Management of Duhok Governorate Environment by Generating Sustainable Solutions (Rooftop Photovoltaic Systems) In Buildings Instead of Regular Electricity: Environment, Management and Techno-Economic Evaluations

Hüseyin GÖKÇEKUŞ, Youssef KASSEM, Ahmed Mohammed Ahmed

Abstract: Population growth and increasing demand for energy have been causing severe environmental problems all over the world. This research is done to find a suitable management way to improve the environmental condition, develop sustainable and economical solutions. This study focused on using Rooftop Photovoltaic Systems for the first time in Duhok governorate, Iraq, due to the rapid growth in the governorate and the great demand for energy, and the high energy production costs. Four regions were chosen in Duhok governorate to install photovoltaic systems. The NASA database as a source for assessing solar energy potential were used. The results show that these areas have enormous potential and annual solar radiation to produce solar energy. The RETScreen expert evaluated the electricity production potential of PV systems. In addition, an economic study of 5kW capacity for grid-Connected rooftop PV projects was carried out in all selected regions. Depending on the financial results and indicators, Rooftop Photovoltaic Systems can be a sustainable and efficient solution to improve the environment and economically installable in the Duhok governorate.

Keywords: Solar energy, Rooftop Photovoltaic Systems, Renewable energy, NASA database.

I. INTRODUCTION

Nowadays, energy consumption is increasing, new energy production methods are being used, and different world issues, such as environmental and economic problems, are increasing because of these energy production methods (Chel and Kaushik, 2018). The technologies commonly used to create electricity are the methods that today impact our environment adversely. Coal, gas, oil, and so on are traditional energy production methods. This is achieved by producing electricity by burning fossil fuels. The consumption of fossil energy has polluted the environment and has led to climate change because of greenhouse gas emissions. In another opinion, the economic aspect seen in many countries has a significant expense. As with the beneficial element, fossil fuels' use allows many illnesses to spread due to the release of thermal gases (Belkilani et al., 2018). The environmental concerns created by fossil fuels have prompted scientific researchers to research healthy alternative energy sources. Many studies have found that renewable energy can address many challenges in developing electricity and is a safe way to produce energy (Aziz et al., 2019). The energy we take from natural sources is renewable, and it is called sustainable energy. Any sources, such as sunshine, geothermal gas, water, wind, and winds, are used to extract renewable energy. Saving this energy is time and weather-based. We take, directly or indirectly, the highest proportion of renewable electricity from the sun.

Light or energy directly from the sun can be used for lighting homes and houses, cooking, power generation, heating, and even cooling from solar energy (Abed et al., 2020). The most severe environmental issue and life-threatening catastrophe on the crust of the planet is climate change. This phenomenon is called global warming, too. In the middle of the last century, global warming was discovered. A serious study began from the outset of its discovery to find suitable ways to eradicate this problem and decrease its harmful consequences. According to the World Health Organization, global warming killed 150,000 people in one year in 2000, and this number could be increased in the next decade (Ibrahim et al., 2020). Most energy generation in Iraq relies on the availability of electricity from thermal power plants using fossil fuels. There are many economic issues because they cost a considerable amount and extract many CO2 emissions. These stations are very upsetting to create a noisy and unacceptable sound that reduces the city's generosity and because of a large number of fire possibilities (Darwish et al., 2019).

Manuscript received on March 04, 2021.
Revised Manuscript received on March 30, 2021.
Manuscript published on March 30, 2021.
* Correspondence Author
Hüseyin GÖKÇEKUŞ, Department of Civil Engineering, Near East University, Nicosia, Cyprus. Email: huseyin.gokcekus@neu.edu.tr
Youssef KASSEM, Department of Mechanical Engineering, Near East University, Nicosia, Cyprus. Email: youssef.kassem@neu.edu.tr
Ahmed Mohammed Ahmed *, Department of Civil Engineering, Near East University, Nicosia, Cyprus. Email: ahmed.mohammed.ahmed.1998@gmail.com

II. LITERATURE REVIEW

A. Renewable Energy in Iraq

With an area of 437,072 km2 and a coastline of 58 km, Iraq is situated in the Eastern Mediterranean. The nation has a 40 million population. This site has a geopolitical and global effect and serves as the first forum on the foreign and commercial side to connect the world's countries. Iraq is one of the countries that enjoy a permanent wealth of renewable energy sources and does not use them despite their availability. Generally, renewable energy is derived from sources not based on fossil fuels, such as electricity, coal, and nuclear power. It is also possible to describe renewable energy as energy flows that are renewed at the same rate of use (Ibrahim et al., 2020). Iraq suffers from a crisis of electricity shortage, and we must work to solve this crisis to increase electrical demands. The Iraqi electricity system depends mainly on the immense thermal energy from the gases emitted from the atmosphere. The Iraqi Ministry of Electricity announced that Iraq does not currently produce any renewable energy. Still, the Iraqi government signed contracts to produce 1,000 MW of solar energy in 2018, which led to an increase of about 2,000 MW by 2025. In 2019, the Iraqi Ministry of Electricity announced the launch of the first round of solar photovoltaic projects, power stations with a capacity of 755 MW, and inviting companies working in this field to participate, as the ministry identified the projects distributed in the governorates of Babel, Wasit, Karbala, and Muthanna. In Iraq, the use of solar energy, wind energy, and biomass is sufficient, but work to develop them can play an essential role in the future of renewable energies in Iraq (Hamdoon et al., 2020). Renewable energy programs are typically moving towards reducing the percentage of carbon emissions in many countries. And the government must set up advanced electrical stations (long-term) in a country like Iraq, which has high temperatures in the summer because the validity of generating electrical energy in the available stations has already expired the pace of urbanization and population growth that causes a rise in the levels of annual demand for electricity by 7-10 %, and if they use of electricity (Azabany et al., 2020).

Also, 48.11 % and 49.62 % of total electricity are produced by oil products and natural gas, according to IEA Electricity Information (2020), while hydropower and solar were exchanged by about 2.20 % and 0.07 % of total electricity in 2018 from just 2.6 percent in 2018 (Kazem, and Chaichan, 2012).

As shown in Figure (1), Iraq's electrical production is mainly generated by oil products, natural gas, and hydropower.

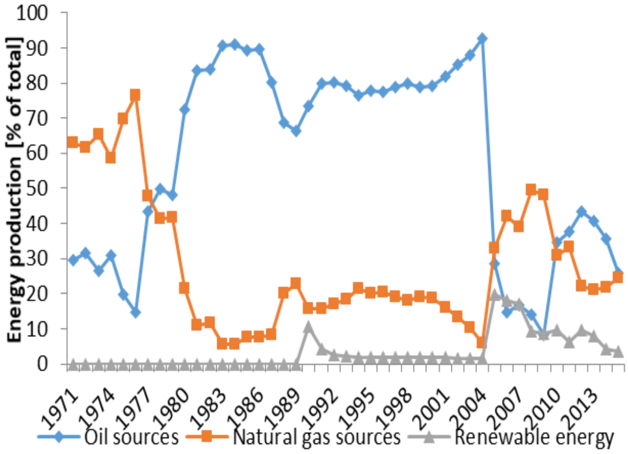

Fig. 1.Electrical production in Iraq.

B. LITERATURE REVIEW

Besides, Abed et al. (2014) concluded that the solar energy system and the hydropower system should be used as alternative sources of energy to generate electricity and to solve the problems that occur in the world and terms of the atmosphere, and that the reduction of CO2 emissions would be an acceptable solution.

Kayim and Mohamed (2019) concluded that solar energy could generate about 1800-23900 kWh/m2 and be delivered 10 hours a day. The study's findings indicated that this percentage of energy generation would be an acceptable way to eliminate its power crisis.

Ahmed (2013), an analysis of wind energy potential in northern Iraq has been undertaken. For three decades, it gathered data and selected five separate locations for wind energy capacity. The findings show that the wind speed in Tikrit is 4.0-4.5 (m / s) in July, and this result will yield (13.5 kW / h) at the predicted limit.

Ibrahim et al. (2020) to look for the best place to mount the solar energy device in Dohuk, Iraq, Boolean logical-AHP technology was used. They found that 68.5 percent of the city area should be used for solar power stations, according to the findings.

Aziz et al. (2019) the feasibility, techno-economic, and environmental ramifications of different hybrid schemes were examined using HOMER software to provide a typical Iraqi rural village with electricity. The results showed that the most economical solution was PV/hydro/diesel/battery hybrid energy systems because of the low net present cost-benefit and a high degree of environmental performance.

Ali M. Rasham (2016), according to his study, it was evident in Iraq that in many regions, there is a tremendous opportunity for the use of wind energy, and three areas in Iraq have been researched to evaluate annual data on wind speed.

As a standard approach, MATLAB software was used. Basra and Nasiriyah were chosen to link to the power grid as acceptable places.

Ahmed et al. (2019) concluded that Iraq's solar energy could be a sustainable solution and a solution to its problems. The use of solar energy is one of the most appropriate solutions to eliminate the electricity shortage, especially the country's environmental crisis and pollution.

Alduori and Fayadh (2016) concluded that we could develop in the field of solar energy because in Iraq, there are additional tools, especially wind directions and friendly temperature, and their study of the variation in annual radiation levels was found. UV rays were found to constitute 3.25% of global radiation. “Float over text” should *not* be selected.

III. MATERIAL AND METHOD

A. Description of Methodology

An economic analysis of study the solar energy potential was provided in four regions in Duhok, Iraq. To give this requirement and realize the potential of solar energy in the selected regions, NASA data was used. The PV systems and the saving methods for their use are discussed. The procedure for analysis in this study is shown in figure 2:

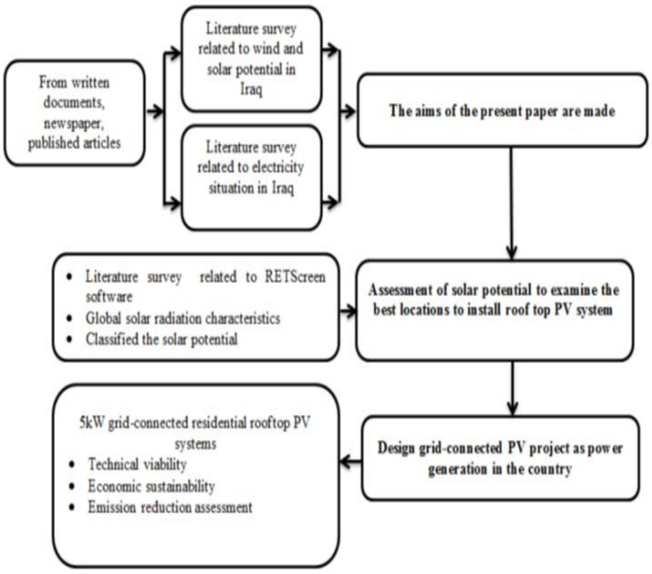

Fig. 2. Schematic explanation for the proposed methodology

B. Design of the PV Power System

The significant parameters that are considered for the design of a PV power plant are, according to (Kassem et al. 2020; Owolabi et al. 2019):

Power generating factor:

$$PGE = \frac{Solar\ irradiance\ \times\ Sunshine\ hours}{Standard\ test\ condition\ irradiance} \quad (1)$$

Solar PV energy required:

$$Energy\ req.\ from\ PV\ modules = Peak\ energy\ req. \times Energy\ lost\ of\ sys. \quad (2)$$

PV module sizing:

$$Total\ Watt\ peak\ rating = \frac{Solar\ PV\ energy\ required}{panel\ generation\ factor} \quad (3)$$

$$PV\ module\ size = \frac{Total\ Watt\ peak\ rating}{PV\ output\ power\ rating} \quad (4)$$

Inverter sizing:

$$Inverter\ size = Peak\ energy\ requirement \times Factor\ of\ safety. \quad (5)$$

C. Grid-Connected 5kW Residential Rooftop PV System

The PV technologies were considered mono-crystalline silicon (mono-Si) for the proposed 5 kW grid-connected rooftop. Seventeen modules of the selected modules mono-Si-CS6X-300M) were needed to create the 5 kW grid-connected residential/household rooftop in the chosen locations. The Growatt 5500MTL-S Dual MPPT 6KW Solar Inverter with a total power of 6000W has been used for the planned PV system. The definition of a chosen inverter is shown in Table 1, and the specification of the selected inverter is shown in Table 2.

Table- I: Technical specification of the Photovoltaic (PV) modules.

PV Module Technology	Mono-si
Manufacture	Canadian Solar
Model	mono-Si-CS6X-300M
Nominal power (W)	300
Open-circuit voltage (V)	45
Short-circuit current (A)	8.74
The voltage point of maximum power (V)	36.5
Current at point of maximum power (A)	8.22
Module area (m2)	1.919
Efficiency (%)	15.63
Warranty (Year)	25
Cost (USD/Wdc)	0.83
Cost (USD/Wdc)	0.83

Table- II: Technical specification of the selected inverter.

PV Module Technology	Value
Rated power (W)	6000
Min PPT Voltage (V)	100
Max PPT Voltage (V)	550
DC startup voltage (V)	100
DC shutdown voltage (V)	80
Max input voltage (V)	550
Max DC power (W)	6500
Max AC power (W)	5000
Max DC current (A)	30
Warranty (year)	10
Efficiency (%)	97.9
Cost (USD)	550

D. Economic Analysis

Physicists, researchers, and engineers have used different modeling approaches to approximate the annual and monthly energy output and the installed solar PV system's power factor. Several science researchers have used RETScreen and other related software, such as HOMER, to evaluate the technological and environmental feasibility of solar PV technologies worldwide.

To evaluate the techno-economic and environmental dimensions of the 5 kW grid-connected rooftop solar PV system, RETScreen Expert software is used to compare its power across selected regions. RETScreen software is a valuable instrument to assess and determine the viability of a clean energy device linked to the grid. RETScreen tools will predict annual and monthly energy production, power factors, and other critical economic metrics based on input data. RETScreen Specialist program was utilized to assess the project's economic feasibility measures. Described as an equation, the following indicators are given below:

Net present value (NPV):

$$(NPV) = \sum_{N=0}^{N} \frac{C_n}{(1+r)^n} \qquad (6)$$

Levelized cost of energy (LCOE):

$$LCOE = \frac{sum\ of\ cost\ over\ life\ time}{s\ o\ f\ electricity\ generated\ over\ the\ li\ f\ etime} \qquad (7)$$

The internal rate of return (IRR):

$$(IRR) = \sum_{N=0}^{N} \frac{C_n}{(1+IRR)^n} \qquad (8)$$

Simple payback (SP):

$$SP = \frac{C - C1}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})} \qquad (9)$$

Equity payback (EP):

$$(EP) = \sum_{N=0}^{N} C_n \qquad (10)$$

The annual life cycle savings (ALCS):

$$(ALCS) = \frac{NVP}{\frac{2}{r}\left(\frac{1}{(1+r)^N}\right)} \qquad (11)$$

GHG emission reduction cost (GHGERC):

$$GRC = \frac{ALCS}{\Delta_{GHG}} \qquad (12)$$

Benefit-Cost ratio (B-C):

$$B - C = \frac{(NPV) + (1 - f_d)}{(1 - f_d)^C} \qquad (13)$$

Capacity factor (CF):

$$CF = \frac{P_{out}}{9 \times 8760} \qquad (14)$$

Pout is the primary energy produced annually, p is the installed capacity of the power, N is the sustainable life of the project in years, Cn is the cash flow in n year after tax, r is the full rate of deduction, C is the initial cost of the project, fd comes as the debt ratio, B is the total interest for the whole project, IG is grants and incentives, Cener energy income per year, Ccapa is annual income, CRE renewable energy produced every year, CGHG is the thermal gas reduction, RE production credit income. Co&M is the yearly cost of service and maintenance borne by Cfuel, the renewable energy initiative. The annual fuel cost is negligible for green ventures, and DGHG is the annual reduction in GHG emissions.

IV. RESULTS AND DISCUSSION

4.1 Solar Energy Potential

Global horizontal irradiation (GHI) is an essential parameter for assessing flat-plate photovoltaic energy generation, solar power concentration, and photovoltaic concentration systems. Air temperature (AT) is one of the most critical parameters for PV system efficiency predictions.

4.1.1 Global Solar Characteristics

The average monthly GHI for regions Duhok, Aqrah, Simele, and Zakho are shown in Figure 3. The monthly GHI values are found to be within the range of 62.179-248.088 kWh/m2. Determination of the average monthly rate of AT for all regions, shown in Figure 4. It was also observed that in the Simele and Duhok regions, the highest and lowest AT values were obtained with values of 33.47 (Jul) and 2.81 ° C (January), respectively.

Additionally, for all regions, Table 3 shows the annual GHI and AT. The maximum yearly GHI with a value of 1847,788 kWh/m2 was found to have been obtained in Simele and Duhok, the lowest GHI values were reported with a weight of 1783.222 kWh/m2, and it is noted that the maximum and minimum air temperature values in Simele and Duhok were reported at 19.2 and 16.4 °C respectively.

Table-III: Annual mean GHI and AT for all selected regions.

Parameters	Duhok	Aqrah	Simele	Zakho
GHI (kWh/m2)	1783.222	1803.248	1847.788	1808.914
AT (°C)	16.425	18.464	19.26	19.166

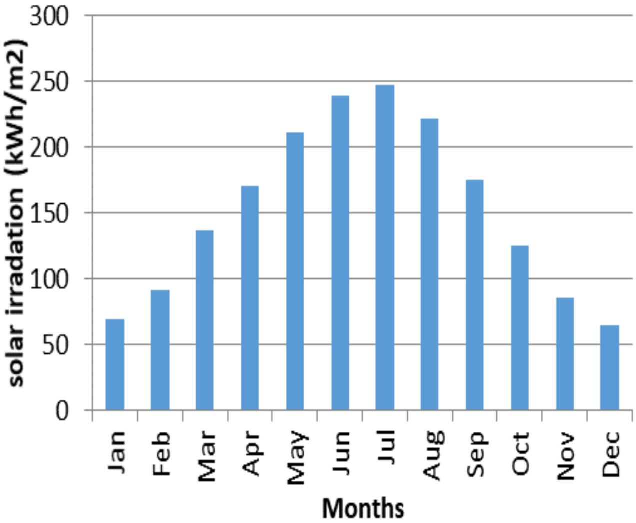

Fig. 3. Average of monthly GHI for all regions

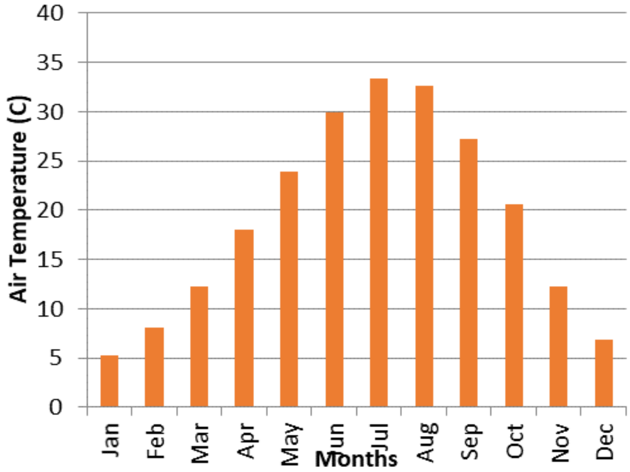

Fig. 4. Average of monthly AT for all regions

5.1.2. Solar Potential Classification

As described above, GHI has been used to assess the solar energy potential in the region. The description of solar energy for the chosen area based on annual global horizontal irradiation is seen in Table 3, based on the solar capacity groups Table 4. It should be remembered that the selected regions have a high solar capacity and have been rated as good or excellent future grades. It was also found that the Simele location solar resource was graded as excellent (class 5). Consequently, due to the high importance of global solar radiation (GHI), it is assumed that Aqrah is the most suitable area for installing large-scale photovoltaic systems. Thus, it should be noted that all selected regions are ideal for installing PV/flat-plate and CSP systems.

Table-IV: Solar potential classification based on annual GHI

Class	GHI (kWh/m2)
1 (Poor)	<1191.8
2 (marginal)	1191.8–1419.7
3 (fair)	1419.7–1641.8
4 (good)	1641.8–1843.8
5 (excellent)	1641.8–2035.9
6 (outstanding)	2035.9–2221.8
7 (superb)	>2221.8

Table-V: HGI Classification based on NASA Data

Class	GHI (kWh/m2)
Duhok	Good
Aqrah	Excellent
Simele	Good
Zakho	Good

4.1.3 Assessment of PV Systems Performance

A fixed-tilt system for a rooftop solar PV system in all selected cities has been suggested for the proposed system. The PVGIS modeling method was used to find the optimal angles for all chosen positions regarding the slope angle and the azimuth angle. For all the selected regions, Table 6 lists the optimal angle for the future PV installation device. RETScreen software was used to examine a 5 kW PV device's economic viability linked to the grid in the chosen locations. For all the selected regions, Table 6 lists the optimal angle for the future PV installation device. RETScreen software was used to examine a 5 kW PV system's economic feasibility for the grid-connected in the chosen locations. The annual electricity generation and capacity factor from the proposed system with PV technology are shown in Figures 5 and 6. At Aqrah, the yearly maximum electricity production was reported, which is 7877.0869 kWh, and at Duhok, the lowest 7737.1227 kWh was recorded. Moreover, it was noted that the capacity factor (CF) values are within the range of (17.3183-17.6316 %), so these values suggest that the regions selected are suitable for developing PV projects.

Table-VI: Optimum angles for the PV system for all selected regions

Parameters	Duhok	Aqrah	Simele	Zakho
Slope angle (°)	-6	-4	-3	-5
Azimuth angle (°)	31	32	32	33

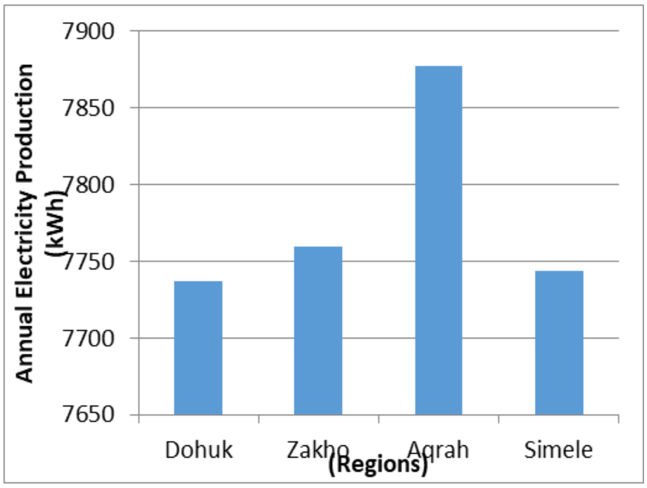

Fig. 5. Annual electricity generation for all selected regions

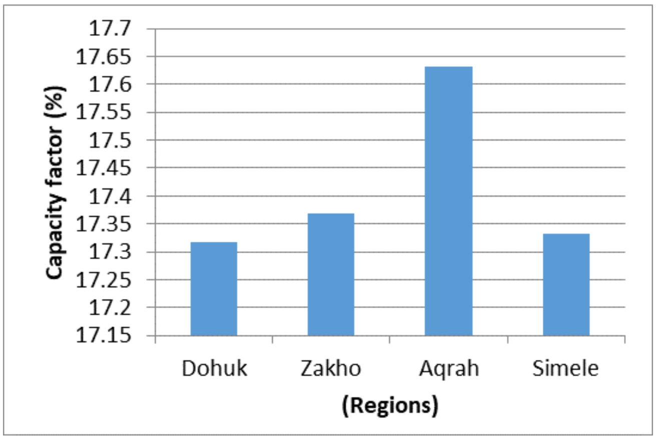

Fig. 6. Capacity factor for all selected regions

4.1.4. Simulation Results of Financial and Emission Reduction Analysis

An economic analysis is a fundamental analysis to understand whether the proposal is commercially feasible and sustainable. The economic feasibility of analysis of the effects of PV power plants teaches consumers and policymakers. The critical economic viability criteria for calculating the PV project are NPV and the payback period. Thus, the study's findings suggest that NPV values are flattering for all regions, as seen in Table 7.

The proposed photovoltaic project shows the most extended payback period in the Dohuk region of 6.7997 years, followed by the Simele region, whose task can import 6.7939 years Aqrah region has the shortest recovery period, which is 6.6789 years, as shown in Figure 7. Moreover, Duhok has the highest equity payback of 3.5736, while Aqrah has the lowest equity payback of 3.5057, as seen in Figure 8. Furthermore, it was observed that the region of Aqrah has the lowest electricity cost of 0.0267$/kWh, followed by the region of Zakho with an average value of 0.0271$/kWh. In contrast, the region of Duhok has the highest average electricity cost of 0.0328$/kWh, as seen in Table 7.

In this study, as seen in Figure 9, RETScreen software was used to approximate the gross annual reduction in GHG emissions for each of the four regions. The Aqrah region project has a maximum reduction in GHG emissions of 7.1156 tCO2. This is then preceded in the Zakho region by the program, with the smallest pollution reduction coming from the Duhok region project. Moreover, the percentage of the internal rate of return (Pre-tax Internal Rate of Return - equity) in all the selected areas, in addition to the (Pre-tax Internal Rate of Return - assets) were very suitable, especially in the Duhok region, as shown in Table 7.

From a management perspective, the results indicated that the annual life cycle savings (year / $) in the Aqrah region were the highest, reaching 1368.552 (year / $), and the Duhok region had the lowest. It amounted to 1203.798 (year / $), as shown in Table 7. Moreover, Mono-si's PV technology provided a higher net present value (NPV) for Aqrah, with a cost of 34,213.8 ($) as shown in Figure 10, About the cost of reducing greenhouse gases ($/tCO2), a reduction in the cost of greenhouse gas emissions was shown in Table 7, and good results were shown in all the selected regions, especially in Aqrah and Zakho regions. The reduced cost of greenhouse gas emissions was -192.33 ($/tCO2) and -191.882 ($/tCO2), respectively.

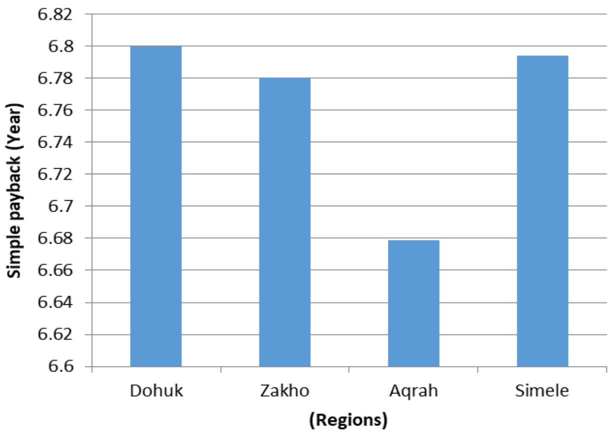

Fig. 7. Simple payback (Year)

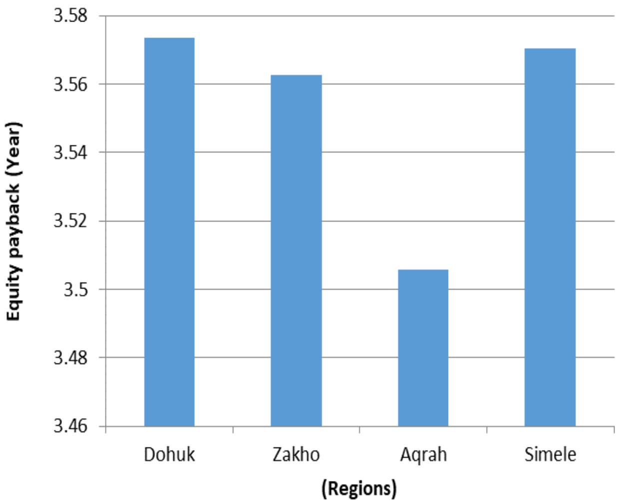

Fig. 8. Equity payback (Year)

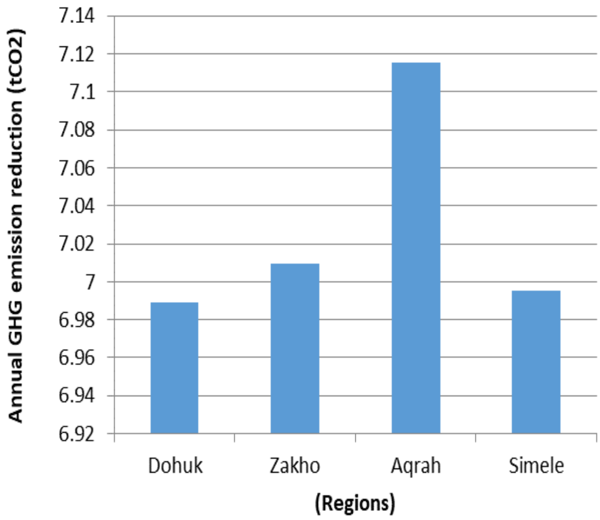

Fig. 9. Annual GHG emission reduction (tCO2)

Retrieval Number: 100.1/ijitee.E86350310521
DOI: 10.35940/ijitee.E8635.0310521

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication

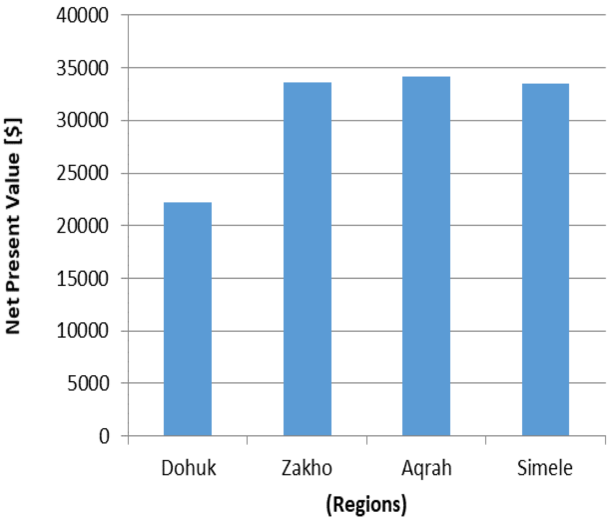

Fig. 10. Present Net Value ($)

Tabl-VII: Financial parameters performance of 5 kW grid-connected solar projects.

Parameters	Duhok	Aqrah	Simele	Zakho
Annual electricity generation	7737.1227	7759.4769	7877.0869	7743.708
CF (%)	17.3183	17.3683	17.6316	17.333
Annual GHG emission reduction (tCO2)	6.9892	7.0094	7.1156	6.9951
Pre-tax Internal Rate of Return - equity (%)	31.58	31.67	32.14	31.61
Pre-tax Internal Rate of Return - assets (%)	17.85	17.9	18.15	17.86
Simple payback (Year)	6.7997	6.7801	6.6789	6.7939
Equity payback (Year)	3.5736	3.5626	3.5057	3.5703
Net Present Value ($)	22179.21857	33624.41858	34213.80283	33545.39428
Annual life cycle savings ($/year)	1203.7975	1344.9767	1368.5521	1341.8158
GHG reduction cost ($/tCO2)	-172.2369	-191.8821	-192.3304	-191.821
Energy production cost ($/kWh)	0.0328	0.0271	0.0267	0.0272

V. CONCLUSION

From the current study, the following conclusions can be drawn:

- The potential of solar energy in the selected regions was evaluated using monthly solar radiations using NASA data. It was noticed all the selected regions have high solar resources and are rated good or excellent. This indicates that PV systems can be installed in all regions, and the most suitable region is Aqrah and is rated as excellent.
- An economic analysis of the 5 kW potential of the grid-Connected rooftop PV project was performed. The four regions selected were suitable for installing photovoltaic systems. The average electricity generated was 7,779.34 MWh / year, and the average capacity factor for solar PV plants is 17.41%.
- It was observed that the region of Aqrah has the lowest electricity cost of 0.0267$/kWh, followed by the region of Zakho with an average value of 0.0271$/kWh. In contrast, the region of Duhok has the highest average electricity cost of 0.0328$/kWh. In general, there is no solar energy project in Dohuk Governorate. The current low price for PV units is encouraging, and it is possible to install a PV system in the governorate.
- From a management viewpoint, the results indicated that the annual life cycle savings (year / $) in the Aqrah region was the highest, reaching 1368.552 (year / $), and the Duhok region had the lowest it amounted to 1203.798 (year / $).
- In general, developing a grid-connected solar PV system helps to provide energy and a suitable sustainable solution to energy production crises and reduce emissions to improve Dohuk Governorate's environment. Also, it allows for significant cost reductions in economic terms due to the high potential of solar energy in the region, technological progress, and the development of new policies in the PV market sector.

REFERENCES

1. Abed, F. M., Al-Douri, Y., & Al-Shahery, G. M. (2014). Review on the energy and renewable energy status in Iraq: The outlooks. Renewable and Sustainable Energy Reviews, 39, 816-827.
2. Abed, F. M., Eleiwi, M. A., Hasanuzzaman, M., Islam, M. M., & Mohammed, K. I. (2020). Design, development and effects of operational conditions on the performance of concentrated solar collector based desalination system operating in Iraq. Sustainable Energy Technologies and Assessments, 42, 100886.
3. Alasady, A. M. A. (2011). Solar energy the suitable energy alternative for Iraq beyond oil. In Proceedings of the international conference on petroleum and sustainable development (IPCBEE), Singapore (Vol. 26).
4. Al-damook, A., & Khalil, W. H. (2017). Experimental evaluation of an unglazed solar air collector for building space heating in Iraq. Renewable Energy, 112, 498-509.
5. Al-Douri, Y., & Abed, F. M. (2016). Solar energy status in Iraq: Abundant or not—Steps forward. Journal of Renewable and Sustainable Energy, 8(2), 025905.
6. Al-Kayiem, H. H., & Mohammad, S. T. (2019). Potential of renewable energy resources with an emphasis on solar power in Iraq: An outlook. Resources, 8(1), 42.
7. Al-Waeli, A. A., & Al-Asadi, K. A. (2018). Analysis of stand-alone solar photovoltaic for desert in Iraq. International Research Journal of Advanced Engineering and Science, 3(2), 204-209.
8. Azabany, A., Khan, K., & Ahmed, W. (2014). Cost analysis of a photovoltaic plant connected to a 315kw solar grid in Erbil, Kurdistan, Iraq. Asian Journal of Science and Technology, 5(8), 475-478.
9. Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., Mohammed, M. F., & Ramli, M. A. (2020). Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. Energy, 191, 116591.
10. Belkilani, K., Othman, A. B., & Besbes, M. (2018). Assessment of global solar radiation to examine the best locations to install a PV system in Tunisia. Applied Physics A, 124(2), 122.
11. Chel, A., & Kaushik, G. (2018). Renewable energy technologies for sustainable development of energy efficient building. Alexandria Engineering Journal, 57(2), 655-669.
12. Darwish, A. S., Shaaban, S., Marsillac, E., & Mahmood, N. M. (2019). A methodology for improving wind energy production in low wind speed regions, with a case study application in Iraq. Computers & Industrial Engineering, 127, 89-102.
13. Dihrab, S. S., & Sopian, K. (2010). Electricity generation of hybrid PV/wind systems in Iraq. Renewable Energy, 35(6), 1303-1307.
14. Hamdoon, O. M., Alomar, O. R., & Salim, B. M. (2020). Performance analysis of hybrid photovoltaic thermal solar system in Iraq climate condition. Thermal Science and Engineering Progress, 17, 100359.
15. Ibrahim, G. R. F., Hamid, A. A., Darwesh, U. M., & Rasul, A. (2020). A GIS-based Boolean logic-analytical hierarchy process for solar power plant (case study: Erbil Governorate—Iraq). Environment, Development and Sustainability, 1-18.
16. Kassem, Y., Çamur, H., & Alhuoti, S. M. A. (2020). Solar Energy Technology for Northern Cyprus: Assessment, Statistical Analysis, and Feasibility Study. Energies, 13(4), 940.
17. Kazem, H. A., & Chaichan, M. T. (2012). Status and prospects of renewable energy in Iraq. Renewable and Sustainable Energy Reviews, 16(8), 6007-6012.
18. Owolabi, A. B., Nsafon, B. E. K., Roh, J. W., Suh, D., & Huh, J. S. (2019). Validating the techno-economic and environmental sustainability of solar PV technology in Nigeria using RETScreen Experts to assess its viability. Sustainable Energy Technologies and Assessments, 36, 100542.
19. Rasham, A. M. (2016). Analysis of wind speed data and annual energy potential at three locations in Iraq. International Journal of Computer Applications, 137(11), 5-16.

AUTHORS PROFILE

Hüseyin GÖKÇEKUŞ, Department of Civil Engineering, Near East University,Nicosia, Cyprus

Youssef KASSEM, Department of Mechanical Engineering, Near East University,Nicosia, Cyprus

Ahmed Mohammed Ahmed, Department of Civil Engineering, Near East University,Nicosia, Cyprus