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Design and Feasibility Study of A Stand-Alone Home Pv Solar System in Baghdad Climate

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Abstract

The question asked by all researchers is when solar panels will replace the national grid, especially in the domestic sector. In this study, a rooftop stand-alone solar electric system is designed to provide all the electrical power to a house in Baghdad-Iraq, using a (How to design PV system) simulation program. The feasibility of this system compared to the performance of the national electric grid and the system of private diesel generators is determined. The proposed solar system capacity is (25 kW), and the space required and the energy payback time are (360 m^2 and 7.82 years), respectively. By using the current system, the net CO_2 mitigation amount is 499,518.2 tons for 30-year. The kilowatt-hour costs for the subsidized national grid, private diesel generators, and the present solar system is 0.01865$, 0.1509$, and $0.108, respectively. The kilowatt cost can reach 0.25kWh if the battery replacement cost is estimated; so photovoltaic systems are still a good choice to generate electricity instead of using the national grid. If solar PV systems to generate electricity are used instead of the national grid, the financial and environmental profits will be good enough. The reason for the study is because the costs of off-grid solar PV systems are high, no specific studies have emerged on such vital topics. Currently, loans from government banks have reduced the impact of this negative factor

Keywords: photovoltaic (PV) system, standalone solar PV system, solar module, renewable energy, carbon dioxide emissions

تصميم ودراسة جدوى لأنظمة كهروضوئية منزلية مستقلة في مناخ بغداد

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الخلاصة

السؤال الذي يطرحه جميع الباحثين هو متى سيتم استبدال الشبكة الوطنية بألواح شمسية ,خاصة في القطاع المنزلي. في هذه الدراسة ، تم تصميم نظام كهربائي شمسي قائم بذاته على السطح لتوفير كل الطاقة الكهربائية لمنزل في بغداد – العراق, باستخدام برنامج محاكاة (كيف تصمم نظاما شمسيا). كذلك تم تحديد جدوى هذا النظام مقارنة بأداء الشبكة الكهربائية الوطنية ونظام مولدات الديزل الخاصة. قدرة النظام الشمسي المقترحة هي

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(25 كيلوواط) والمساحة المطلوبة ووقت استرداد الطاقة (360 م^2 و 7.82 سنة) على التوالي. تبلغ كمية التخفيف الصافي لثاني أكسيد الكربون عامًا 499،518.2 طنًا لمدة 30. تبلغ تكاليف الكيلووات في الساعة للشبكة الوطنية المدعومة ومولدات الديزل الخاصة والنظام الشمسي الحالي 0.025 دولارًا و 0.5525 دولارًا و 0.108 دولارًا. يمكن أن تصل تكلفة الكيلووات إلى 0.25 كيلو وات في الساعة في حالة ان احتساب كلفة استبدال البطاريات قد تم تقديرها ، لذلك لا تزال الأنظمة الكهروضوئية خيارًا جيدًا لتوليد الكهرباء بدلاً من استخدام الشبكة الوطنية. في حالة استخدام أنظمة الطاقة الشمسية الكهروضوئية لتوليد الكهرباء بدلاً من الشبكة الوطنية ، فإن الأرباح المالية والبيئية ستكون جيدة بما فيه الكفاية. ترجع اسباب هذه الدراسة إلى أن تكاليف أنظمة الطاقة الشمسية الكهروضوئية خارج الشبكة مرتفعة ، ولهذا السبب لم تظهر دراسات محددة حول مثل هذه الموضوعات الحيوية. في الوقت الحالي ، قللت القروض من البنوك الحكومية من تأثير هذا العامل السلبي.

.1. Introduction

A study by the International Energy Agency (IEA) on global energy consumption showed that in 2050, solar array installations would meet about 45% of the energy demand in the world. But, as a result of the wars Iraq fought that led to great damage in the electricity sector, losses in the transformation sector, and because of the high annual population increase (about 2.58%), there is a vast shortage between power generation and the demand, where the energy supply in Iraq is 46% of the total required load [1-5]. The capacity of solar energy projects in Iraq does not exceed (1395kW), in addition to small projects to supply electric power to farms and homes [6]. Since the second Gulf War in 1991, the national grid has provided consumers with about half of the energy requirement [7]. The rest of the energy is supplied by a private energy producer by diesel generators at a high cost and regular payment per month. Also, the distribution wiring has an unsuitable shape unsafe, and the electronic changeover reduces the reliability, as shown in Figure 1.

Figure 1: private diesel grid [8].

The development in the technology of photovoltaic (PV) system caused a great increase in efficiency and a reduction in the PV system cost [9-11]. Solar PV systems are among the most efficient means of generating electricity in Iraq [12-16]. Iraq and most countries have started to use PV panels to generate electrical energy. The rate of solar irradiation incident in the south and middle of Iraq is high. The average daily irradiation in Baghdad is approximately 5.27

kWh/m^2/day [17]. One of the solutions for the problem of vast shortage between power generation and the demand that have been applied is the on-grid PV system, but it does not send power to the grid when it turns off the grid, due to missing a synchronizing system. So, the stand-alone (off-grid) system could be a good choice to solve the previous problems [18].

The design of the solar PV power system is essential for achieving the most outstanding performance, reliability, and durability. The objective of every design is to optimize the performance of the system by accounting for many data obtainable during the design period [19]. Several studies have been performed worldwide to estimate the performance and feasibility of different solar PV systems. They have concluded that the PV system is a feasible and viable choice to supply the present and future electricity demand. Many Iraqi and foreign researchers studied the performance design of solar PV systems using on-grid connection technology [20-25]. Korsavi et al. studied the 5kW rooftop solar PV system in Iran. Under subsidized average tariffs, the systems were not economically beneficial, discouraging private and public sectors from investing in these systems. While at the actual price of the generation (0.21% $/kWh), the investment is feasible. Environmentally, the solar PV system can approximately decrease 1613900 kg of CO_2 production during the lifetime of solar PV panels [26]. The main components were studied for power generation in the solar system. The analysis was simplified so that project developers and practitioners could use commonly available spreadsheets to calculate incoming and outgoing cash flows. To estimate the feasibility of the project within certain boundary costs [27]. Ali et al. studied and compared various stand-alone power systems for the remote town of Mount Magnet in Western Australia [28]. Chandel et al. designed and evaluated the performance of a 2.5 MW solar photovoltaic power plant, the payback period was 7.73 years [29] Ali et a, considered the environmental and economic aspects of designing the optimal system feasibility. A stand-alone (off-grid) solar PV system was studied; the electrical load was taken into consideration on a daily basis and with different scaling for system components, including PV modules and chargers' controller, inverter, storage batteries, and other accessories. It was required to configure the design to be suitable for independent operation in housing communities, small businesses, and urban areas [30]. Mahmood et al. designed and simulated a stand-alone PV system that can be installed on the roof of a garage to use the electrical energy generated by this system to meet the energy request. The price per kilowatt hour unit was (0.238 $/kWh) [31]. Sami et al. studied a stand-alone PV system designed to feed a transceiver station. The cost of one kWh was 0.1081527 $/kWh, excluding the cost of replacing parts and systems operation and management [32]. Ahsan et al. studied a 1 kW stand-alone solar PV system that produced 3101.2kWh/year for houses in rural areas in India. The cost analysis for the designed and performance of the system was evaluated using PV-Syst software [33]. Mustafa et al. studied the operation, and economic aspects of 11 kW solar PV systems to detect the best and most active way to supply its 100% electricity demand, as rural houses in India can be turned into smart houses [34]. Alkhalidi and Al Dulaimi studied the Design of a stand-alone solar PV system that supplies 100% of the electricity requested at the German Jordanian University. The calculations were done based on the corresponding weather data, the institute's geographical location, and the daily demand data [35]. Rahmanov and Mahmudova studied the improved energy efficiency of solar PV systems for buildings in Azerbaijan using PV-Syst software with air circulation for cooling systems in remote areas [36]. Cho and Valenzuela achieved a model to get an efficient PV-battery system that covered the energy demand by home appliances since solar radiation is unpredictable and depends on the weather [37]. Bagalini et al. present a study about a PV-battery energy system. The analysis showed that such a system is not economically viable due to low subsidized electricity prices, but in the future with falling technology costs and doubled electricity tariffs, PV-battery investment will become profitable [38]. Tsianikaset et al. investigated two factors that influence battery systems used to support photovoltaic arrays, the first is the value of the electric load, and the second is the battery price. The fact that forecasts predict a sharp decline in battery prices will enhance the resilience and effectiveness using of renewable energy [39]. Bhayo et al. presented a developed assessment methodology for a PV-battery power system to satisfy the electric demand of 3.2kWh/day for a rural housing unit and water pumping. If water is pumped to a high storage site, it may be used for hydropower generation by hybrid PV-Battery-Hydro [40]. Patidar and Sharma focused on the hybrid standalone system using energy sources (photovoltaic, wind, battery, and diesel generator) for the system. The system operation was managed in such a way that the system could harvest the maximum amount of energy from renewable sources [41]. Jurasz et al. investigated the impact of many types of load input data (for example, typical daily load, real load, and monthly adjusted typical load) on the cost of energy supply by stand-alone PV-battery systems providing different loads with various reliability levels [42].

The present study aims to design a stand-alone solar system to cover the demand for houses in Baghdad using (How to design solar PV system) simulation program. This work also studies the feasibility of replacing the national electric grid with solar systems in light of low prices and increasing the efficiency of the components of solar energy systems through the design of a home solar system in Baghdad.

1.1 System Description

The location of the proposed system to be installed is in Al- Zahraa city in Baghdad as specified in Figure (2)

Figure 2: Satellite image for the house located in Al-Zahraa city(Baghdad).

Figure 2 shows the nature of the residential area. It also indicates that the location is suitable for installing the system through the absence of barriers that cause partial shading.

The solar module type that can be used is REC 280TP (280W), which is efficient and can tolerate high temperatures. The specification of the module (280w) is listed in Table (1).

Table 1- The technical specification of solar module(280W) [43]

Parameters	*.Value*	*Parameters*	*.Value*
No. of Cells	72(series)	p_{max}	280 (W)
Weight	27 (kg)	Temperature coefficient V_{OC}	-0.31(V/ºC)
Dimensions	195.8*99.9*5 (cm)	Temperature coefficient I_{Sc}	0.045% / ºC
I_{Sc}	9.40(A)	Temperature coefficient P_{max}	-0.39 %/ºC
V_{OC}	39.2(V)	Module efficiency	17%
I_{mp}	8.78(A)	NOCT	44.6(ºC)
V_{mp}	31.9 (V)	Type of cell	Pc-Si

2. Estimation of energy production:

The output power *P*(*max*) of the solar PV module can be found [44-45] from the following equation:

$$P(max) = I_{max} \times V_{max} \quad (1)$$

The conversion efficiency is calculated as the ratio between the maximal generated power to the incident power on the area of solar cell [46]:

$$\eta_{elec} = \frac{p_{max}}{A\, G_T} \times 100\% \quad (2)$$

Where: (A) is the area of the modules, (GT) is the total solar irradiance. By using (How to design Solar PV system) simulation program [47] which gives the rules that are followed to determine the energy demand. The required capacity for a PV system (E_r) should be the daily energy demand of the house (D) in addition to the expected system losses (L_s). The system losses can be assumed to be approximately 30% of the total demand. Therefore:

$$E_r = (D * L_s) \quad (3)$$

Total watt peak rating (w_p) of PV panels' capacity required is:

$$w_p = E_r / 5.27 \quad (4)$$

Where: 5.27kW/m^2 is the average panel generation factor (daily solar irradiance in Baghdad) [48].

The number of modules ($No_{modules}$) of the present system depends on w_p of the modules:

$$No_{modules} = w_p \,/\, P_{max} \quad (5)$$

The storage capacity of a battery should be large enough to store sufficient energy to operate the appliances at night and on cloudy days. Therefore, solar energy during the day is enough for the houses requirements. Battery Specifications are shown in Table (2):

Table 2: The Technical Specifications of Battery [49]

Parameters	*.Value*
Nominal Voltage (V_b)	48.0 V

Depth of Discharge (DOD)	40.0%
Battery Capacity (C_b)	200.0 Ah
Battery Efficiency(μ_b)	90.0%
Life of a Battery (B_L)	4 years

Battery Capacity Required(C_r) is:.

$$C_r = \frac{(D) * \text{Days of Autonomy}}{V_b*(1 - DOD)*\mu_b} \quad (6)$$

The capacity of each battery sets the total number of batteries:

$$\text{No. of Batteries} = C_r \,/\, C_b \quad (7)$$

The system inverter size (C_{inv}) depends on the peak watts requirement. The inverter size should be more than the maximum power requirement. That means inverter size should be at least 25%–30% higher than total connected load:

$$C_{inv} = w_p * 1.3 \quad (8)$$

To determine the $No._{inv}$ of inverters using the inverter rated power (W_{inv}) of 15kW:

$$No._{inv} = C_{inv} \,/\, W_{inv} \quad (9)$$

Modern smart inverters have the property of cutting off the increase of current, so an inverter with a capacity more than (w_p) is not needed, but the large capacity of the inverters is useful for future expansion. The size of an array (Z_{array}) (The number of modules to be connected in series) depends on the inverter voltage Voc and module voltage Voc:

$$Z_{array} = V_{oc\ inverter}/V_{oc\ module} \quad (10)$$

Where: $V_{oc\ inverter}$ is equal to 600 V. The number of arrays (No_{arreys}) in the solar field are:

$$No_m / Z_{array} = \text{No of arrays} \quad (11)$$

$$\text{Maximum voltage input to the inverter} = (V_{max\ module})*(Z_{array}) \quad (12)$$

The total energy consumed per square meter is 1516.59 kWh/m^2, which represents the energy consumed for materials, manufacturing, transportation, installation and management [48]. The total area of the modules ($A_{modules}$) of the solar system is:

$$A_{modules} = No_{modules} * L_{module} * W_{module} \quad (13)$$

Where: L_{module}, W_{module} are the length and width of the module, respectively. Total Embodied Energy (E_{em}) is the energy that went into making the system:

$$(E_{em}) = A_{modules} * 1516.59\text{kWh/m}^2 \quad (14)$$

The electricity generated (E_g) per year is:

$$E_g = D * 329.6 \text{ day/year} \quad (15).$$

Where: (329.6 day/year) is represents the number of sunny days in a year. The operating time of a PV system required to recover the energy it consumed is known as the energy payback time (EPBT), and it is given by:

$$(EPBT) = E_{em} / E_g \quad (16)$$

The required area of the system depends on the module layout and their arrangements. The number of modules on an array is 15 modules, arranged as six arrays. The width of the solar field is the same as that of an array (15 m). The ratio of ground covered by modules is about 0.5 of the ground volume, the distance between successive arrays will be
$= 1.995 * 2 \approx 4$ m

The length of the system field = 4 ∗ No of arrays
The area of the system required = Z_{array} ∗ length of the system field
The current price of the land in Al-Zahraa city is about 500$/m^2$, the total cost of the system land will be = Area of the system required ∗ 500
The emission of CO_2 due to electricity generation is 0.707 kg of CO_2 per kWh [48],
The average emission of CO_2 due to the embodied energy of the PV system is

$= (E_{em} * 0.707)$

The mitigation of CO_2 emissions is the quantity of CO_2 emissions decreased by generating the energy from the PV system, Yearly CO_2 mitigation is $= Eg * 0.707$
The distinction between the CO_2 emissions and CO_2 mitigation over its system life, i.e. 30 years, equal the net CO_2 mitigation for the system [49].

$$\text{Net } CO_2 \text{ Mitigation} = (\text{Yearly } CO_2 \text{ Mitigation} * 30 \text{ year}) - (CO_2 \text{ Emissions}) \quad (17).$$

2-1- Electricity tariffs:

The cost of electricity is set, for the domestic sector, which is the largest electricity consumer, at a rate of 59% and is subsidized by the government by 93%. The government supports the price of a kilowatt of electricity supplied by the Iraqi national network. The cost of (1-1500, 1501-3000, 3001- 4000 and 4000+) kWh is (0.0083, 0.029, 0.066, 0.1) $/kWh, respectively [50]. Electricity prices with government support are one of the cheapest electricity wages in the region.

2.2 Energy Calculation of the House Demand.

"How to Design a Solar PV system" [48] program gives the rules which are followed to determine the energy demand of a house of four rooms, a kitchen, and a bathroom in Baghdad city (33^o, 44^o). The equipment details are listed in Table 3. Also, the table contained the daily energy demand required by the solar PV system.

Table 3: The total required energy for a house.

Name of equipment	*No*	*Rating W*	*Total Consu -mption*	*Total Consu- mption*	*Hours of operation*	*Total*	*Total Consumptio*

			Kwh hot	Kwh cold		Consumptio n kwh/day hot	n kwh/day cold
Air-condition	1	3000	3	-----	14	42	**-----**
Air-condition	2	1200	2.4	-----	14	33.6	**-----**
Light	6	40	0.24	0.24	12	2.88	**2.88**
Light	5	20	0.1	0.1	12	1.2	**1.2**
Fan	4	100	0.4	-----	18	7.2	**-----**
LED TV	2	36	0.72	0.72	8	5.76	**5.76**
Digital satellite	2	10	0.02	0.02	8	0.16	**0.16**
Refrigerate	1	200	0.2	0.2	8	1.6	**1.6**
Freezer	1	350	0.35	0.35	8	2.8	**2.8**
Heater	1	3000	------	3	8	--------	**24**
Washingmachine	1	480	0.48	0.48	1	0.48	**0.48**
Laptop	1	60	0.06	0.06	6	0.36	**0.36**
Mobile charger	2	5	0.01	0.01	2	0.02	**0.02**
Sum			7.98	5.18		98.46	**39.66**

The overage electrical demand of the house is 7.98 kWh during the hot season from the 1st of May till the 1st of December when the temperature is between (30-50ºC) in the daytime. The required demand (D) for a day is 98.46(kWh/day) and 39.66 (kWh/day) for the hot and cold seasons, respectively. The required demand is reduced to 5.18 kWh during the cold season; the average daily demand is 96.06 kWh/day as a result of turning off some types of equipment, such as the air-conditioners and fans during the cold season (2nd of December till the 31st of April), where the temperature is between (0-25ºC) in the daytime. The annual demand has been estimated at 24861.6 kWh.

2.3 Financial assessment of the system

The solar PV energy price in the Iraqi market is 1$ \Watt without the battery price. The cost of four 12V batteries is 800$, and the rack cost is (5$). The system needs annual maintenance and management fees of 1% of the cost of investment and equipment replacement (1% of the PV panels yearly, inverters every five-six years and batteries every four years) [51].

3. Results and Discussion

The complete details associated with the proposed system are listed in Table (4).

Table 4: details of the proposed system

Parameters	.Value

Daily demand	69.06 kWh/day
Total watt peak rating (w_p)	25 kW
No. of modules($No_{modules}$)	90(280W)
Total area of modules	176 m^2
Total area of land required	360 m^2
No of batteries	19(48V)(200Ah)
No of modules in panel	15 modules
No of array	6 array
No of invertor	2(15 kW)
Cost of Batteries	15580$.
Net CO_2 Mitigation	499518.2 kg
Total cost	40580$.

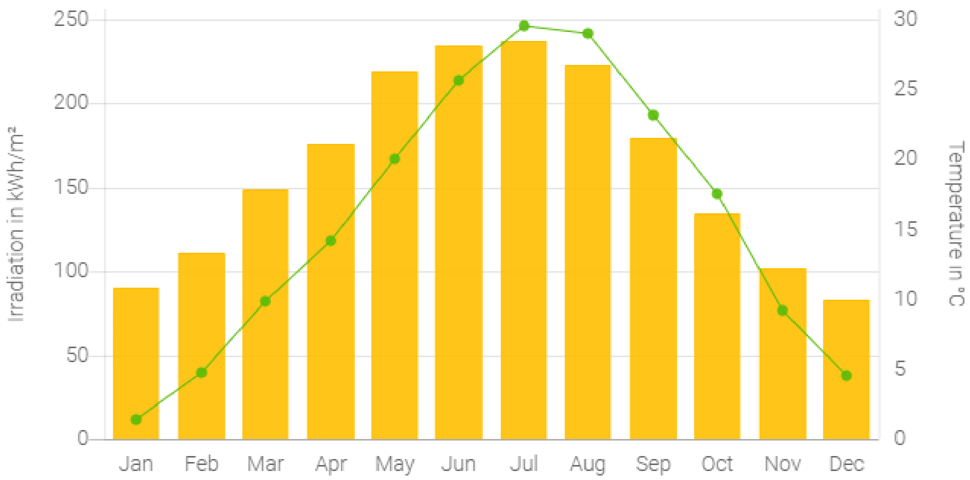

Figure 3: The average monthly solar irradiance and temperature in Baghdad city.

Using the PV-Syst simulation program, the amount of incident solar irradiance at a tilt angle of 15^o is 1964.1 MWh/m^2. The monthly solar irradiance and temperature in Baghdad city are shown in Figure (3). The main reason for using solar cell systems throughout the year is the huge amount of solar radiation available in Baghdad climate.

One of the advantages of the winter season (October-May) is that there is no need to operate cooling devices such as air conditioners and fans that consume electrical energy, which leads to low power consumption. In summer, the increase in temperature causes a decrease in the output power, with an increase in the amount of solar irradiance at the same time. Using the PV-Syst (V6.88) program shows that the total losses of solar power production are 17.2%. Figure 4 illustrates all sources of energy loss in the system using the PV-Syst (V6.88) program. But these losses could be eliminated using a cooling system to cool the panels, and coating the solar panels with a nano-material to expel dust. And thus recover losses at the lowest cost.

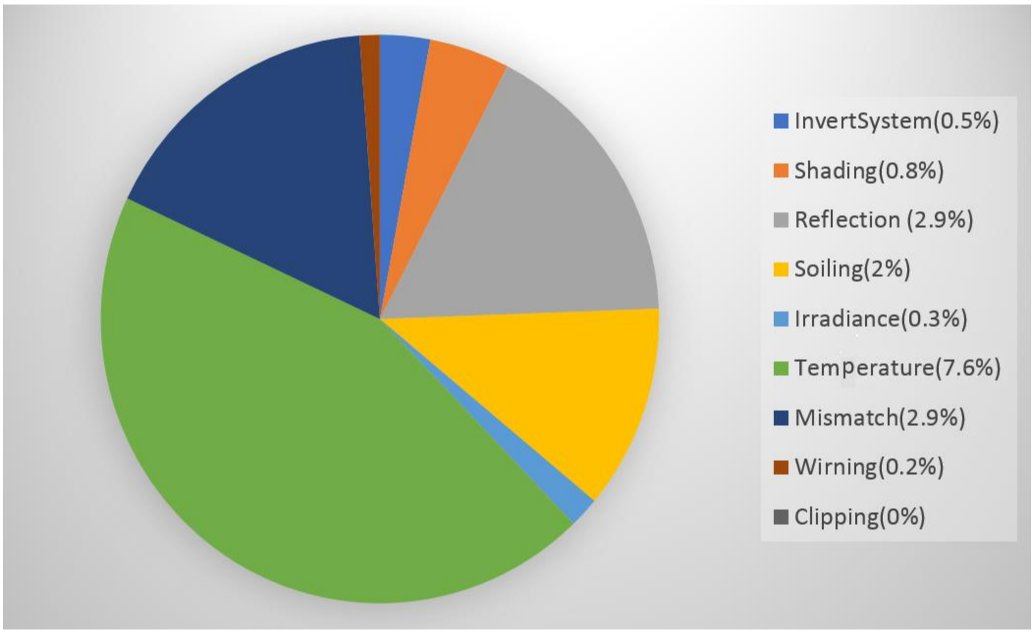

Figure 4: System losses using PV-Syst (V6.88) program.

Using the meteorological data and the percentage of daily losses, the average actual efficiency of the output power of the system was about 14.2%. The output power obtained for 180m^2 module area of the proposed system using Equation (2) is shown in Figure 5.

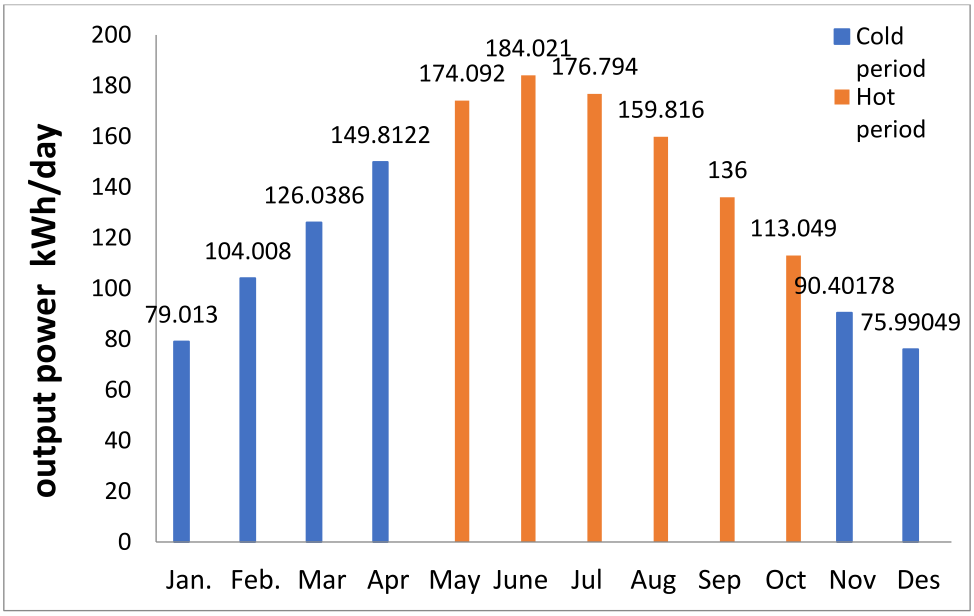

Figure 5: The average daily power produced per month.

Energy production by the PV solar system depends on the amount of incident solar radiation. This naturally corresponds to the changing levels of seasonal temperatures and the increasing requirements of the country's need for electrical energy in summer, when temperatures exceed the limits of 45 degrees Celsius during the day.

3. 1 Subsidized National Grid

The price of supplied electricity from the national grid at the subsidized price for the six hot months is 329.4$, and the price of electricity provided by the system for the six months of cold months is 59.4$[42], the annual price of supplied electricity from the national grid is 388.85

$\year. The price of electricity provided by the national grid for 30 years is 11665.6 $; therefore, investments in solar energy projects in the areas covered by the national grid are ineffective because of government support for electricity prices. The average price of one kW produced by the national grid is 0.01865$[52].

3. 2. Unsubsidized National Grid

The actual price of one kWh of electricity unit is 0.2$ [26], and the monthly price of electricity provided by the national grid is 414.36 $\year. The annual price of supplied electricity from the national grid is 4972.32$\year. The price of supplied electricity from the national grid for 30 years is 149169.6$; therefore, investments in solar energy projects in the areas covered by the national grid with actual price are effective.

3. 3. Private Diesel Generator

Approximately 46 % of the energy in Iraq is provided by private diesel generators with an average monthly price of about 50 $/kWh. The present house needs 8 kWh, with a price of 400$/month, 4800$/year, and 144000$ for 30 years. The price of one kW produced by a private diesel generator is 0.1509$.

3. 4 Unsubsidized National Grid+ Private Diesel Generator

The price of one kW produced by a private diesel generator is 0.1509$. The total price for the two suppliers (unsubsidized national grid and private diesel generators) is 5188.85$ for one year and 155665.5$ for 30 years. The time for reinvestment of the solar systems is about 7.82 years, depending on the price of the unsubsidized national grid and private diesel generator.

3. 5. Solar System

The price of one kW of electricity produced by a solar system is 0.108$. Depending only on the current solar system to provide all the daily demand, at an average price of 0.108$ per kWh, the total price is 5175.10836$/year, and for 30 years, the total price is 155253.2508$. The complete details of price of one kWh, daily, monthly, yearly and 30 years' production for national, private diesel generation and solar systems are shown on Table (5)

Table 5: Price of one kWh, daily, monthly, yearly and 30 years' production for subsidized national grid, private diesel generation and solar systems

Type of system	*Price of kWh*	*Demand supplies*	*Yearly Price of production*	*30 year Price of production*
Subsidized National Grid	0.01865$	54%	388.85 $	11665.6$
Unsubsidized National Grid	0.2$	100%	4972.32$	149169.6$
Private diesel Generator	0.1509$	46%	4800$	144000$
Unsubsidized National grid + Private diesel Generator		100%	5188.85$	155665.5$
Solar system	0.108$	100%	5175.10836$	155253.2508$

A stand-alone solar PV system requires replacing the batteries every 4 years (about 7.5 times in 30 years) and the inverter every 6-7 years. Where replacing batteries and inverters is approximately twice the investment cost, the price of one kWh of electricity is still accepted at 0.25$. But, in future, the price of solar system equipment will be reduced with an increase in efficiency. A huge financial and environmental profit will be achieved using solar panels to generate electric power instead of the national grid. Additional advantages of the solar cell system are that it doesn't present environmental problems, such as audio-visual noise associated with the diesel operating system, and does not emit pollutants, such as CO_2 gas. The CO_2 gas mitigation is shown in Figure (6); it is related to the amount of daily production of power.

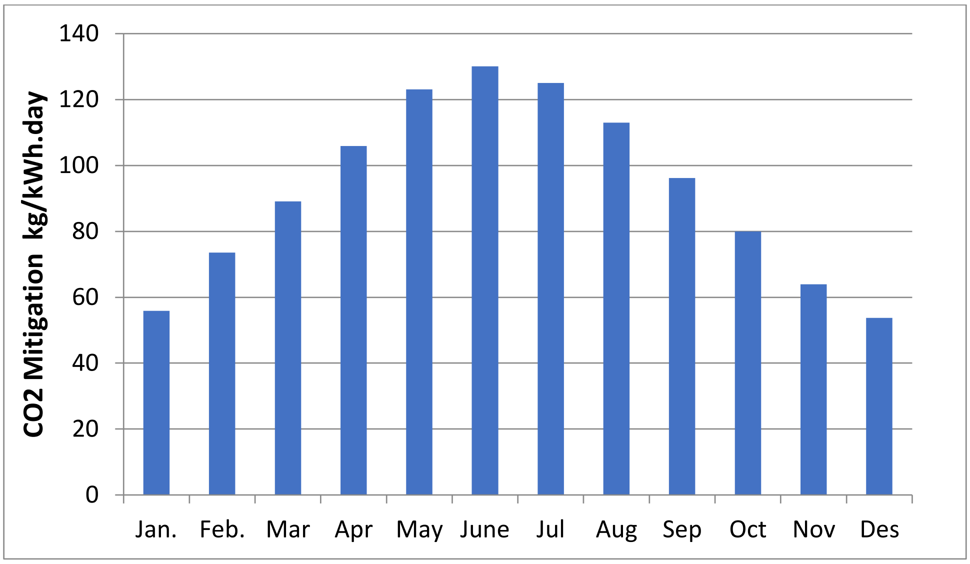

Figure 6: The daily CO_2 mitigation

The net CO_2 gas mitigation is 499518.2 kg for 30 years. Such solar systems have spread widely, and have multiple environmental and economic benefits, the most important of which is reducing CO2 emissions which are emitted in large quantities annually throughout their lifespan. Figure (7), represents the amount of CO_2 that has been withheld by 1,200 present PV systems for 25 years.

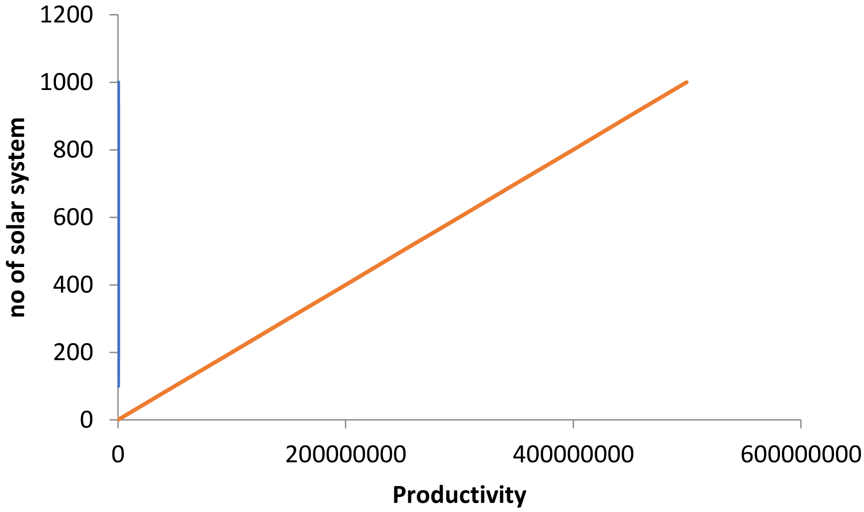

Figure 7: The daily CO_2 mitigation

The comparison between the times for reinvestment of different reference can be seen in Table (6).

Table 6: The time for reinvestment of different reference

Reference	The time for reinvestment

Aziz et al.[18]	13.4 years
Ali et al.[28]	7.73 years
Al-Khazzar[25]	46.9-50.5 years under subsidized average tariffs
Present study	7.82 years under subsidized average tariffs + private diesel Generator

From Table 6, it can be noted that the time of reinvestment in Iraq is the best compared to the rest.

4. Conclusion

The best stand-alone designs that can cover an average daily demand of 69.06 kWh/day is the 25 kWh system. The use of a rooftop solar system in any area covered by the electric grid is usually uncompetitive and high-cost, but it is different in Iraq due to the insufficient power supply and the use of electric power produced by the private sector, which makes the cost of electricity supply high. The most critical challenges that impede the investment of solar energy systems outside the national and local electricity grid is the high cost of investment, but in return, low-interest financial loans were provided by government banks to install renewable solar energy systems, so the trend is now ready to start using the network of solar energy systems on a large scale wide.

5. Disclosure and conflict of interest

"The authors declare that they have no conflicts of interest."

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