the generation rate is high in all three places, and this gives an indication that investing in solar energy in Iraq is feasible and has a promising future.

Table 3: The optimal configurations of the studied places

ity	V (kW)	EN (kW)	attery	PC ($)	OE ($)	enewable fraction (%)
asra	300	100	78	1.03 M	0.0257	52.7
aghdad	300	100	78	1.03 M	0.027	52.7
losul	300	100	78	1.02 M	0.025	53

4. Conclusion and Future Works

Using electric vehicles instead of traditional vehicles is considered the best solution to reduce the problems of fuel depletion, increasing the fuel prices and air pollutions. Most of the EVCS that provide electricity EV depend on fossil fuel energy so renewable sources of energy must be considered as a priority to solve or reduce these problems. In order to design an electric system, it is very important for the investor to consider the minimum configuration cost for fulfilling the load demand. In this study, the examination of installing PV, DG and battery are carried out to obtain the optimal configuration and sizing of the system components to supply electricity for EVCS in highway roads in Iraq using HOMER software. The results indicated that the system with capacity of 300Kw of photovoltaic (PV), 100KW of generators (GEN) and 78 unit of batteries is found as the optimal system in all three cities with NPC of 1.03 $M, 1.03$M and 1.02 $M, and COE, with values 0.0257 $, 0.0257 $ and 0.0255, in Basrah, Baghdad, and Mousl, respectively. The renewable fraction is found as 52.7%, 52.7% and 53% in Basrah, Baghdad, and Mousl, respectively. This setup achieves annual energy production of 704351 kWh from PV and 509681 kWh from GEN. This arrangement keeps the battery storage at a high state of charge (SoC). The outcomes are anticipated to be advantageous for students, researchers, and organizations engaged in renewable energy and standalone systems. Future research is recommended to evaluate the feasibility of implementing renewable energy systems for EV charging stations in other places.

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