The Economic and Financial Feasibility of the Solar Power System Installation Project at Al-Kut Olympic Stadium

***Nagham Hameed Abdulkhudhur Alayseri, **Ali Alhadi Rashid Abbood**

*College of Administration and Economics, University of Wasit, Iraq

DOI:10.37648/ijtbm.v15i03.004

[1]Received: 31/05/2025; Accepted: 29/07/2025; Published: 02/08/2025

Abstract

The electricity shortfall may be reduced by the utilization of renewable energy sources, especially solar power. One of the biggest and most prominent sports venues in central Iraq, Al-Kut Olympic Stadium, is the subject of this research, which looks at the possibility of grid-connected solar power production there. Finding out whether Al-Kut Olympic Stadium can accommodate a 1,250 MW grid-connected solar power plant is the main goal of this study. The primary goal of this research is to assess the three categories of solar energy—actual measurement, dataset, and surface radiation—in order to determine the stadium's capacity to use solar power. The findings indicate that the solar resource at the chosen location is of outstanding quality. Secondly, we want to use solar modules to learn how different orientation angles affect economic feasibility indicators, capacity factors, and solar energy production. According to the findings, it is financially viable to implement the suggested system at its peak performance. In order to optimize energy output while minimizing power production expenses, it is recommended to consider orientation angles, solar modules, and market pricing.

Keywords: *Solar energy; economic criteria; renewable energy.*

1. Introduction

Many scientists are looking to renewable energy sources like solar power as a way to lower electricity production costs and decrease emissions of greenhouse gases because of the growing demand for electricity, which is mostly generated by burning fossil fuels. An essential step toward environmentally friendly, emission-free manufacturing is the utilization of solar thermal energy. As a result, solar power has gained a reputation as one of the most promising renewable energy sources due to its high environmental friendliness, practicality, and economic viability. There have been a lot of research looking at the possibility of utilizing solar cells to generate power. But greenhouse gas emissions from fossil fuel use have harmed the ecosystem and accelerated global warming. Researchers are looking into alternative energy sources that may provide energy while also safeguarding the environment due to the environmental challenges caused by rising usage of fossil fuels. Because it is abundant, cheap, and environmentally friendly, solar power has quickly grown in importance as a renewable energy option. Photovoltaic (PV) modules may transform it into power. Photovoltaic systems have been instrumental in assisting several nations in meeting their power demands. Carbon dioxide emissions have been drastically cut, both locally and worldwide, thanks to the incorporation of renewable energy sources. Many scholars have assessed Iraq's access to renewable energy sources in view of these incidents. Solar energy resources are abundant in Iraq, according to this study, hence the nation has great potential to

---

[1] *How To Cite The Article:* Alayseri N.H.A., Abbood A.R. (August 2025); The Economic and Financial Feasibility of the Solar Power System Installation Project at Al-Kut Olympic Stadium; *International Journal Of Transformations In Business Management,* Vol 15, Issue 3, 46-62, DOI: http://doi.org/10.37648/ijtbm.v15i03.004

generate clean energy from solar power. It is believed that natural gas now supplies 98% of Iraq's electrical needs, with diesel accounting for the remaining 2%. Thus, investigating the potential uses of renewable energy in many sectors is essential with the aim of decreasing reliance on fossil fuels. We are evaluating grid-interactive solar PV systems for use at Al-Kut Stadium from a technical and economic perspective to back up such initiatives. A feasibility assessment on the solar energy project at Al-Kut Olympic Stadium is carried out and submitted to management in order to accomplish this. Issue for Investigation. The ongoing blackouts in the country's electricity grid are the primary focus of the investigation. Because of this, diesel generators are used more often to provide power, which has both monetary and environmental consequences. Clean, sustainable, and ecologically friendly energy sources, like solar power, must be the center of all this work.

1.1 Study Hypothesis

The research is based on the hypothesis that establishing a project (Economic Feasibility Study for the Establishment of a Solar Energy Project at Al-Kut Olympic Stadium) in Wasit Governorate will contribute to bridging the gap in equipping the stadium with solar energy. This project is also a vital and important project with economic feasibility.

1.2 Study Importance

Solar energy can be considered a major source of renewable energy in Iraq, and there is a need to attract investors to renewable energy technology by strengthening existing infrastructure and laws. Furthermore, solar energy will certainly help solve the problem of the shortage in electricity supply. The importance of this research also lies in the expected profits it will generate for anyone considering establishing this project, in addition to the use of low-cost solar energy, which will reduce reliance on traditional energy sources (oil and gas), which are expensive.

1.3 Study Objectives

1. To identify solar energy, its components, and its operational objectives.

2. To open up an investment opportunity for the Wasit Governorate Electricity Department and seek the assistance of the private sector through a proposed economic feasibility study for the aforementioned stadium.

3. To prepare a technical, financial, and economic feasibility study for a project to use solar energy as a source of electricity generation that alternates with national electricity, instead of relying on private generators.

4. This research aims to provide a sustainable energy source that reduces environmental pollution.

2. Literature Review

The conceptual framework for renewable energy and diagnosing its potential in Iraq's investment climate

2.1 The concept of renewable energy

Experts in renewable energy have sought to pin it down. Energy that is produced in a sustainable and natural way is one way that it is described. Additionally, it is defined by never running out and appearing in nature in both boundless and occasionally restricted quantities. However, it never runs out and doesn't harm the environment when used (Abdullah Al-Shamali et al., 2019, 8). It is referred to as "the use of natural resources, such as direct solar energy and others, to reduce carbon emissions and improve the environment through environmentally friendly projects." The following are some of Iraq's most significant renewable energy sources (IPCC Special Report, 2011, 34)

2.2 The Importance of Renewable Energy

Energy consumption and GDP growth seem to be proportionate, according to some research. Rapid economic expansion necessitates the use of more energy from a variety of sources. Because of its practical applications and potential to help satisfy a wide range of human needs, renewable energy is a matter of paramount significance. The fact that it is linked to solar energy gives it a reputation for being sustainable and having endless supplies, at least in the short term. Clean and favorable to the environment, this energy source provides a stark contrast to the many environmental issues generated by fossil fuels. As a result, spending money to fix environmental harm is unnecessary (Sharif Hina, 2019, 173). Increasing the utilization of renewable energy sources has several benefits, including lowering the negative effects on the environment and human health, fostering economic and social growth, and guaranteeing the supply of electricity.

2.3 The Potential of Renewable Energy in Iraq

For almost 30 years, Iraq has been dealing with an energy problem caused by ongoing power outages, and no solutions have been found. The chronic energy crisis in Iraq and the destruction of several power plants have reduced the producing capacity in most inhabited regions, both of which have contributed to the worsening of electricity supply in the nation. In order to satisfy the energy demand across the country, Iraq's electrical industry depends on a public grid that links all of the country's power plants. Consequently, power outages have become more frequent and severe over much of Iraq. Western governorates have outages of five to eight hours daily, while northern governorates see outages of one to four hours. (Hossain and colleagues, 2020) In 2020, peak demand hit 10,000 MW, as reported by the General Electricity Company. Carbon dioxide and greenhouse gas emissions rise due to higher energy consumption, which is caused by rising demand, especially in the energy and industrial sectors. In addition, Iraq's energy consumption demand is expected to rise over time, which will lead to an increase in the amount of fossil fuels required to generate electricity. Given Iraq's abundance of renewable energy sources, particularly solar power, it stands to reason that they might be some of the most effective means of reducing reliance on fossil fuels and associated carbon dioxide emissions. From 7.5 kW/m2 in the southern parts to 8.0 kW/m2 in the middle regions, the average yearly solar radiation per horizontal surface varies. Renewable energy, and solar power in particular, has been the subject of much research. Source: Dalkilic (2019) By speaking with consultants, managers, and decision-makers from several government agencies, researchers in Iraq looked at the present and future of renewable energy, focusing on Wasit Governorate. Based on the findings, renewable energy sources may be the best option for satisfying the energy needs of the governorate. Renewable energy sources were also emphasized as a possible solution to the governorate's present and future energy problems. Researchers found ways to cut carbon emissions, save money, and generate renewable energy (Mosey, 2013). The feasibility of switching from a grid-connected HPS to a solar-powered LED street lighting system for a 4-kilometer route was determined after examining relevant prior research. The findings shown that a solar-powered LED lighting system operating independently may decrease emissions of carbon dioxide, save gasoline, and be practically implemented. Wasit Olympic Stadium: what changes are possible there? Thus, the study postulated that the electrical grid of Wasit Governorate would see a decrease in peak load demand if solar PV systems were substituted for a diesel-powered generator. The study analyzed the radiation characteristics and duration of sunlight over Wasit, Iraq, by conducting a feasibility evaluation of developing a photovoltaic plant in Wasit Governorate. It did this by evaluating the average monthly solar radiation duration and sunshine duration. We need to reinforce current infrastructure and regulations to entice investors to renewable energy technologies, and solar energy may be seen as a significant source of this type of energy. Solar power is another certain way to alleviate the nation's power outage woes. Put simply, a large number of studies have looked at the possibility of using solar energy to create power, and the results have shown that Iraq, and Wasit Governorate specifically, has a lot of room to grow in this area. Solar power has other environmental benefits, including a lower carbon footprint, according to research in this area. The power industry and the use of fossil fuels. A lack of solar energy potential analysis in these studies meant that no one could say for sure where in Iraq PV installations would be most effective in the future. In addition, not a single one of these articles used RET Screen, an essential tool for project decision-making, to assess the long-term viability of a grid-connected PV facility situated in an appropriate area of Iraq. For the purpose of analyzing project uncertainty, we will use the future return of a renewable energy project as an example. Assem (2021) noted

2.4 Photovoltaic Systems

Semiconductor technologies known as solar photovoltaic systems directly transform sunlight into electricity. In contrast to a mobile generator, they do not produce any noise or pollution when operating because they do not have any moving components. Installation at a spot that doesn't get much shadow is standard practice; typical sites include garages, roofs, and sheds set up on the ground. The average yearly horizontal solar resource on a worldwide scale is 4.6 kWh/m² per day, demonstrating the effectiveness of PV systems. This figure, however, does not represent the maximum power that a PV panel is capable of generating. Many variables affect how much power a single panel can generate; these include collector type, panel tilt, temperature, sunshine level, and weather (Windarta, 2021). To ensure compatibility with the building's and utility's power systems, an inverter is necessary to convert direct current (DC) to alternating current (AC) at the necessary voltage. Fuse, relays, conduits, switches, and the system as a whole make up the balance. No batteries are needed with a grid-connected PV system; the electricity is directly sent into the building's electrical grid. Numerous tiny cells, or "cells," make up photovoltaic panels. Each cell generates its own little current and voltage. A bigger current may be generated by connecting these individual cells in sequence. Shade has a devastating effect on photovoltaic panels. Covering a solar panel with clouds prevents it from soaking up the sun's powerful rays. When one cell is shaded, it prevents current from flowing and wastes energy instead of generating it, just like a resistor in a series circuit. The suitability of a location for solar panels may be ascertained by measuring solar access, which is defined as the amount of direct sunshine that can reach the solar collector (Benjamin, 2016). The average energy consumption of the on-site utilities is a major factor in determining the system size, which is the next step after finding a location with adequate solar access, for a photovoltaic system. As a general rule, net metering agreements' economics dictate whether or not the site may receive more energy than it consumes. So that the size of the system may be altered according to the demand of the utility, systems will be separated by location.

3. Research Methodology

3.1 Feasibility Studies Used in the Proposed Project

The first task of this study is to determine environmental feasibility by determining the percentage reduction in greenhouse gas emissions resulting from the construction of a photovoltaic (PV) solar power plant. This can be done by comparing the results of greenhouse gas emissions from a PV power plant with those of a conventional power plant. The annual percentage reduction in greenhouse gas emissions can also be assessed for a PV power plant compared to a conventional power plant. The reference case here represents the annual carbon dioxide emissions in tons of a conventional power plant. Discussing greenhouse gas emissions is a vital aspect of constructing a PV solar power plant. The importance of this issue stems from the greenhouse effect, which is primarily caused by greenhouse gas emissions from the use of fossil fuels in conventional power plants. Therefore, the proposed project can be described as harmless and environmentally feasible.

3.2 Legal Feasibility Study

The project (Economic Feasibility Study for the Establishment of a Solar Energy Project at Al-Kut Olympic Stadium) is consistent with the country's prevailing legal regulations and legislation. It is described as having legal justification and an attractive investment project, according to the Iraqi Gazette dated April 17, 2017, Issue No. 4443, Resolution No. (10), based on what was approved by the Council of Representatives in accordance with the provisions of Clause (First) of Article (61) and Clause (Third) of Article (73) of the Constitution. The President of the Republic decided on March 16, 2017, to issue the following law: Law No. (53) of 2017, Ministry of Electricity Law, Clause Three: Regulating investment activities, including the construction and rehabilitation of projects related to the provision of electrical energy. Clause Four: Regulating the entry of the national and foreign private sector into investment in the fields of constructing new production and distribution stations, and providing the necessary legislative and institutional environment for this purpose. Clause Five: Supporting and encouraging the use of renewable energy in various fields and localizing its industries. Item Six: Gradual transition from central management to decentralized management in the activities of operating and maintaining production and distribution facilities.

3.3 Technical and Engineering Feasibility

3.3.1. Project Location

The proposed project is located at the Wasit Olympic Sports Complex in Wasit Governorate, a site that benefits from excellent solar energy resources and sufficient space for photovoltaic system installation. Additionally, solar electrification of the sports complex could promote future research and development activities in the governorate. The sports complex includes a large football field, a small football field, basketball, volleyball, tennis, and handball courts, an indoor games building, and a swimming pool. The large football field is equipped with four lighting poles, each containing 30 lamps with a power rating of 60 kW. The total power requirement for the large football field is 240 kW. The electrical load of the field is considered irregular due to its dependency on the nature and timing of activities held there. The total area of the field is 29,500 m², including 6,500 m² of covered spectator seating and 2,500 m² of covered VIP seating, totaling 9,000 m² of usable rooftop area. Various activities take place in the stadium throughout the year, including multiple training days and other events. The daily energy demand for the large football field was calculated based on the total required power and the number of operating hours. It was found that the field consumes approximately 1,250 kWh/day, with an equivalent diesel consumption of 200 liters per hour. Monthly energy requirements were determined by multiplying the daily energy demand by the number of operational days per month, as shown in Table 1.

Table (1): Sports Fields and Other Facilities in Wasit Olympic Stadium

Facility Type	**Land Area (m²)**	**No. of Lighting Poles**	**No. of Lamps**	**Power (kW per hour)**
Large Football Field	7,140	4 large	120	60 kW
Small Football Field	800	4 small	40	20 kW
Indoor Games Building	648	4 small	40	20 kW
Handball Court	800	2 medium	30	20 kW
Tennis Court	23.77	1 large	18	10 kW
Volleyball Court	162	2 small	10	10 kW
Basketball Court	420	2 small	10	20 kW
Rooms (10 total)	50	200 medium lamps	200	25 kW
Gardens (5 total)	3,780	6 medium	60	30 kW
Annex (6 total)	76	75 lamps	20	5 kW
Covered Spectator Area	6,500	12 very small	22	20 kW
Covered VIP Seating	2,500	7 very small	10	8 kW
Athletics Field Annex	6,500	4 large	120	60 kW
Total	29,500	48 poles + 275 lamps	700 various	**308 kW**

Source: Compiled by researchers based on data from the Administrative Authority of Wasit Olympic Stadium.

3.3.2. Types of Photovoltaic Systems

1. **Ground-Mounted Systems**

   Ground-mounted PV systems are typically chosen when roof space is insufficient or unavailable. These systems are generally more cost-effective to install and offer multiple design and installation options based on site-specific conditions.

2. **Roof-Mounted Systems**

   In many cases—particularly in this study—roof-mounted photovoltaic systems are preferred due to the availability of covered areas. Though slightly more expensive than ground-mounted systems, rooftop installations are advantageous as they are elevated, usually unshaded, and safer from ground-level interference. Optimal installation is recommended on roofs less than 5 years old or those with at least 25 years remaining before replacement.

3.3.3 Photovoltaic System Components

Photovoltaic solar systems typically consist of six major components:

1. **Photovoltaic Array**

   The PV array is composed of multiple interconnected solar panels that convert sunlight into DC electricity. PV systems are customizable to various installation sizes and electrical requirements.

2. **Charge Controller**

   The charge controller regulates the flow of DC electricity from the panels to the batteries, preventing overcharging. Although not essential in all systems, especially grid-connected ones, charge controllers are important for systems with battery storage.

3. **Battery**

   Batteries store unused solar energy for later use—such as during nighttime or overcast weather—enhancing the overall efficiency and reliability of the system. Including a battery is optional but beneficial.

4. **Inverter**

   The inverter is a crucial component that converts DC electricity into AC, which is required by most electrical devices and grid systems.

5. **Utility Meter**

   The utility meter measures the electricity consumed by the facility. When connected to a PV system, it also tracks how much solar power is utilized on-site.

(IJTBM) 2025, Vol. No. 15, Issue No. III, Jul-Sep e-ISSN: 2231-6868 p-ISSN: 2454-468X

6. **Electrical Grid**

If the stadium is connected to the national grid, it can draw power when solar production is insufficient, ensuring uninterrupted operation.

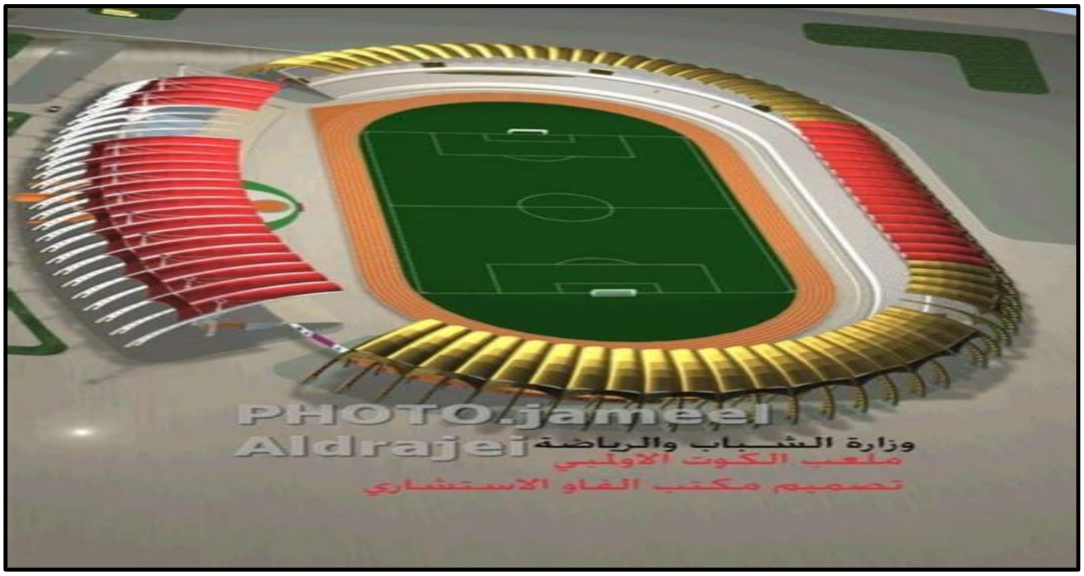

Figure (1): Front view of the large football field, athletics field, and main canopy areas.

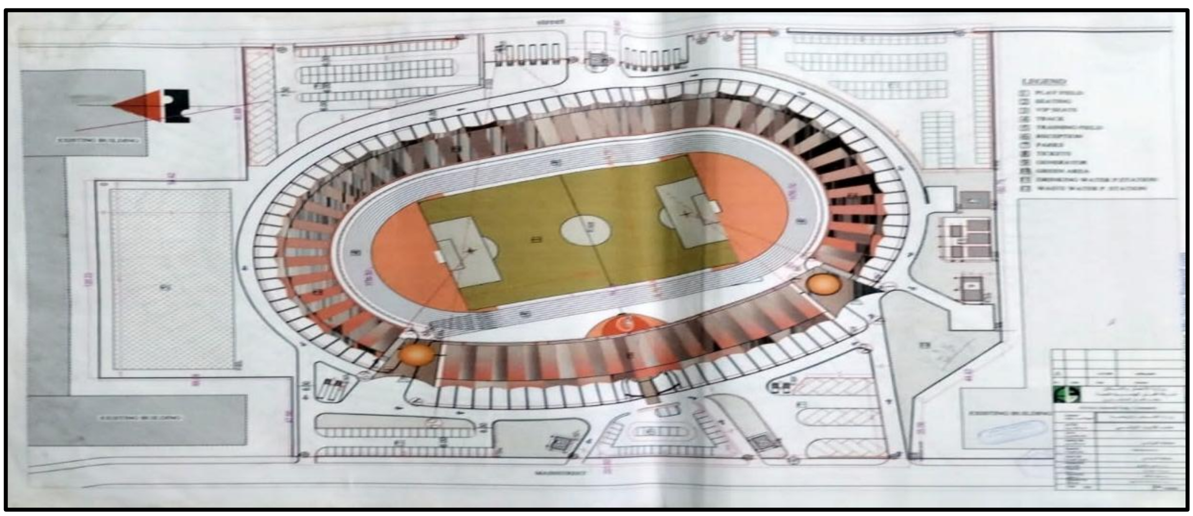

Figure (2) Map of the large stadium at Al-Kut Olympic Stadium

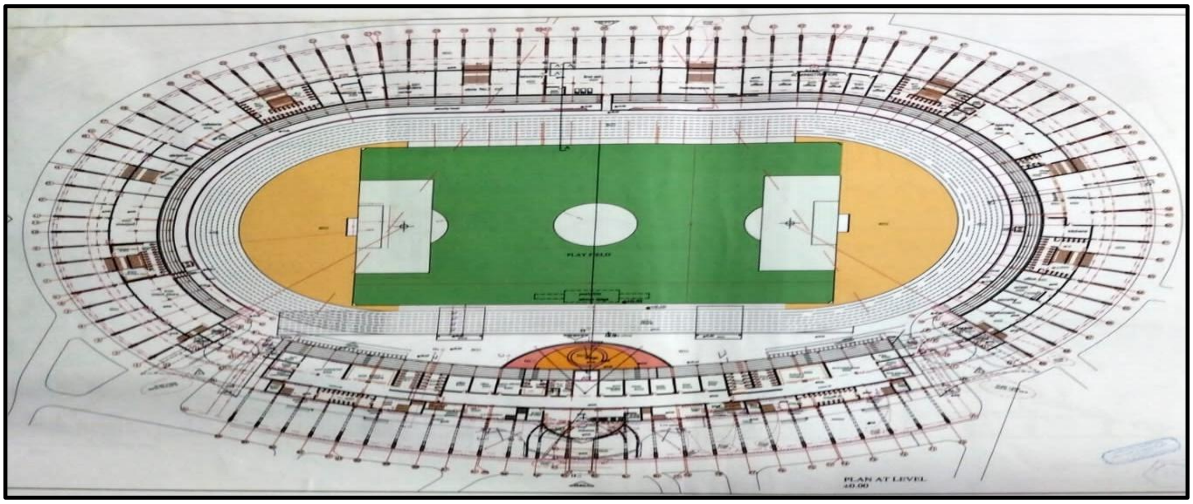

Figure (3) Urban planning of the large football stadium, the square, the field, and the main canopies

Specifications of Materials Used in the Proposed Project

1. Model A:

- Electrical Current: 30 Amps
- According to Inpowers Company specifications.

Table (2): Specifications of Materials for Proposed Model A

No.	Material	Description	Qty	Total Qty
1	Solar Panels	Brand: Inpowers Solar, 450W, Type: 120 Wp	20	500
2	Panel Mount Structure	Iron frame, 2-inch angle, 3 mm thickness	210m	500 sets
3	Inverter	Capacity: 1000W, Company: Mason, Voltage: 52V, Efficiency: 95%	20	500
4	Batteries	Nominal Voltage: 12V, Capacity: 150 Ah, Internal Resistance: 3.4 mΩ, Max Discharge Current: 840A (5s)	50	500

Source: Prepared by researchers based on Inpowers data.

2. Model B:

- Electrical Current: 20 Amps
- According to Kinjo Company specifications.

Table (3): Specifications of Materials for Proposed Model B

No.	Material	Description	Qty	Total Qty
1	Solar Panels	Brand: Kinjo Canada, 350 Wp, Voc: 46.6V, Vmpp: 39.2V, Isc: 9.51A, Impp: 8.94A, Efficiency: 19.9%	20	500
2	Panel Mount Structure	Iron frame, 2-inch angle, 3 mm thickness	210m	500 sets
3	Inverter	Capacity: 1000W, Company: Canadian, Voltage: 56V, Efficiency: 94%	20	500
4	Batteries	12V, 80 Ah, 8 mΩ, 840A (5s)	50	500

Source: Prepared by researchers based on Kinjo Canada data.

Table (4): Solar Panel Specifications Comparison

Specification	Inpowers (Model A)	Kinjo (Model B)
Pmax	120 Wp	350 Wp
Voc	21.51 V	46.6 V
Vmpp	18.2 V	39.2 V
Isc	7.19 A	9.51 A
Impp	6.67 A	8.94 A
Efficiency	16.3 %	19.9 %
Total Cost (ID)	126,000,000	129,000,000

Table (5): VRLA Battery Specifications

Specification	Brand A (Inpowers)	Brand B (Kinjo)
Nominal Voltage	12 V	12 V
Nominal Capacity	150 Ah	80 Ah
Internal Resistance	3.4 mΩ	8 mΩ
Max Discharge Current	840A (5s)	840A (5s)
Price (ID)	39,000,000	41,000,000

Note: Brand A is the most popular Inpowers brand in Iraq. Brand B is the Kinjo brand, also well-known in Iraq.

Required Manpower to Implement the Project

Solar equipment manufacturers usually employ engineers, workers, and technicians during the project duration. Materials engineers contribute to developing, processing, and testing materials used in solar energy products. In this industry, they work with semiconductors, metals, plastics, glass, and composites. Table (6) outlines the required manpower for executing the solar energy project at Al-Kut Olympic Stadium:

Table (6): Required Manpower for Project Implementation

No.	Position	Specialization	Quantity
1	Consultant Engineer	Engineering	4
2	Electrical Engineer	Electricity	4
3	Civil Engineer	Civil	2
4	Technician	Electrical	10
5	Skilled Laborer	Welding	5
6	Worker	Manual Labor	22

Source: Based on interviews with engineers specialized in solar system installation and maintenance.

Based on Table (6), the following administrative and maintenance team is needed for project operations:

Table (7): Administrative and Maintenance Team

No.	Position	Quantity	Work Duration
1	Project Management	3	From Year 1 to Year 15
2	Electrical Engineer	5	Full project duration
3	Civil Engineer	2	1 year
4	Technical Workers	8	At least 15 years
5	Maintenance Workers	6	Full project duration

Source: Based on interviews with engineers specialized in solar system installation and

Table (8): Installation Wages (Civil, Electrical, Technical, and Other Works)

No.	Detail	Total Annual Wage (IQD)
1	2 Civil Engineers @ 750,000	18,000,000
2	4 Consultants (Half-Year) @ 800,000	19,200,000
3	4 Electrical Engineers @ 1,000,000	48,000,000
4	22 Workers and Technicians @ 500,000	132,000,000
	Total	**85,320,000**

Table (9): Furniture Costs

No.	Item Description	Amount (IQD)
1	Mobile Caravan (3×6) x1	5,600,000
2	Air Conditioner x2 @ 500,000	1,000,000
3	Projector Screen x2 (42") @ 400,000	800,000
4	Security Cameras x6 @ 25,000	150,000
5	Leather Chairs x10 @ 50,000	500,000
6	Office Desks x2 @ 150,000	300,000
7	Computers x2 @ 400,000	800,000
8	Printer/Scanner x1 @ 400,000	400,000
	Total	**9,550,000**

Table (10): Establishment Costs

No.	Detail	Amount (IQD)
1	Government Licensing & Taxes	1,800,000
2	Design & Studies	700,000
3	Engineering Consultations	1,500,000
4	Government Insurance	2,500,000
	Total	**6,500,000**

Table (11): Total Basic Project Costs

No.	Detail	Amount (IQD)
1	Total Labor Wages	85,320,000
2	Furniture Costs	9,550,000
3	Establishment Costs	6,500,000
4	Solar System Installation	129,000,000
	Total	**230,382,000**

Annual Operating Costs

Operating costs include daily management, maintenance, accounting, legal, banking, marketing, travel, R&D, utilities, salaries, and depreciation.

Table (12): Annual Depreciation Costs

No.	Detail	Dep. Rate	Cost (IQD)	Depreciation (IQD)
1	Solar System	12%	129,000,000	15,480,000
2	Establishment Costs	50%	6,500,000	3,250,000
3	Furniture	30%	9,550,000	2,865,000
	Total		145,050,000	**21,595,000**

Source: Based on Unified Accounting System, Republic of Iraq, Financial Audit Bureau, 2011.

Table (13): Total Annual Operating Costs

No.	Detail	Monthly Salary (IQD)	Annual Salary (IQD)
	Fixed Costs		
1	Project Manager x1	1,000,000	12,000,000
2	Accountant x1	500,000	6,000,000
3	Maintenance Staff x6 @ 600,000	3,600,000	43,200,000
4	Service Staff x2 @ 350,000	700,000	4,200,000
5	Depreciation Costs		21,595,000
	Fixed Cost Total		**86,995,000**
	Variable Costs		
6	Maintenance		3,600,000

	Total Annual Operating Costs		**90,595,000**

4. Results of the Economic Feasibility Study for the Proposed Project at Al-Kut Olympic Stadium

4.1 Operation and Maintenance

Photovoltaic panels come with a performance warranty of 25 years, typically including a standard warranty of 5 or 10 years (with extended warranties available). It is essential to verify system performance on the vendor's provided website and inspect wiring and racking connections. For this economic analysis, an annual operation and maintenance (O&M) cost of 0.17% of the total installed cost is used based on other fixed-tilt, grid-connected photovoltaic systems. For single-axis tracking systems, an annual O&M cost of 0.35% of the total installed cost is applied based on current single-axis tracking system data.

Site characteristics are essential for designing a renewable energy system. These include site location, space availability, grid connectivity, energy demand, and available renewable energy sources. The presence of a grid connection at the selected site allows for a grid-connected system design, avoiding the higher-cost off-grid battery storage systems. Battery-based systems are often not cost-effective due to high costs and frequent maintenance. Accordingly, the electricity infrastructure at the Wasit Olympic Stadium was recently organized by developing technical guidelines for the installation and operation of rooftop grid-connected PV systems, including energy definitions. Cost-effectiveness and local availability of renewable sources were key drivers in designing this interactive PV system.

4.2 Selection of Photovoltaic Unit and Inverter

There are various types of photovoltaic units in the global market, including monocrystalline, polycrystalline, and amorphous silicon units. Parameters such as cell type, system cost, warranty, size, and wattage are essential for selecting the appropriate PV unit. Additionally, power rating and material type under PV USA Test Conditions (PTC) are fundamental for choosing solar panels. A suitable PV panel is identified based on the ratio of unit capacity to price and unit area. Key unit characteristics—such as area, power rating, cost, and efficiency—form the basis of PV system development. Among them, power rating and panel weight are the most critical. Equation (1) was used to select the suitable PV unit for the proposed station:

Panel Selection = (Unit Power × Unit Efficiency) / (Unit Price × Unit Area)

Note: The efficiency of the PV units chosen in this study exceeds 16%.

1. Solar Power Plant

A solar power plant utilizes sunlight as an energy source, using solar cells to convert photon radiation into electrical energy. These cells are made from pure silicon layers and semiconducting materials. Solar power stations are considered eco-friendly, producing no pollution or hazardous waste. However, their energy efficiency is affected by factors such as solar radiation, panel temperature, panel orientation, and shading.

2. Technical Analysis

This analysis is based on the designed solar power plant capacity, component specifications, panel orientation, and energy generation. Several factors influence the energy output of a solar plant, including solar radiation at the site (Al-Kut Olympic Stadium), panel tilt and orientation, sunlight availability, temperature, and component performance. Energy output will degrade over time due to panel aging and other factors. The plant's performance ratio, expressed as a percentage, reflects system efficiency and total losses during operation. System losses depend on solar panel efficiency, temperature, and inverter performance.

3. Techno-Economic Analysis

Techno-economic analysis evaluates the financial viability of an engineering investment by comparing alternatives to identify the most profitable. Typically, such investments have long economic lives, while currency values change over time. Therefore, financial metrics like Net Present Value (NPV) are used:

NPV = Present Worth of Benefits (PWB) – Present Worth of Costs (PWC)

4. Data Collection

According to photovoltaic geographic information system (PVGIS) data, the average solar irradiance in Wasit Province from 2020 to 2022 was approximately 5 kWh/m²/day. The data includes solar radiation, regional temperature, wind speed, and humidity levels.

5. Components of the Solar Power Plant

Key components include solar panels, SCC, batteries, and inverters. Two options for panels and batteries were selected and simulated using PVSyst software.

6. Economic Analysis

The investment feasibility for a solar mini-grid system at the site is evaluated based on NPV, factoring in total investment costs, operational costs, energy savings, discount rates, and inflation values. Investment costs were gathered from online marketplaces, offline shops in Baghdad, and surveys. Discount and inflation rates were obtained from the official investor. The study site is a remote area, and the only viable alternative electricity supply is from solar power stations.

Table (14): Initial Investment Costs

No.	Description	Quantity	Unit	Unit Price	Total Cost
1	Solar Panels (120 Wp)	500	Panel	ID 100,000	ID 50,000,000
2	Battery (12V, 150Ah)	50	Battery	ID 800,000	ID 40,000,000
3	Inverter (1000W)	50	Inverter	ID 350,000	ID 17,500,000
4	Solar Charge Controller	500	Device	ID 20,000	ID 10,000,000
5	Solar Panel Mounting Structure	500	Package	ID 10,000	ID 5,000,000
6	Grounding Packages	150	Package	ID 5,000	ID 750,000
7	Power Cables	2	Package	ID 350,000	ID 700,000
8	Electrical Protection	1	Package	ID 200,000	ID 200,000

9	Services and Miscellaneous	Lump Sum	Package	ID 3,000,000	ID 3,000,000
	Total				**ID 127,150,000**

These solar components and batteries, charged by the national electric grid, will be compared from an economic analysis perspective.

Table (14): Initial Investment Costs

No.	Description	Quantity	Unit	Unit Price	Total Price
1	Solar Panels 120 Wp	500	Solar Panel	ID 100,000	ID 50,000,000
2	12V 150Ah Battery	50	Battery	ID 800,000	ID 40,000,000
3	1000W Inverter	50	Inverter	ID 350,000	ID 17,500,000
4	Solar Charge Controller	500	Device	ID 20,000	ID 10,000,000
5	Solar Panel Mount	500	Package	ID 10,000	ID 5,000,000
6	Grounding Kits	150	Package	ID 5,000	ID 750,000
7	Power Cable	2	Package	ID 350,000	ID 700,000
8	Electrical Protection	1	Package	ID 200,000	ID 200,000
9	Services and Others	Group	Package	ID 3,000,000	ID 3,000,000
	Total				**ID 127,150,000**

The study compares generators and batteries powered by the government electricity company from an economic analysis perspective.

Investment Costs and Revenues

The investment cost for each component in the microgrid photovoltaic (PV) system is shown below:

Table (16): Investment Costs and Revenues

No.	Description	Monthly Cost (ID)	Annual Cost (ID)
1	Generator Cost	14,400,000	172,800,000
2	Total Solar Energy Installation	....	230,382,000
	Profit = Revenue – Sales		**57,582,000**

Source: Prepared by the researchers.

Analysis of the data in the tables reveals that every 20 solar panels generate 30 Amps, and the generators at Al-Kut Olympic Stadium produce 1250 MW, consuming 200 liters of kerosene per hour. Operating for 6 hours daily results in 1200 liters per day or 36,000 liters per month. At a cost of 400 ID per liter, the monthly cost is 14,400,000 ID.

The total annual cost for operating the stadium with kerosene generators is approximately 172,800,000 ID. By contrast, installing 500 solar panels for 25 years, including maintenance, requires about 230,382,000 ID, yielding an annual difference of 27,750,000 ID. Annual operating and maintenance costs for microgrid PV systems typically range from 1–2% of the initial investment, plus battery replacement costs. Based on Tables 1, 2, 3, 4, 5, 12, 13, and 14, the total investment cost for 500 panels is around 128,000,000 ID, with an annual operating cost of 43,860,000 ID, totaling 230,382,000 ID.

Table (17): Energy Savings from Solar Power Plant System

Category	kWh	Price (Million ID)
Energy Saving 1	567	1.467
Energy Saving 2	568	1.467
Energy Saving 3	567	1.467
Energy Saving 4	570	1.467

Source: Prepared by the researchers based on interviews with solar system installation engineers.

According to site load data, the generator used is rated at 1 KVA. The investment cost is outlined below:

Table (18): Generator Unit Cost

Item	Quantity	Unit Price	Total Price
1 KVA Silent Generator Set	1	ID 35,720,000	ID 35,720,000
Cable	1	ID 500,000	ID 500,000
Protection	1	ID 200,000	ID 200,000
Services and Others	1	ID 500,000	ID 500,000
Total			**ID 36,920,000**

Source: Prepared by researchers based on Al-Kut Olympic Stadium data.

Based on the equation $S = K \times P \times T$, fuel use is 200 liters per day. At 400 ID/liter, annual fuel use reaches 172,800,000 ID. Generator operating costs are shown in Table (18).

Table (19): Key Financial Formulas Used in the Project

Description	Formula
Payback Period (PP)	PP = Initial Capital Cost / Annual Cash Flow
Net Present Value (NPV)	NPV = Total Present Values of Inflows – Outflows
Internal Rate of Return (IRR)	IRR = Discount rate at which inflows = outflows
Profitability Index (PI)	PI = NPV / Initial Investment Cost

Source: Prepared by researchers based on prior studies.

The economic performance of the solar power system for Al-Kut Olympic Stadium was analyzed using PP, NPV, IRR, and PI. The initial investment cost (for 98 kW capacity at $700/kW) was estimated at $68,600. O&M costs were 0.22% of the initial investment. The designed system produces 134.688 MWh annually, with 56.065 MWh/month exportable to the grid after meeting a 1250 MWh/month demand.

With a project life of 25 years, the system's NPV was ID 1,450,800,000. Using an 8% discount rate, the IRR was found to be 10%. However, with bank financing and a discount rate of 6.5%, the IRR dropped to 3.315%, and PI was 0.59, showing economic viability but a slower return. Break-even occurs in year 20.

5. Conclusion and Recommendation

5.1 Conclusions

The solar system is off-grid and uses two types of solar panels and batteries.

Power demand is 1250 kWh. NPV is ID 1,450,800,000. Despite high investment, solar power is more economical than generators or grid power.

Variation 1 is most economically and technically viable with the lowest investment (ID 127,150,000) and minimal power difference.

5.2 Recommendations

1. Launch a national campaign promoting renewable energy, with accessible financing options.
2. The Ministry of Electricity should install solar systems to support the national grid.
3. Encourage replacement of diesel generators with solar systems and develop a solar resource data bank (irradiance, temperature, dust, etc.).

4. Conflict of Interest

The authors declare that they have no conflict of interest.

5. Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

6. References

Abdullah Al-Shammari et al. (2019). *Energy and climate change in the Middle East and North Africa: Youth perspectives towards a sustainable future*.

Abughinda, O. A. M., Camur, H., & Kassem, Y. (2020). Solar energy potential and feasibility study of a 10MW grid-connected solar plant in Libya. *Engineering, Technology & Applied Science Research, 10*(4), 5358–5366.

Ahshan, H. R., Al-Abri, R., Al-Zakwan, H., & Ambu-Saidi, N. (2020). Design and economic analysis of a solar photovoltaic system for a campus sports complex [Conference paper]. https://www.researchgate.net/publication/337543050_Solar_PV_System_Design_for_a_Sports_Stadium. https://doi.org/10.1109/GCC45510.2019.1570520864

Cruz Mendoza, M., Martinez-Gomez, E., & Li, H. (2022). Feasibility analysis of promoting wind and solar energy in Texas farms. *Sustainability, 14*, 2222. https://doi.org/10.3390/su1404222

Dalkilic, A. S. (2019). A feasibility study of solar energy—Techno-economic analysis from Aksaray City, Turkey. *Journal of Thermal Engineering, 5*(1), 25–30.

Intergovernmental Panel on Climate Change. (2011). *Special report on renewable energy sources and climate change mitigation*.

Kassem, Y., Gökçekuş, H., & Güvensoy, A. (2021). Techno-economic feasibility of grid-connected solar PV system at Near East University Hospital, Northern Cyprus. *Energies, 14*, 7627. https://doi.org/10.3390/en14227627

Medina, B. (2016). *Greenest City Scholar, Master's of Engineering Leadership, Clean Energy Engineering*. University of British Columbia.

Mosey, G. (2013). *Feasibility study of economics and performance of solar photovoltaics at the VAG Mine Site in Eden and Lowell, Vermont*. National Renewable Energy Laboratory (NREL).

Sharif, H. (2019). The importance of renewable energy in environmental protection to achieve sustainable development. *Voice of Law Journal, 6*(2).

Windarta, J. (2021). Technical and economic feasibility analysis of solar power plant design with off-grid system for remote area MSME in Semarang City. *IOP Conference Series: Earth and Environmental Science, 896*, 012007. https://doi.org/10.1088/1755-1315/896/1/012007