doi.org/10.54473/IJTRET.2024.8302
International Journal of Trendy Research in Engineering and Technology
Volume 8 Issue 3 June 2024
ISSN No. 2582-0958

ASSESSMENT OF ECONOMIC AND ENVIRONMENTAL FEASIBILITY OF INTEGRATED GRID-CONNECTED PHOTOVOLTAIC SYSTEMS IN AQRAH, DUHOK, IRAQ

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Received 05 April 2024 Received in revised form 10 May 2024 Accepted 13 May 2024
Available online 17 May 2024

ABSTRACT

This study investigates the economic and environmental feasibility of implementing a 7 kW grid-connected photovoltaic (PV) system in Aqrah, Duhok Iraq. Economic analysis reveals a net present value (NPV) of 42,213.7 ($) and a payback period of 6.91 years, indicating the system's commercial viability despite a longer payback duration compared to alternatives. The region's low electricity cost of $0.0159/kWh further enhances the project's economic attractiveness. In an environmental context, RETScreen software estimates a significant annual reduction in greenhouse gas (GHG) emissions, with a maximum reduction of 7.4523 (tCO2). These findings underscore the positive impact of the PV project on mitigating climate change and promoting sustainability in the area.

Keywords: photovoltaic system, economic feasibility, environmental sustainability, RETScreen software, greenhouse gas emissions, climate change mitigation, renewable energy.

I. INTRODUCTION

The rapid growth in population and technological advancements have significantly increased energy consumption, especially in the electricity sector, in recent years. This heightened demand is particularly evident in many rural and remote areas, notably in developing countries, where access to electricity remains limited [1, 2]. Meeting these challenges necessitates a substantial increase in electricity generation. While fossil fuel resources currently meet a significant portion of global electricity needs, it's crucial to acknowledge their limitations. These traditional energy sources are finite and depleting rapidly, threatening the global energy balance in demand and export [3]. Additionally, the heavy reliance on fossil fuels contributes significantly to greenhouse gas emissions, aggravating global warming and climate change issues [4,5]. These environmental concerns are intricately linked with economic challenges, underscoring the urgent need to transition towards more sustainable and renewable energy sources for a cleaner and more resilient future [6]. The escalating global population and heightened energy consumption have brought about significant environmental challenges [7]. The adverse environmental impact of fossil fuel usage has spurred scientific exploration into viable alternative energy sources. Various studies emphasize the reliability of renewable energy as a promising solution to the current energy production-related issues [8]. Among renewable resources, solar energy stands out due to its limitless potential. The direct harnessing of sunlight's energy through photovoltaic (PV) tools is increasingly acknowledged as a fundamental aspect in shaping the future of the world's energy supply [9,10].

Despite the abundant availability of renewable energy resources, Iraq has yet to fully utilize them. The country continues to grapple with a persistent electricity shortage crisis despite possessing a consistent wealth of renewable energy sources [11]. Addressing this crisis is crucial to meet the escalating electricity demand. Currently, Iraq heavily relies on large-scale thermal energy derived from gases released into the atmosphere [12]. However, concerted efforts to develop and harness renewable resources could significantly impact the country's future energy landscape [13-17]. Fossil fuels account for over 80% of Iraq's electricity generation.

Despite initiatives to capture natural gas and embrace renewable energy sources, the country still flares billions of cubic meters of gas annually [18]. The Kurdistan Region and Iraq grapple with persistent electricity shortages and crumbling infrastructure, posing significant challenges to residents and businesses alike. Despite efforts to provide reliable access to electricity, the average availability of national electricity is limited to only around 10-12 hours per day [19]. This shortfall necessitates reliance on commercial power plants during the remaining hours, exacerbating the strain on the already struggling infrastructure [20, 21]. The pressing need for infrastructure upgrades and effective energy solutions is evident. Without adequate access to electricity, essential services, industries, and daily life activities suffer. Moreover, unreliable power supply hampers economic growth and development prospects for the region. In addition to the challenges of availability, the cost of electricity adds to the burden consumers face.

The study seeks to examine the environmental sustainability of PV systems, evaluate their economic feasibility in the Aqrah district of the Duhok governorate, and develop strategies to promote the growth of the PV market.

II. METHODOLOGY

A. Study area

Aqrah District, situated in the northern region of Iraq, is a notable area within the Duhok Governorate. Despite being a disputed territory, Aqrah District has a population of approximately 212,000 residents as of 2018.

This district experiences a diverse climate, featuring mild winters and hot summers typical of the region. Annual high temperatures average around 24.93ºC (76.87ºF), while lows reach about 13.33ºC (55.99ºF). Aqrah District receives an average annual precipitation of 82.36mm (3.24in), with March being the wettest month, accumulating 195.66mm (7.7in) of rainfall. Conversely, July is the driest month, with only 0.83mm (0.03in) of precipitation. Rainfall occurs on approximately 92.52 days annually, accounting for around 25.35% of the year, leaving the remaining 272.48 days (74.65%) with no rain. With a humidity level of about 44.55%, Aqrah District experiences a climate that significantly influences local life and environmental conditions.

B. Assessment of Solar Potential

A variety of methods are utilized to estimate global solar radiation by leveraging satellite data, where the satellite captures the light emitted from Earth. In the context of assessing solar energy potential in Aqrah, Duhok, Iraq, data from the National Aeronautics and Space Administration (NASA) were employed. This analysis was conducted to comprehensively understand and unlock the solar energy potential in the area. The discussion encompasses comprehensively understanding and unlocking strategies aimed at optimizing their usage and enhancing efficiency [20, 21].

Through the utilization of NASA data and rigorous analysis, this study endeavors to provide valuable insights into harnessing solar energy resources effectively in Aqrah, Duhok, Iraq, thus con Global horizontal irradiation (GHI) is a critical parameter in evaluating the potential for flat-plate photovoltaic energy generation, solar power concentration, and photovoltaic concentration systems [23]. It serves as a fundamental metric in assessing the energy generation potential of flat photovoltaic (PV) systems [24].

C. Economic Evaluation and Reduction of Emissions

The economic and environmental aspects of a 7 kW grid-connected rooftop solar PV system are being assessed using RETScreen Expert software. This software is chosen for its capability to perform power comparisons across the selected region, offering valuable insights into the performance and efficiency of clean energy devices. RETScreen serves as a valuable tool for evaluating the viability of grid-connected solar PV systems and other renewable energy technologies [24, 25].

In particular, for the assessment of the project's economic feasibility parameters, the RETScreen software application is being utilized. This specialized module within the RETScreen software suite provides comprehensive analysis tools tailored specifically for assessing the economic viability of renewable energy projects.

III RESULT AND DISCUSSION

A. Solar Potential

Global horizontal irradiation (GHI) is crucial for assessing flat-plate photovoltaic energy generation, solar power concentration, and photovoltaic concentration systems. Air temperature (AT) is also vital for predicting the efficiency of photovoltaic (PV) systems.

Table 1 presents the average monthly GHI, while Table 2 displays the monthly Air Temperature (AT) determination for the Aqrah district over ten years. These results offer valuable data for understanding solar resource availability and environmental conditions in the region, enabling accurate assessments of solar energy project performance and feasibility. By analyzing GHI and AT data over time, stakeholders can make informed decisions regarding the design, installation, and operation of photovoltaic systems, optimizing energy generation and efficiency in Aqrah.

Table 1. The average monthly in ten years of Global Horizontal Irradiation (kWh/m^2)

Month/Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Jan	74.67	74.76	80.92	57.1	68.61	60.96	58.9	71.83	71.13	61.62	68.05
Feb	80.33	85.61	76.03	79.15	84.7	88.11	89.34	108.99	91.21	92.58	87.605
Mar	126.45	145.68	115.91	122.19	146.46	126.65	131.32	133.62	128.11	118.28	129.467
Apr	141.54	175.38	157.61	154.74	148.66	176.8	179.78	172.62	170.35	178.78	165.626
May	181.78	206.78	206.22	201.78	198.51	209.72	201.73	206.54	206.8	210.88	203.074
Jun	240	238.53	212.09	232.34	237.28	238.75	245.79	237.49	237.93	231.67	235.187
Jul	236.6	243.45	239.31	247.78	238.17	239.76	248.49	248.37	246.88	248.36	243.717
Aug	217.06	212.74	222.16	218.47	227.12	224.59	226.01	223.45	220.71	219.49	221.18
Sep	183.05	157.85	165.83	176.91	173.18	178.79	177.16	179.79	171.34	182.2	174.61
Oct	124.99	122.5	128.28	126.29	127.18	121.69	140.95	109.91	110.5	138.69	125.098
Nov	86.74	86.93	76.79	105.35	82.49	74.77	82.08	80.64	83.16	93.08	85.203
Dec	68.58	64.28	51.79	75.47	73.5	63.9	62.73	60.37	64.54	59.15	64.431

Table 2. The monthly rate in ten years of Air Temperature (˚C)

Month/Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Jan	2.5	1.1	3.4	7.7	4.2	4	4.8	5.4	4.8	4	4.19
Feb	6.6	5.3	7.9	8.2	6	5	8.1	6.8	7.1	8.5	6.95
Mar	10.2	14.2	11.1	13	10.7	7.8	11.4	11.7	10.6	10.7	11.14
Apr	14	21.6	15.9	16.9	15.9	19.3	17.6	18.2	16.5	17	17.29
May	26.5	24	24.4	23.2	22.4	24.8	22.2	24.3	24.4	23	23.92
Jun	30.5	30	29.7	30.1	29.4	30.7	29.1	29.3	29	29.4	29.72
Jul	33.1	32.6	31.7	33.4	33.6	33.1	31.6	32.3	33.5	33.2	32.81
Aug	32.3	33	30.5	33.4	31.4	31.7	31.2	32.3	32.4	33.5	32.17
Sep	27.6	27.1	24.7	28.5	26.3	27.1	25.2	26.5	28.7	26	26.77
Oct	21.5	19.6	20.7	21.2	17.8	20	18.1	18.1	20.4	20.8	19.82
Nov	11.9	10.9	10.8	13.9	7.4	12.7	12.4	9.6	10.1	11.2	11.09
Dec	5.1	4.8	8.2	8.1	4.9	6.6	3.3	7.3	4.4	4.3	5.7

In 2023, the selected area continues to exhibit noteworthy solar potential, with an Annual Mean Global Horizontal Irradiation (GHI) value of 1869.6 kWh/m². Additionally, the average Air Temperature (AT) in this region remains stable at 18.5°C. Classified based on the annual GHI, the area maintains its designation within the "Excellent" range, affirming the abundance of solar energy resources available, See Fig.1. This classification underscores the region's continued suitability for solar energy harnessing, further highlighting its significant potential for sustainable power generation.

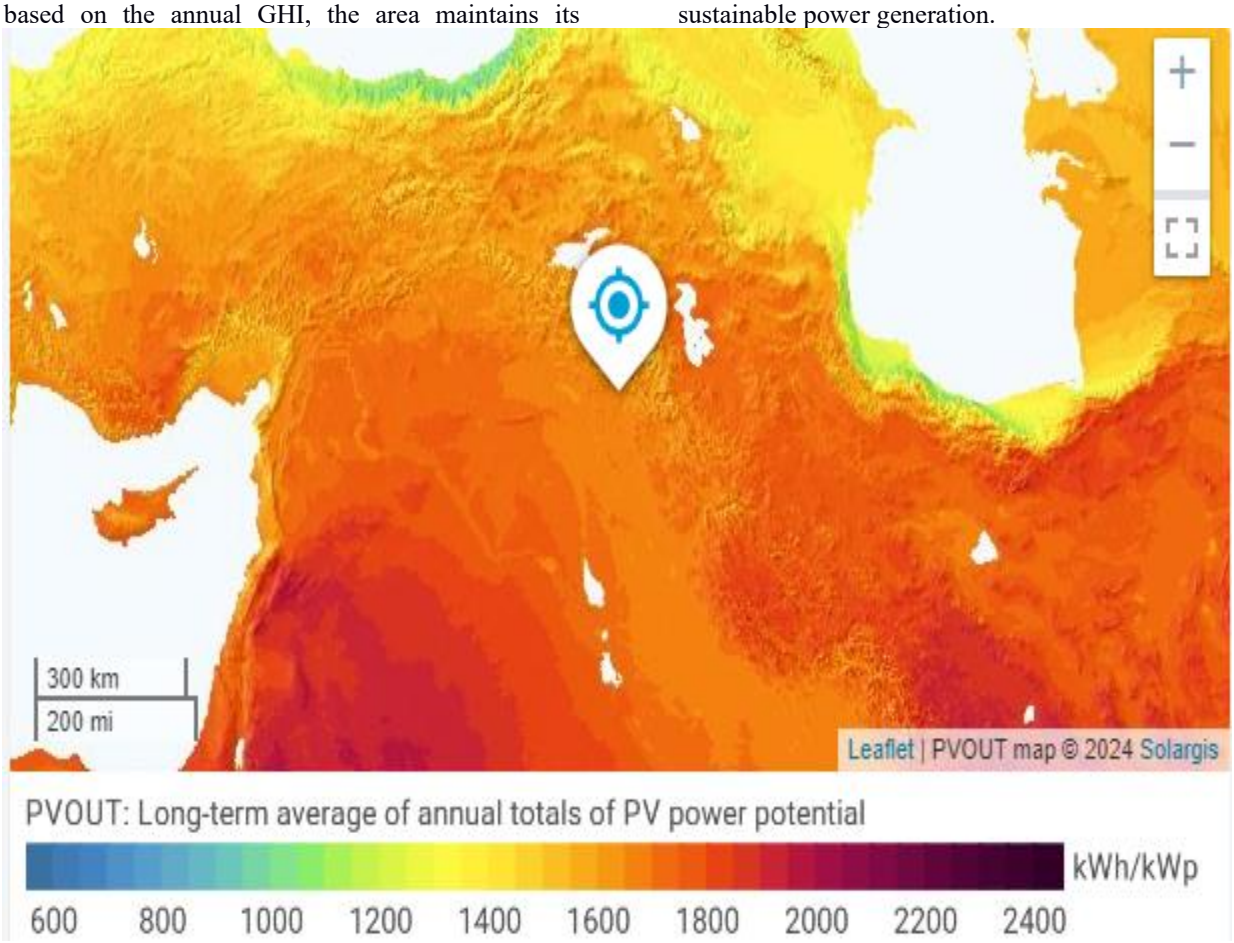

Fig.1 PVOUT map

The economic feasibility of a 7 kW grid-connected photovoltaic (PV) system in the chosen area was thoroughly examined using the RETScreen software. Through this analysis, key findings emerged, highlighting the system's impressive annual electricity generation of 2125.1 kWh/m2 per year and 11.268 MWh per year. The PV system, categorized as Small Residential, utilized default azimuth (180º) and tilt (32º) for PV panels, with an installed capacity of 7 kW. Additionally, the recorded capacity factor (CF) of 17.7% further underscored the system's efficiency and productive potential. Moreover, Monthly averages of Total photovoltaic power output are shown in Fig.2. These outcomes collectively suggest that the selected area is not only conducive but also highly suitable for the development of photovoltaic projects, affirming the viability and promising prospects for the integration of PV technology.

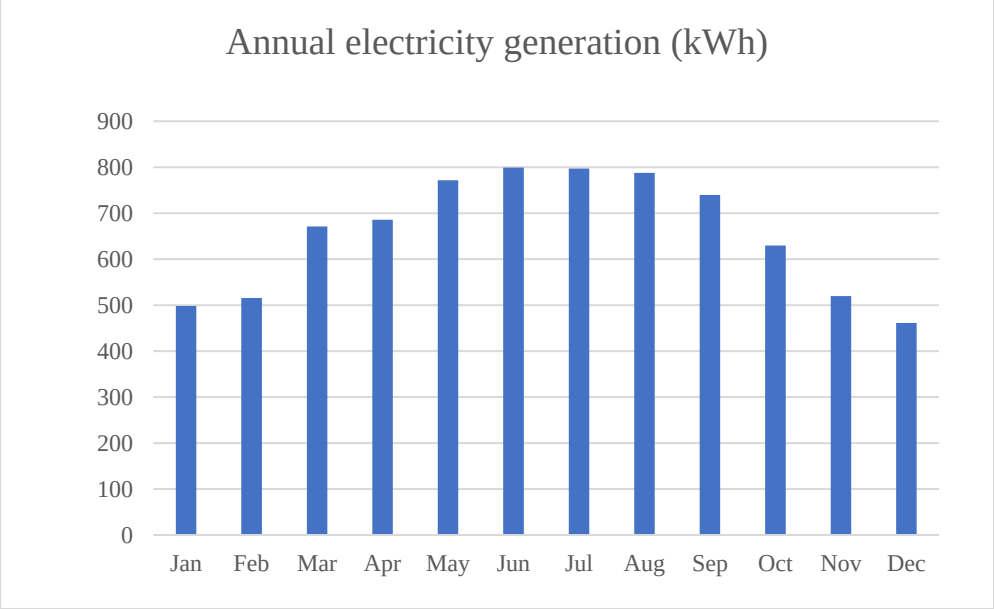

Fig.2 Monthly averages of Total photovoltaic power output

B. Financial Implications and Emission Reduction

Economic analysis is crucial for assessing the commercial viability and sustainability of proposals, providing valuable insights for consumers and policymakers. Evaluating the economic feasibility of PV power plants involves key criteria such as net present value (NPV) and payback period. The study results indicate an NPV of $42,213.7 and a payback period of 6.91 years, the longest among alternatives. Additionally, the region boasts the lowest electricity cost at $0.0159/kWh.

In the environmental context, RETScreen software estimates the gross annual reduction in greenhouse gas (GHG) emissions for the selected district. Findings reveal a significant achievement, with a maximum reduction in GHG emissions reaching 7.4523 metric tons of carbon dioxide (tCO2). This underscores the positive environmental impact of the project, contributing to climate change mitigation and fostering sustainability in the area.

IV CONCLUSION

The economic and environmental assessments conducted using RETScreen software highlight the favorable prospects for implementing a 7 kW grid-connected photovoltaic (PV) system in the selected area. Despite a longer payback period of 6.91 years, the system demonstrates strong economic viability with a net present value (NPV) of $42,213.7, supported by the region's low electricity cost of $0.0159/kWh. Additionally, the PV project offers significant environmental benefits, with a maximum annual reduction of 7.4523 metric tons of carbon dioxide (tCO2), contributing to climate change mitigation and sustainability efforts. These findings underscore the feasibility and desirability of integrating PV technology into the region's energy infrastructure, paving the way for a cleaner, more sustainable future. Continued investment in solar energy projects like these is essential for advancing renewable energy adoption and addressing environmental challenges on both local and global scales.

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