



CO₂ Emission in Green Buildings: An Analysis of Energy Efficiency and Financial Viability in Jordan

George Sammour, Mohammed Issa Shahateet*

Princess Sumaya University for Technology, Jordan. *Email: msh@psut.edu.jo

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ABSTRACT

This paper aims to use photovoltaics as a case study of a green building in Jordan to provide electric power, boost the power provided by the national grid, and enhance energy policies to reduce CO₂ emissions. The photovoltaic PV panels are used to provide nearly 7.4 kW of electricity power for the lighting. The study uses Renewable Energy and Energy Efficiency Technology Screen (RETScreen) computer software to achieve this aim. Three different aspects were subjected to the analysis: Firstly, the proposed case power system; secondly, emission analysis; and finally, financial analysis. The worksheet of the analysis of emission reduction is used to estimate the emission of CO₂ in the proposed project. The study findings reveal that the GHG emission factor in tCO₂/MWh equals 0.924, while the net annual GHG emission reduction in tCO₂ is 8,367.4, which is equivalent to the consumption of 19,459 barrels of crude oil.

Keywords: Greenhouse Gas Emission, RETScreen, Data-Driven Energy Policy, Energy Efficiency Technology, Green Building, Jordan

JEL Classifications: Q40, Q43, Q48, Q56, Q57

1. INTRODUCTION

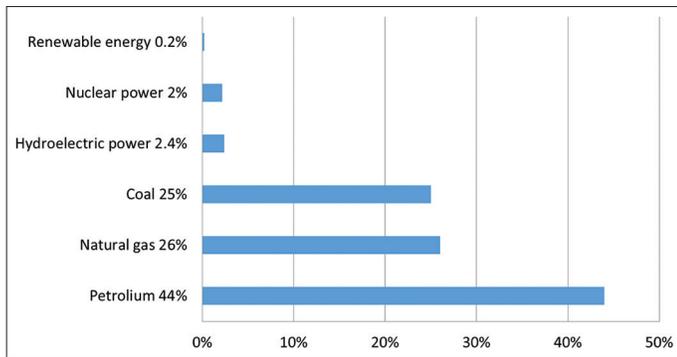
The integration of renewable energy systems, particularly photovoltaic (PV) technology, has recently gained significant importance in the design of sustainable buildings. The movement toward green buildings, which attempts to increase energy efficiency and minimize carbon footprints, has sparked more research on photovoltaic systems (PV) and their effectiveness in reducing CO₂ emissions. The most practicable approach to minimize dependence on fossil fuels and the emission of CO₂ in urban areas is constructing photovoltaic systems and green buildings. The use of cosmopolitan energy is higher than 102 trillion KWh every year. This energy equals a hundred seventy million barrels of oil daily, Jeffery et al. (2006). Global energy consumption is generally from 6 primary sources, as shown in Figure 1.

The energy sector in Jordan is intensively dependent on the import of oil and the import of its products to cover its need for energy.

The account for energy imports represents nearly 10% of domestic product growth. This situation led the Jordanian government to implement and encourage renewable energy projects, as explained by Obeidat (2013). Jordan is one of the “sun-belt countries” with a daily solar radiation of more than 8 kW/m² in the summer. This study contributes to the literature on energy savings in green buildings and the methods of energy calculations in order to reduce CO₂ emissions.

2. LITERATURE REVIEW

During the last few years, several studies have addressed the importance of energy calculations for GHG emissions and the role of energy savings in influencing the environment. These studies concentrated on the critical objectives of sustainability, which achieve energy efficiency and reduce carbon emissions. A massive number of studies have been carried out in this field, but a significant number of studies are still required to investigate the limitations of this topic.

Figure 1: Consumption of global energy

Zheng et al. (2022) proposed an approach to investigate the heating potentials of renewable energy, evaluate its suitability, and guide targeted policies. The research applied the factor analysis method to focus on the country's development level, the population's quality, the government's support, and the potential of using renewable energy techniques. The study finds that the proposed systematic approach will encourage RE and transfer towards using clean energy systems. Reviewing global building energy consumption, performance systems, and energy-saving techniques, Akram et al. (2022) found that 40% of the total energy is consumed in the building sector, and central heating systems can save up to 11% of energy. The automatic HVAC control system can reduce up to 20% of the building's total heating load. Among other recent studies that addressed this issue are Liu et al. (2024) for carbon reduction policies that promote sustainable construction development in China's green buildings and Ma et al. (2023) for increased energy efficiency and carbon emission mitigation in buildings.

Another stream of studies discussed economic and technological methods to reach more efficient savings in energy and maintain cleaner energy production in green buildings, such as Chauhan and Saini (2016), who presented a study on using local resources for renewable energy and its economic feasibility and cost-effectiveness—the size of the integrated RE system in India. The size of this system and the size of optimization are examined in this study. The annual production of electric power from photovoltaic and CSP technologies is presented in Hernández-Moro and Martínez-Duart (2013). Their study also calculates the levelized cost for the generated electric power for photovoltaics and the CSP used. They developed a mathematical model for the current value of levelized cost and its future evolution from 2010 to 2050. The imported and exported CO₂ emissions in China are calculated by Sun et al. (2016). A model of weighted regression and its economic feasibility is used in this study. Lastly, optimization techniques for the transfer structure of carbon emission in China's province were suggested, in addition to examining the benefits of the reductions in carbon emission. The findings indicate how to provide and maintain the modes of cleaner production and the economic effect of spillover of emissions, which are more significant for imports than exports.

Amponsah et al. (2014) presented the technologies of using renewable energy to produce electric power and estimated the

life cycle for the emission of greenhouse gases from various renewable energy technologies. Their studies were on the variability of life cycle assessment to track the greenhouse gas emissions of heat generation and electricity from the technology of Renewable Energy RE. Their findings also stressed the importance of considering renewable energy systems' whole lifecycle to comprehend their environmental impact completely. It will take continued research and development and encouraging laws and incentives to integrate cutting-edge PV systems in urban settings.

Couture et al. (2010) reviewed that the most widely used policy in renewable energy is the "feed-in tariffs" for deploying RE. The "feed-in tariffs" policies in the European Union have led to the deployment of more than 15,000 and 55,000 megawatts of photovoltaic solar cells and wind energy between 2000 and 2009. These are equivalent to the deployment of 75% and 45% of global photovoltaic and wind power, respectively. Their study focused on reducing the use of fossil fuels to reduce energy consumption in domestic and industrial fields. In this context, their research laid the groundwork for understanding the fundamental concepts of PV technology and its use in integrated building systems (Banos et al., 2011). Scofield (2013) examined energy consumption and greenhouse gas (GHG) emissions using data from 953 office buildings in New York City. The rating of energy performance is also studied in this work. Other research studies related to this topic include Qu and Zhao (2022) for carbon emission reduction indicators in green buildings, Rao et al. (2021), and Liao and Li (2022).

In sum, this review highlights the need to consider the challenges and benefits of future work to explore more methods of energy calculations and methods to reduce energy waste and assess the performance of PV systems in reducing greenhouse gas (GHG) emissions.

3. METHODOLOGY AND DATA

3.1. Methodology

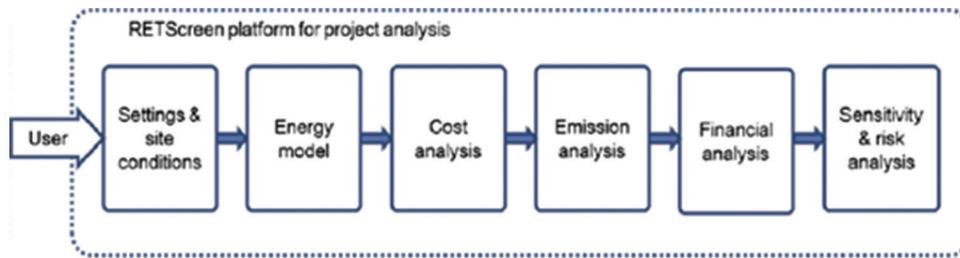
The Renewable Energy and Energy Efficiency Technology Screen (RETScreen) is a software used in this study to analyze greenhouse gasses (GHG) emissions. The RETScreen is a model for the analysis of techno-economics, which is used to evaluate the technical and financial feasibility of any projects in the world Bakos and Soursos (2002). This software is used worldwide to study and analyze the life cycle of any project, in addition to reducing GHG emissions, MNR Ministry of Natural Resources (2005) and Thevenard et al. (2001). It is also used for the solar heating of air and water and refrigeration, Markovic et al. (2011).

The RETScreen computer program consists of 6 steps to evaluate the installation of the photovoltaic system used in the project. Figure 2 displays the flow diagram of the procedure.

For the first step of the "Energy Model," the following information is downloaded to the system:

The language: English;

The currency in which the monetary data of the project will be reported: Jordan Dinar;

Figure 2: RETScreen model flow diagram

The units; Metric or Imperial units: Metric;
 The defined project location: Amman/King Abdullah;
 Heating value: Lower heating value;
 Type of proposed study): PV and Grid type: Isolated grid and internal load).

Figure 3: Project general information

Project information		See project database
Project name	Embassy of the Kingdom of the Netherlands	
Project location	Jordan	
Project type	Power	
Technology	Photovoltaic	
Grid type	Isolated-grid & internal load	
Analysis type	Method 1	
Heating value reference	Lower heating value (LHV)	
Show settings	<input checked="" type="checkbox"/>	
Language - Langue	English - Anglais	
User manual	English - Anglais	
Currency	Jordan	
Units	Metric units	

Settings in parenthesis refer to this project conducted herein. The project information is shown in Figure 3.

There are two interesting points to explain here: the values of Higher and Lower Heating, where the value of the measure of the released energy is the Heating Value for the burning of fuel. The Higher Heating belongs to the steam due to combustion, and the Lower Heating is the condensed steam transformed into water. In this project, the setting used is for power only.

3.2. Data

The site reference is used to estimate the production of annual photovoltaic energy used in the project (MNR, 2005), which was conducted in Jordan, Amman city, at the Netherlands Embassy.

The user identified the data from the “RETScreen” database. The data used for the project of this work is shown in Table 1:

The software also identifies pressure, daily solar radiation, and wind speed. These data are presented in Figure 4:

In this work, the power generation was based on using a photovoltaic system to convert solar radiation to electricity, representing the renewable energy technology used. There are three basic applications of photovoltaic systems. These are on- and off-grid (without and with batteries) generator sets and water pumping. In the power model of RETScreen, the photovoltaic used and its application should be downloaded to the system worksheet. The grid type should also be selected as neither “Central-grid” nor “Isolated-grid” in the option of the software used. Using the “Central grid” is preferable to include all the energy the photovoltaic system provides. The user has to define also the following:

- Power capacity;
- Photovoltaic system manufacture;
- Model;
- Capacity factor;
- Electricity delivered to load;
- Electricity for a base rate or proposed case.

The data of the proposed power system case is shown in Figure 5 below.

Table 1: RETScreen database of site conditions used for the project

Variable	Unit	Climate data location	Project location
Latitude	°N	32.0	32.0
Longitude	°E	36.0	36.0
Elevation	M	779	779
Heating temperature	°C	2.1	-----
Cooling temperature	°C	34.0	-----
Earth temperature	°C	23.1	-----

There are 36 solar cell panels used in this project, each with 200W of power capacity, and the total power is 7.2 kW. Suntech is the manufacturer of solar photovoltaic cells used in this project. Finding actual electricity tariffs for the embassies in Jordan is very hard; unfortunately, no satisfactory answer has been given, as it is categorized based on the level of consumption and the sector that consumes it. For the Netherlands Embassy, the tariff is estimated to be 240 Fils for every kilowatt hour used, which presents half of its price. For example, the electricity price the government purchases from generation sectors based on a year unit is 559, 572, 584, and 598 Fils for every kilowatt hour used from 2007 to 2010, respectively. The Renewable Energy and Energy Efficiency Technology Screen (RETScreen) is a software utilized to calculate the reduction in GHG. CO₂, CH₄, and N₂O are the gases that are calculated in the software to study the reduction in the analysis of the emission of these gases. The data on the reduction in CO₂ emission and the data on energy generation for the embassy were used as a case study.

Figure 4: Weather conditions identified to “RETScreen”

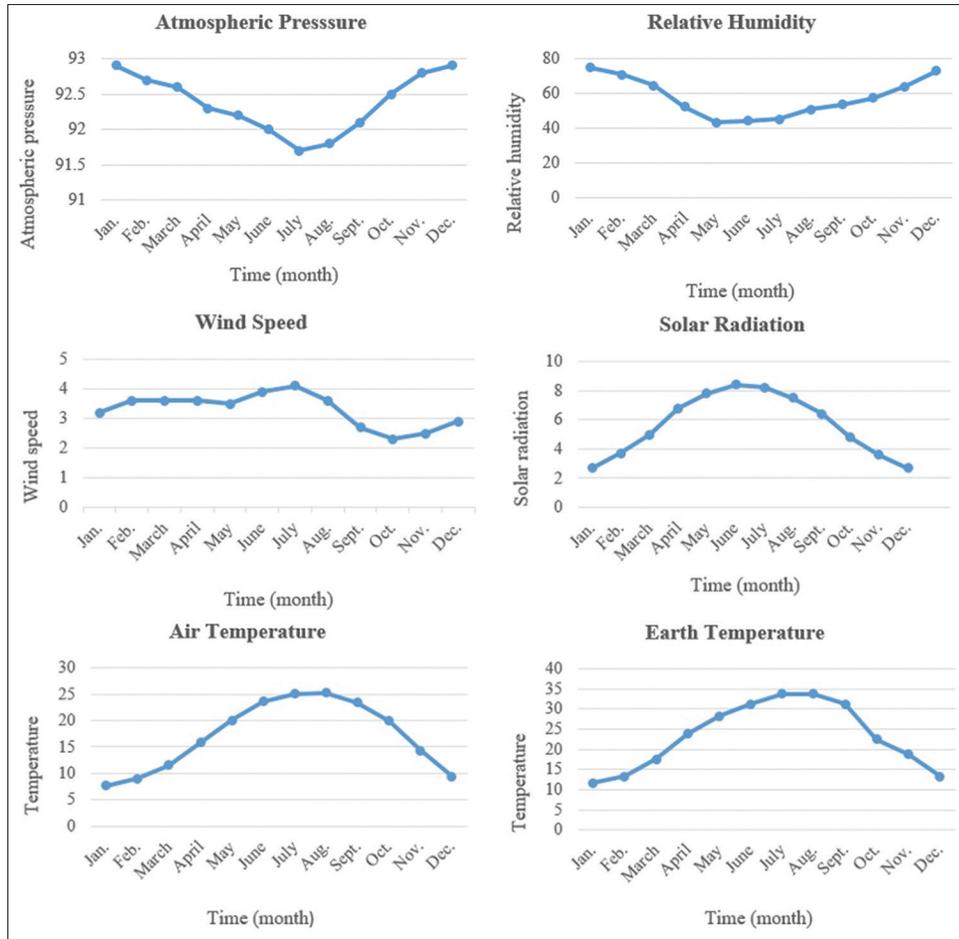


Figure 5: Power system proposed case used in the project

RETScreen Energy Model - Power project				<input checked="" type="checkbox"/> Show alternative units
Proposed case power system		Incremental / initial costs		
Technology	Photovoltaic			
Analysis type	<input checked="" type="radio"/> Method 1 <input type="radio"/> Method 2			
Photovoltaic				
Power capacity	MW	7.20	4.7%	\$ 22,000
Manufacturer	Suntech			
Model	poly-Si - STP200 - 18 (36 units)			
Capacity factor	%	13.9%		
Electricity delivered to load	MWh	9	0.9%	
Electricity exported to grid	MWh	0.0		
Electricity rate - base case	JOD/MWh	240.00	JOD/KWh	0.240
Fuel rate - proposed case power system	JOD/MWh	0.00		
Electricity export rate	JOD/MWh	0.00	JOD/KWh	0.000
Electricity rate - proposed case	JOD/MWh	0.10	JOD/KWh	0.000
		Electricity delivered to load	Electricity exported to grid	Remaining electricity required
Operating strategy		MWh	MWh	MWh
Full power capacity output		9	0	997
Power load following		9	0	997
				Power system fuel
				MWh
				Operating profit (loss)
				JOD
				Efficiency
				%
Select operating strategy	Power load following			

Figure 6: Emission analysis for the netherlands embassy, tons of CO₂

Emission Analysis				
Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor
Country - region	Fuel type	tCO ₂ /MWh	%	tCO ₂ /MWh
Jordan	Natural gas	0.896	3.0%	0.924
GHG emission				
Base case	tCO ₂	9,288.1		
Proposed case	tCO ₂	925.9		
Gross annual GHG emission reduction	tCO ₂	8,362.1		
GHG credits transaction fee	%	0.0%		
Net annual GHG emission reduction	tCO ₂	8,362.1	is equivalent to	19,447 Barrels of crude oil not consumed
GHG reduction income				
GHG reduction credit rate	JOD/tCO ₂	0.00		

4. RESULTS AND DISCUSSION

The input data refers to the required parameters to be fed into the processing step to get output information. Consequently, without one or more of those, the processing step fails to produce the output information entirely or partially, or it may produce inconsistent and uncorrected information. On the next side is the output information, the corrected results obtained from the proper processing methods. Conversely, the processing methods and tools determined what would be the input data as well as the output information. Thus, it is necessary to identify the processing methods and tools in a clear statement. As mentioned previously, the processing tool is RETScreen, and methods were identified according to relevance to the required output information.

The reduction of the amount of GHG was calculated using "RETScreen software." A worksheet for the analysis of GHG emissions is also used. In order to have the emission analysis on the RETScreen software, the user needs to identify and find the following variables and their values, which represent the required inputs:

1. The region of the country;
2. Identify the type of fuel from the software list;
3. Identify the emission factors for CO₂, CH₄, and N₂O for the fuel used;
4. Identify the electricity generation efficiency for the identified fuel type;
5. Identify the percentage of the losses of transmission and distribution for the electric system used;
6. Identify the GHG emission factor for the electric system used;
7. Identify the credits (%) need to pay annually as a transaction fee.

These data are summarized below in a list manner:

4.1. Input

1. The factor of GHG emission without losses of transmission and distribution equals 0.895
2. The factor of GHG emission with losses of transmission and distribution equals 0.924
3. The losses of transmission and distribution for the electric system used equals 3.0%.

Figure 6 shows the output of the study, which is measured in tons of CO₂ averted yearly.

After identifying the values above, they were downloaded to the software and run the system to have the output, which is as follows:

4.2. Output

- Base case (tCO₂): 9,288
- Propose case (tCO₂): 925.9
- The annual reduction in the emission of GHG: 8,632, which is equal to 19,447 crude oil barrels
- Income of reduction in GHG– not estimated.

5. CONCLUSION

Jordan is geographically appropriate for using a photovoltaic system to produce electric power as it is one of the sunny countries; thus, the uses of such systems are financially practical, considering that solar energy is the primary source of renewable energy source obtainable on our planet. Photovoltaic systems are environmentally friendly, and their use in green buildings leads to a reduction of the emission of greenhouse gasses and climate change. The annual energy saving was found to be 9,315 kWh. It was also found that the annual elimination of GHG was 920.7 tCO₂. In addition, the use of PV systems reduces electricity bills.

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