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Enhancing the Efficiency and Reliability of a Standalone Solar Energy System for Homes in Iraq

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Abstract - This study explores the knowledge regarding unconnected solar energy systems, their configurations, and the effects of Iraq's warm weather. Furthermore, it investigates the advantages and disadvantages of implementing such systems in Iraq. The research recognizes the efficacy of off-grid solar energy systems and their potential to provide clean electrical energy to meet the needs of Iraqi citizens while reducing harmful environmental emissions. The study employs an applied research project to assess the operational efficiency of off-grid solutions. The PVSYST application was used to simulate the solar energy system data. The research aims to develop off-grid solar energy systems, assess the suitability of building roofs, examine how heat affects panel productivity, and evaluate the impact of shading on energy levels, among other objectives. The study also covers the components of solar energy systems and how to assess their quality to withstand Iraq's typically hot climate.

Keywords - High Performance, Standalone Home System, Solar Energy, Solar radiation.

I. Introduction

Energy consumption and economic development are linked, especially when a nation has experienced rapid economic growth. Cost-effective and efficient energy connectivity is crucial to ensuring continuous improvements. Energy is the main input and a prerequisite for rapid industrialization, industrial progress, mechanization, and modernity in industrial facilities all over the globe [1]. Despite this, the demand for energy around the world is growing, and researchers from around the world are debating how to satisfy this demand. Between 2010 and 2030, the world's electricity consumption is expected to increase by 33%. According to figure 1, the demand for electricity grew globally from 145 billion Megawatts in 2007 to 218 billion MW in 2035 [2].

Iraq is an exceptionally high solar radiation country, with hours of solar radiation ranging from more than 3000 hours per year and its richness in oil, gas, and other resources. The total average solar radiation in Iraq ranges from 4-5.6 KWH/m2/day in the north and, in central and southern Iraq, the radiation rate is 5-7KWH/m2/day [3]

The bulk of energy consumption forecasts indicate that the current and expected fuel supplies are not self-sustaining [4]. Clean energy is a potential option for sustainable electricity production. Renewable energy use has increased over the last few decades, but it is still not very common. Only renewable energy sources, like solar energy, can ensure a consistent flow of electricity. Only 13 percent of the current sustainable supply is made up of renewable energies (10% Biofuel, waste, 2.3% Hydro, solar, wind, groundwater, and heat, among many others, 0.9%). By 2040, it is anticipated that the European Union will generate 50% of its electricity from renewable sources, compared to 30% in China and Japan, over than 25% in the US, and less than 10% in Iraq [5].

For many remote applications all over the globe, standalone PV systems are more reliable and a superior choice. Regular sizing calculations, knowledge of hardware accessibility and performance, the use of good technical practices when installing machinery, and the creation and execution of an ideal operation and upkeep plan are all necessary for obtaining reliable long-term achievement from a PV system [6]. The development and optimization of solar power systems, both with and without software, are the subject of numerous studies that aim to achieve the best performance at a minimal expense and with the longest possible life cycle. Design and optimization using sun tracking to examine the impact of temperature on the net presented cost (NPC) and cost of energy (COE) in the Iraqi metropolis of Anbar (see figure 1).

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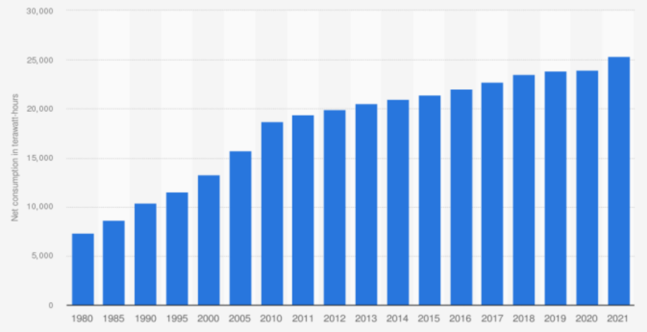

Figure 1. Net electricity consumption worldwide in select years from 1980 to 2021.

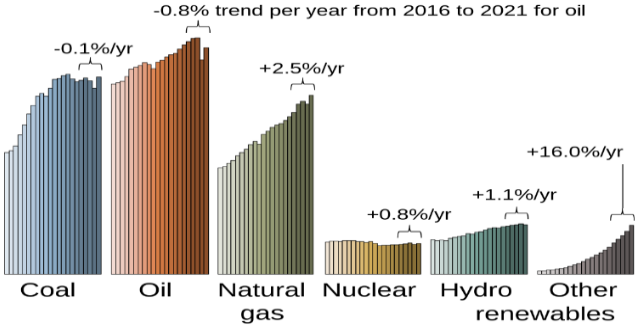

Figure 2. The primary energy suppliers in the globe are shown in the graph.

94% of the energy used on our planet already comes from solar energy. It raises the average temperature of the Earth's surface and atmosphere from -273.2 degrees to +14 degrees. The world has changed due to the application of modern technologies in the use of solar photovoltaic energy in producing electrical energy in the fields of feeding homes, homes and residential complexes, feeding factories, and using them in transportation. The use of solar photovoltaic and thermal energy has become a given in human life due to technological advancements in solar energy systems and the development of smart energy systems. In the transportation and agricultural sectors, it lowered the emission of damaging gases to the environment by using all types of fuels [7].

Currently, 32.4% crude, 21.4% gasoline, as well as 27.3% coal, along with 5.7% nuclear energy, are used to produce about 81% of the world's power [9, 10]. Gross primary energy generation sources are shown in figure 2 for the year 2010. The fact that fossil fuels still account for the majority of the world's energy supply would be the primary explanation for the increase in (CO_2) density. In accordance with global carbon output. In 2012, the amount of carbon dioxide released from coal, gasoline, natural gas, cement, as well as gas were respectively 43%, 33%, 18%, 5.3%, and 0.63% [8].

Photovoltaics (PV) is the direct transformation of electromagnetic radiation into electricity. And solar panels are one of the fundamental components of solar energy systems, together with the grandfather regulator, inverter, and batteries, as well as the other basic components used in installing solar energy systems. Solar panels comprise several cells integrated and joined in series and parallel to make a solar panel with a predetermined capacity. Solar panels may be built and utilized in solar energy systems to create electricity for houses, farms, companies, and labs and vast power networks. Electron-hole pairs are created when light (or solar radiation) strikes a semiconductor. There are two sorts of cells: mono- and multi-crystal cells [6].

Solar energy is a renewable and infinite energy source: Solar energy is an endless resource that is accessible every day. Solar energy endures as long as the sun continues to shine, and its permanent availability stimulates its use and usefulness. Solar energy has many applications: Solar energy may create electricity with photovoltaic cells [9]. By placing solar panels on the roof, it is feasible to meet a home's electrical demands with solar power, and since this power is stored in batteries, it is available day and night. In regions where power lines cannot reach, photovoltaic technology generates energy. It helps improve rural living conditions in developing nations, particularly in health care, education, and agriculture. This technique has been widely adopted in developed nations and incorporated into the electric grid [10].

The objective of this practical applied research is to know and evaluate the performance of the solar energy systems separated from the grid in Iraq and to know the impact of the atmosphere of Iraq on it. And give practical results to those who want to install solar energy systems and the extent of the economic feasibility of installing them, especially in Iraq suffering from power outages for years. The most significant effect is made by photovoltaic (PV) technology because it can generate electricity anywhere there is sunlight, even in regions where no other source of electricity is available [2]. Photovoltaic cells operate silently and without pollution.

Inversely correlated with temperature and directly correlated with working cell temperature are NPC and COE, respectively [3]. Study the PV system optimization for an electric car on the educational institution campus in Dhaka while you're there. They discovered that charging electric vehicle stations with less energy results in a reduction of greenhouse gas emissions of about 21% of overall production. With the model that was created, a technically and financially viable power supply solution to the island can be readily achieved by sizing and optimizing with the GA method to reach lower COE values [11]. Pumped storage is an additional use that uses a standalone PV system.

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II. Iraq's Climate Analysis

Iraq's entire land area is 437,072 km2, and its latitude ranges from 29 to 37 ° N. It is the 58th largest nation on earth and is situated in the central region's northern region [12]. However, these places are affected by the sun's beams' angle of incidence on Earth. Additionally, the total quantity of radiance and the number of daylight hours, are longer on hot summer days (roughly 14 hours) and shorter on cold winter days. (Approximately 10 hours).

Table 1. A comparison of the horizontal and vertical solar energy [12].

Position	Region	Horizontal Plane Solar Irradiation (Wh/m2/year)	Vertical Plane Solar Irradiation (Wh/m2/year)	Inclined Plane Solar Irradiation (Wh/m2/year)	Optimal Inclination (o)
(San Bernardino)	USA	5294	3637.5	5875.8	56
(Phoenix)	USA	5280	3685.8	5895.8	57
(Seville)	Spain	4868.3	3443.3	5410.8	53
(Badajoz)	Spain	4705.8	3405	5268.3	51
(Newcastle)	Australia	4590	3154	5031	57
(Abu Dhabi)	UAE	5533.3	3186.6	5847.5	66
(Cairo, Egypt)	Egypt	5290	3227.5	5647.5	60
(Mosul)	Iraq	4841.6	3319.1	5319.1	54
(Mosul)		5011.6	3227.5	5402.5	56
(Al-Anbar)		5000	3136.66	5347.0	57
(Karbala)		5104.16	3236.6	5492.5	57
(An Nasiriya)		5129.16	3219.16	5505.8	59
(Al Basrah)		5035.8	3086.6	5276.66	60

From June through August, the northern region of the planet receives sunlight that is nearly vertical or vertical to it. Due to the summer's low relative humidity and the country's high temperatures, the prevalent high-pressure rotation also makes rain scarce in some regions of Iraq [13]. Iraq also has direct natural radiation solarity that ranges from 1800 kWh/m2/year to 2390 kWh/m2/year [14], placing the nation in an incredibly promising position and at the forefront of nations that produce solar power. Solar radiation is contrasted horizontally and vertically in table 1. According to The Solar Energy Handbook (2016) [15], optimally inclined plants are being constructed in some places around the globe, including many in Iraq.

III. Policies for Solar Energy

More severe illnesses would be reduced as a result of the reduction in NOX and SO2. Heart issues will drop compared to 490 to 720 by 2030. By 2030, 320–470 fewer cases of various types of asthma would be diagnosed annually. The impact of pollution decreases on health is shown in table 2.

Table 2 Human health benefit for lesser emissions [10].

Scenario	2015 (Min)	2015 (Max)	2030 (Min)	2030 (Max)
Total PV installation(GW) Cases reduced	5	10	70	100
Death	22	50	300	440
Chronic Bronchitis	16	35	205	301
Heart stock	40	82	495	720
Respiratory problem Asthma (0 – 64)	3	4	25	37
Pneumonia (65 +) Total	7 10	16 20	100 125	150 187
Cardiovascular problem All cardiovascular	9	21	125	181
Visit to Emergency Room for Asthma	25	50	325	470
Acute Bronchitis	35	78	479	697
Lower–higher Respiratory symptoms	716	1612	9849	14,326
Loss of working days	2540	5708	34,895	50,750
Less Restricted Activity Days	17,44	39,24	239,79	348,78

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The main environmental benefits of PV-based energy over other green sources can be summed up. This system's use would have a big impact on the ecosystem. (That is, decreases in CO2 emissions, no noise production, and other significant health benefits).

On the current market, renewables are significantly cheaper than fossil fuels, which prevents broad adoption. To make renewable energy more affordable to compete with fossil fuels, government support for renewable energy projects is crucial. Growth must lower the cost per unit of power through energy policies that include legislation, energy conservation advice, international agreements and incentives for investment, taxation, and other tools of public policy [11].

Several ASEAN (Association of Southeast Asian Nations) nations have independently adopted both short- and long-term approaches in recent years. The percentage of renewable energy in the nation's fuel mix was unanimously decided upon by the nations that make up ASEAN in 2015. By 2020, it is desired that 23% of the region's fuel blend will come from renewable sources. The 33rd ASEAN Electricity Ministries Meeting, which took place on October 7, 2015[12], made the decision. For renewable energy in ASEAN, Energy Integration into the Market (EMI) is another promising choice. It seeks to reduce the current immobility as well as satisfy the nation's rising energy demand.

One suggestion is to combine local electricity markets or international energy traders under a new name, which would entail that wealthier countries would buy surplus green energy from poorer nations due to their geographical location [6]. The predicted average increase of energy usage in ASEAN nations is more than twice as high as the global average. The capacity of these nations to generate and transmit power could be hampered by this. Each ASEAN member state took various actions and made an assortment of diverse attempts to promote renewable energy sources in the ASEAN region.

Traditional energy production methods have exacerbated serious environmental problems that are harmful to human health, including changes in the climate, air pollution, acid rain, and warming temperatures, among others. The fact that solar energy can only be used during the day and works best when it's sunny is obviously a failure. Solar power is therefore not necessarily the most efficient energy source in places with unsustainable environmental conditions or environmental trends. The degree of air pollution in the region where solar cells are being used can also affect their effectiveness [8].

Technologies with zero or no emissions include solar power devices. PV cells actually have very little of an effect on emissions of greenhouse gases [3]. The PV system produces no CO2, NOX, or SO2 emissions while it is operating, so it has no impact on global climate. When generating energy, photovoltaic systems reduced CO2 emissions by (0.53) kg per kWh. According to table 2, installing PV systems will reduce 69 to 100 million metric tons of CO2, 126 thousand to 184 thousand tonnes of SO2, and 68 thousand to 99 thousand loads of NOX by 2030 [7].

IV. Stand-alone PV system (Off-Grid Systems)

They are systems that convert sunlight into electrical energy during the day and at night that depend on battery storage and are considered the most expensive part of solar energy systems. These systems are also used in places with no electricity network, such as remote areas and deserts. We in Iraq use them in homes because there is no regular electric power, as they can cut off the electricity at any moment, day or night. The capabilities of these systems are low compared to those connected to the network.

V. Experimental methodology

Since 2016, it has been using the practical study space at my house. This technology has been in use ever since Iraq's electrical power system developed a flaw due to the various degrees of corruption within the Iraqi government. The frequent power outages and the reliance of the majority of participants on diesel generators hamper this straightforward investigation. This hands-on investigation using the PVSYST application was fascinating, and the findings were satisfying. The operation of these systems may be developed, and it can be developed if the state promotes the use of renewable energy. In this study, we got the following (see figure 3).

1. Solar radiation in Iraq, and Iraq was one of the countries with solar radiation ranging between 1000-2300 watts per square meter.
2. We learned about solar radiation from NASA through the PVSYS program.
3. Studying the roofs of buildings, knowing their area, and knowing the amount of power that can be generated from them.

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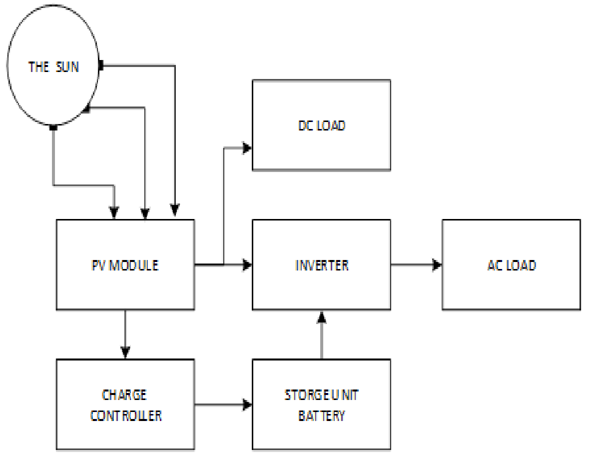

Figure 3. Off-grid solar power systems block diagram.

VI. Proposal PV System Design

A system of solar photovoltaic systems that are not connected to the network and consist of batteries to store energy when there is no sun or light operates during the day on the energy of the panels generated by the fall of light on the brightness of the solar panels, and at night entirely on the storage batteries; therefore, the amount of energy stored must be known and the amount of energy consumed at night must be known for the system to continue to function. It is always used in locations devoid of electrical current. In Iraq, energy is routinely shut off throughout the day and night. Therefore, remote places distant from power plants are also used. This system installs in a private home to connect an external generator to this home, as shown in figure 4.

The practical installation of solar energy system with a capacity of 3900 watts off-grid, which was implemented in my home in Iraq, Anbar Ramadi, and the PVSYST program was used to study it, analyze and simulate the full data of the solar energy system of 3900 watts separate from the grid. It has components of a solar energy system as (see figure 2):

1. Solar panel 390W number 10
2. Solar inverter 4KW number 1
3. Solar Battery 208A, 12V number 12
4. Combiner box number 1
5. 6mm wires with 10mm wires
6. MC4
7. Iron structure for carrying PV.

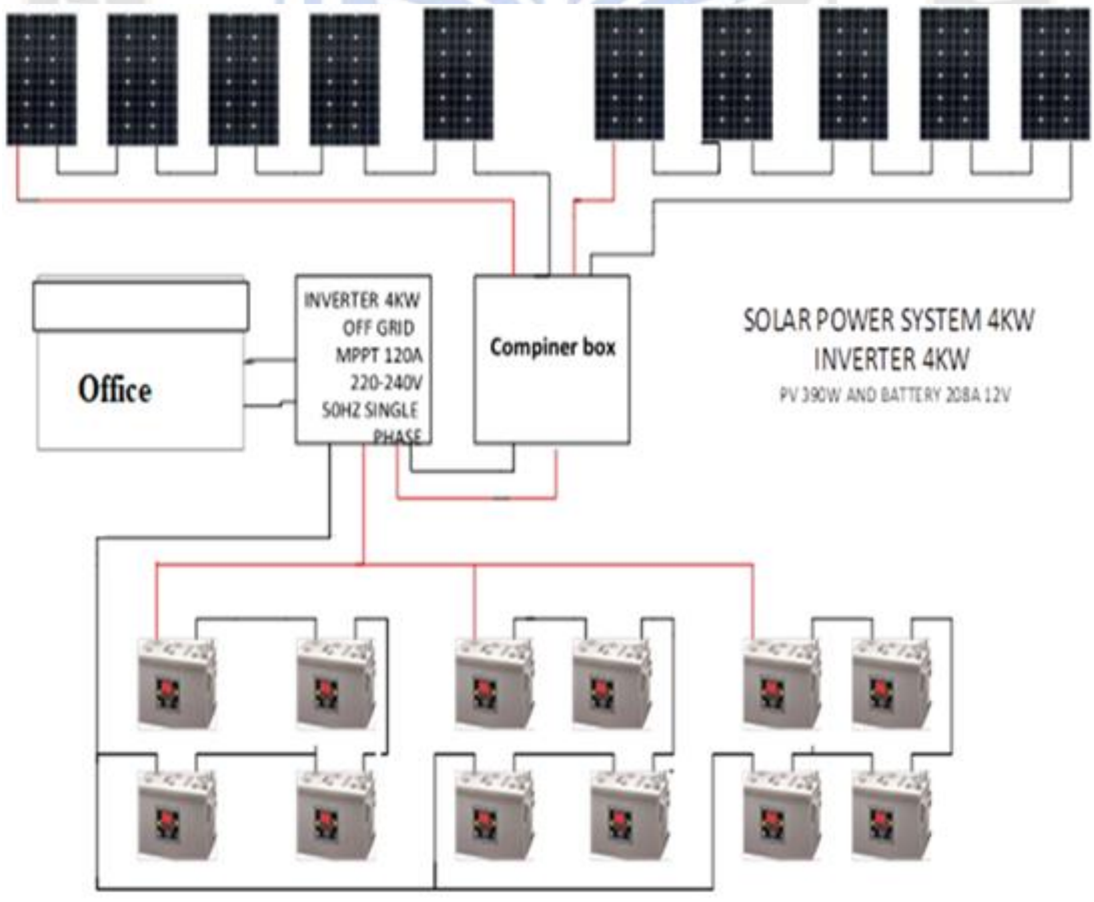

Figure 4. Solar photovoltaic systems (PV) Off Grid.

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Figure 5. Piratical installation of solar photovoltaic systems (PV) Off Grid.

Table 3. The specifications of the solar panel.

Module	**GCL- M6/72GDF**
Maximum Power (Pmax)	390 W
Voltage at Maximum Power (Vmpp)	40.12 V
Current at Maximum Power (Impp)	9.73 A
Open Circuit Voltage (Voc)	48.93 V
Short Circuit Current (Isc)	10.2 A
Panel Efficiency	19.4%
Power Tolerance (Positive)	+1.5%

It regulates the flow of electricity in accordance with its purpose. The maximum array current and the maximum current through the load must both be able to endure a good voltage regulator. By increasing the current in a short circuit of the modules linked together in parallel by the safety parameter Fsafe, one can determine the voltage regulator's size. The voltage regulator I's maximum current is revealed by the outcome:

$$I = ISC * Np * \text{Fsafe} \quad (1)$$

To ensure that the regulator can handle the maximum current generated by the array, which may surpass the calculated value, the safety factor is used. and to manage a load current that is higher than what was anticipated due to, say, the addition of machinery. In other terms, this safety margin enables a small system expansion. The Array of short electricity Amps split by the Amps associated with every control system gives the number of controllers:

N_controller=1/(Amps each controller) (2)

VII. Solar radiation

It's important to note that this solar radiation is present all year round. The differences between the seasons are something we've taken note of. Using NASA's PVSYST software, I determined that the proportion of solar radiation received by the roof of my home in Iraq throughout the year is quite high.

Any solar power setup has the potential to perform well. In this system, we installed the solar panels by installing the fixed panel structure, not the movable one, at an angle of 30 degrees towards the south to give the best production of electrical energy over the four seasons. The fixed angle is 32 degrees to operate in all seasons with minimal losses as in figure 6 and figure7.

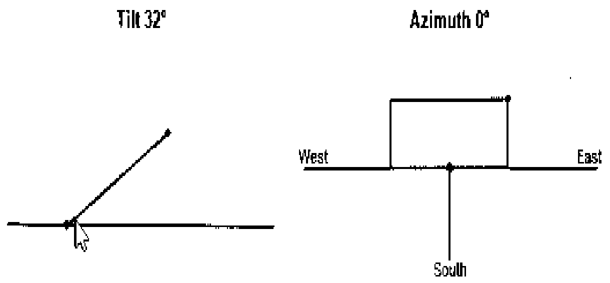

Figure 6. The direction and degree of solar panels.

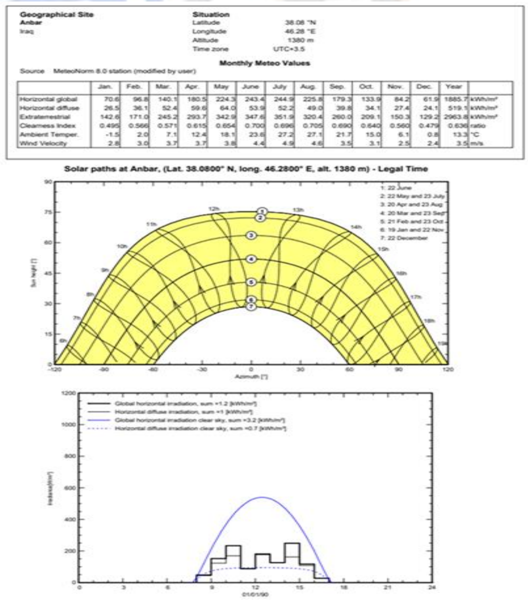

Figure. 7 Solar radiation paths.

VIII. Load profile of home

These are production graphs and curves during the year and the least energy loss, as in figure 8.

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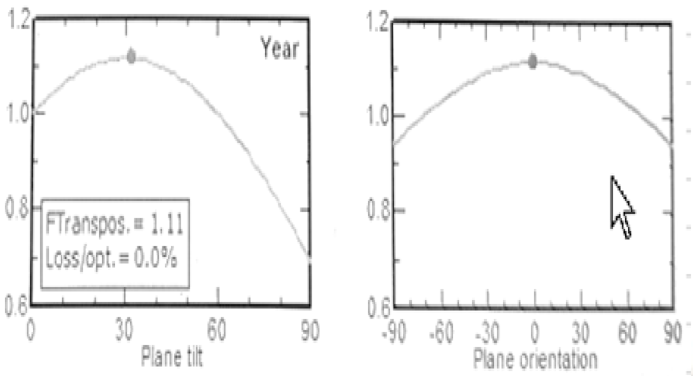

Figure 8. Production graphs and curves during the year and the least energy loss.

Table 4. Daily household consumers, Constant over the year, average = 14.0 kWh/day

Item	Number	Power (W)	Use Hour/day	Energy wh/day
Lamps (LED or Fluo.)	20	20w/lamp	10	4000
TV, PC, Mobil	3	100W/app	8	2400
Domestic appliances	2	400W/app	4	3200
Fridge/Deep-freeze	1	-	24	1200
Dish-and cloth-washer	2	-	2	1000
Us1	2	200W tot	2	800
Us2	2	300W tot	2	1200
Stand-by consumers	-	-	24	240
Total daily energy	-	-	-	14040Wh/day

Table 5. Losses in the solar panels of the PVSYST program

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 25 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.9 % at STC

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	30°	45°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.992	0.960	0.888	0.811	0.676	0.427	0.000

This information and data on losses in the panels were taken from the PVSYST program, according to the table 4.

The table 5 shows the annual production and consumption according to the program PVSYST. In addition to the losses in the storage bank batteries.

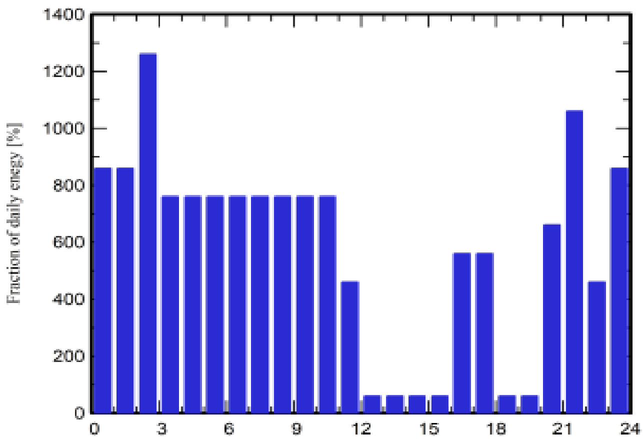

Figure 9. The information and data of the distribution loads.

Table 6: The annual production and consumption.

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac ratio
January	89.0	143.5	501.3	52.4	4.47	430.8	435.2	0.990
February	103.0	139.1	479.1	60.5	0.00	393.1	393.1	1.000
March	151.1	170.8	575.5	113.1	0.00	435.2	435.2	1.000
April	175.6	165.5	547.4	105.0	0.00	421.2	421.2	1.000
May	204.2	165.0	533.0	76.8	0.00	435.2	435.2	1.000
June	221.0	165.8	522.6	80.7	0.00	421.2	421.2	1.000
July	216.9	168.1	522.8	66.5	0.00	435.2	435.2	1.000
August	193.9	170.9	531.8	75.1	0.00	435.2	435.2	1.000
September	168.0	179.3	565.3	122.8	0.00	421.2	421.2	1.000
October	131.5	167.1	541.5	84.2	0.00	435.2	435.2	1.000
November	98.8	154.8	524.3	81.7	0.00	421.2	421.2	1.000
December	76.9	123.6	427.7	28.5	45.43	389.8	435.2	0.896
Year	1830.1	1913.5	6272.1	947.1	49.91	5074.7	5124.6	0.990

Figure 10 show information and data on the natural energy production in kilowatt-hours in all months of the year. The percentage of the organization's performance according to the program PVSYST in all months of the year is shown in figure 10.

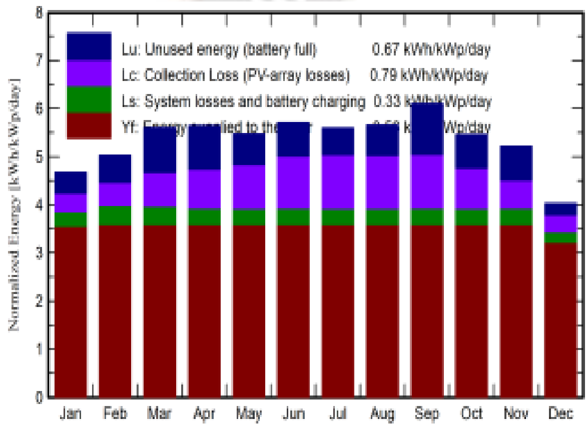

Figure 10. Contains information and data on the natural energy production (kWh).

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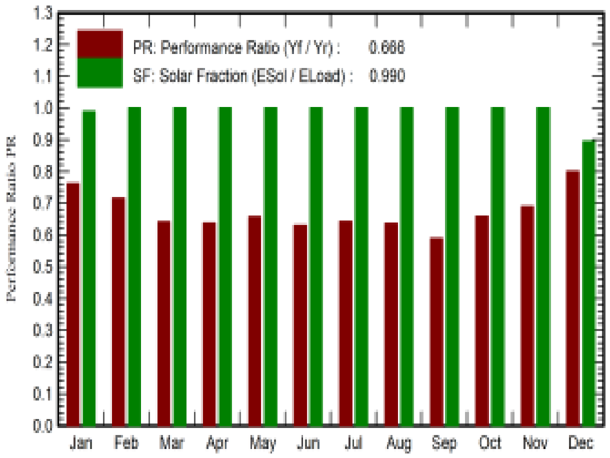

Figure 11. Percentage of the organization's performance.

Balances and main results for all months of the year according to the program PVSYST and according to the table 7 below.

Table 7. Balances and main results for all months.

System Production			
Available Energy	6272 kWh/year	Specific production	1608 kWh/kWp/year
Used Energy	5075 kWh/year	Performance Ratio PR	66.63 %
Excess (unused)	947 kWh/year	Solar Fraction SF	99.03 %
Loss of Load		**Battery aging (State of Wear)**	
Time Fraction	0.9 %	Cycles SOW	69.3 %
Missing Energy	50 kWh/year	Static SOW	92.9 %
		Battery lifetime	3.3 years

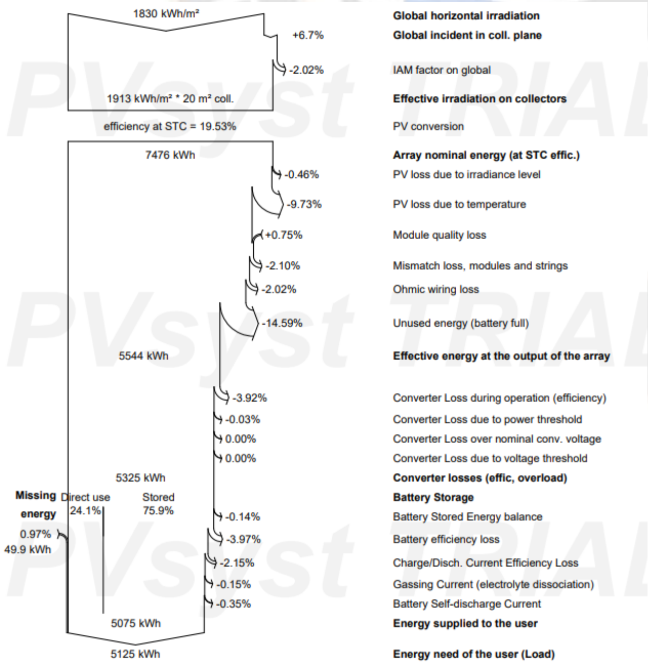

Figure 12. Loss diagram.

This chart shows the input power of the panels and the power output in kilowatts for a full year from the data in the program PVSYST.

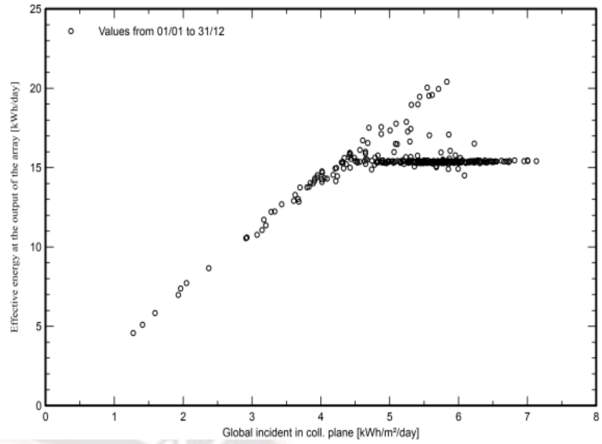

Figure 13. Daily input/output diagram.

These losses are in the system in general, according to the diagram taken from the program PVSYST. Losses in radiation and the effect of heat, losses in panels and bonding, losses in the conversion from DC to AC, losses in wires, in storage batteries, in charge as well as all efficiency are shown clearly in this diagram. Energy production reference in all months of the year and according to the chart below and according to the program PVSYST.

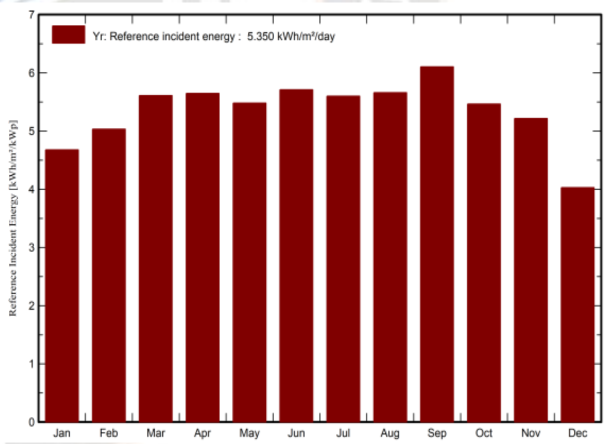

Figure 14. Reference incident energy in collector plane.

The layout's results, as shown in figure 13, include the rating and quantity of the (PV, modules, batteries, charge controller, inverter, and the cross-section area of the wire connection). The program is put through its paces on a variety of cases, and the preciseness and precision of the tool suggested in this paper are validated by published document results figure 14. The example that is provided possesses a result that is entirely consistent with the analytical approach. It is suggested that the program be improved to include the inclination and tilt angle impact.

Iraq has a physical location that includes a zone with abundant sunlight as well as more rather than 2000 kwh/m2 of annual solar irradiance. How to use solar energy systems is a topic of considerable interest. A process and method to plan standalone photovoltaic frameworks was suggested by numerous websites and software packages. Create a straightforward calculation program for sizing standalone PV systems and apply it to a particular load requirement. The work that is being presented has the advantage that anyone with a basic understanding of engineering or the solar system can operate the program by entering technical information that promotes the use of solar cell energy and has significant positive effects on the environment, economy, and society.

IX. Conclusion

In this study, we have investigated the design of large-scale, off-grid solar photovoltaic (PV) systems for institutional use, which can be installed on buildings and parking garages. The design process for off-grid solar PV systems involves several stages, including assessing local solar radiation data, identifying and assessing potential roofs, selecting the appropriate PV system components, and creating a system layout.

The development of a 3900W PV solar array for the researcher's home was a key factor in moving completely off the grid. The study followed a rigorous protocol, and the initial method was refined based on the results of a practical assessment of various components.

Based on the findings, a standardized approach to designing large-scale off-grid solar PV systems should be established. The modelling results suggest that implementing this research could result in an annual energy production of approximately 1608 kW, potentially avoiding the emission of around 8 tons of CO_2 by a crude oil-fired thermal power plant.

These results highlight the potential benefits of designing large-scale off-grid solar PV systems for institutional use, which can contribute to reducing carbon emissions and promoting sustainable energy practices. Future research should focus on further refining the design process and exploring innovative ways to optimize the efficiency of these systems

Conflicts of Interest:

The authors declare no conflict of interest.

Author Contributions:

Adil wrote the initial manuscript draft. Al Mashhadany, Conceptualization and methodology, investigation, results analysis and validation. Sameer, Mustafa, and Fore-check the writing of article, and Fatma supervisorial of this work.

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