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Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Sammour, George/Shahateet, Mohammed Issa (2024). CO2 emission in green buildings: an analysis of energy efficiency and financial viability in Jordan. In: International Journal of Energy Economics and Policy 14 (6), S. 548 - 553.
https://www.econjournals.com/index.php/ijeep/article/download/17270/8372/40160.
doi:10.32479/ijeep.17270.

This Version is available at:
http://hdl.handle.net/11159/703054

IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(6), 548-553.

EJ EconJournals

CO_2 Emission in Green Buildings: An Analysis of Energy Efficiency and Financial Viability in Jordan

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Received: 23 July 2024 **Accepted:** 13 October 2024 **DOI:** https://doi.org/10.32479/ijeep.17270

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 CO_2 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 CO_2 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 tCO_2 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

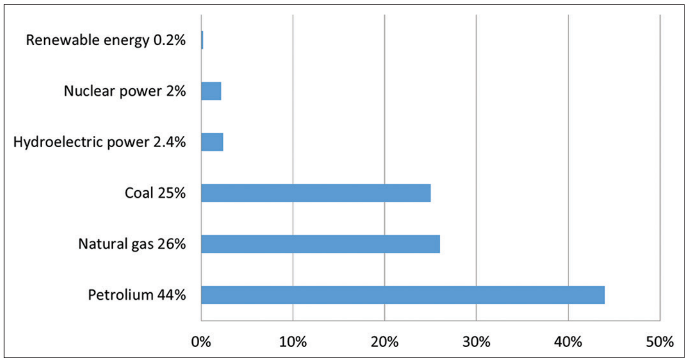
The integration of renewable energy systems, particularly photovoltaic (PV) technology, has recently gained significant importance in the design of sustainable buildings. The movement toward green buildings, which attempts to increase energy efficiency and minimize carbon footprints, has sparked more research on photovoltaic systems (PV) and their effectiveness in reducing CO_2 emissions. The most practicable approach to minimize dependence on fossil fuels and the emission of CO_2 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/m^2 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 CO_2 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 CO_2 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).

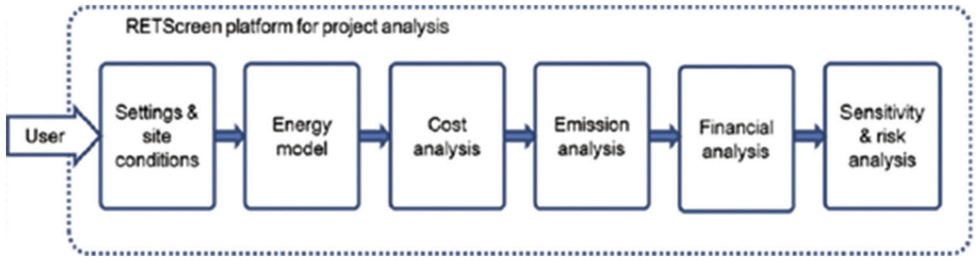
The RETScreen computer program consists of 6 steps to evaluate the installation of the photovoltaic system used in the project. Figure 2 displays the flow diagram of the procedure.

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).

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.

Figure 3: Project general information

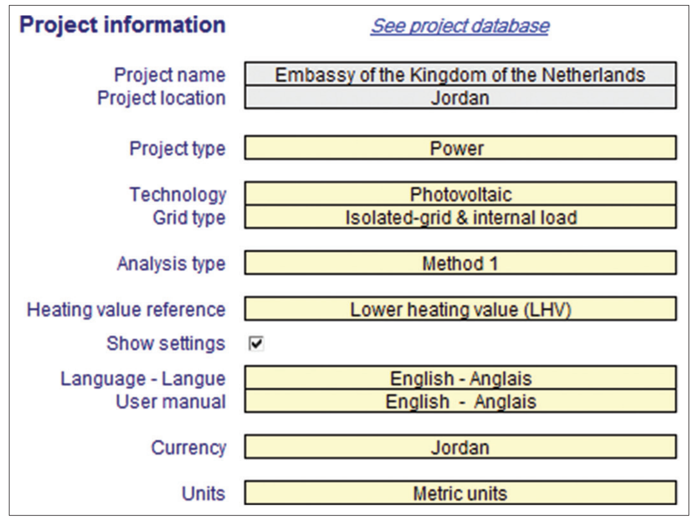


Table 1: RETScreen database of site conditions used for the project

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. CO_2, CH_4, and N_2O 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 CO_2 emission and the data on energy generation for the embassy were used as a case study.

Figure 4: Weather conditions identified to "RETScreen"

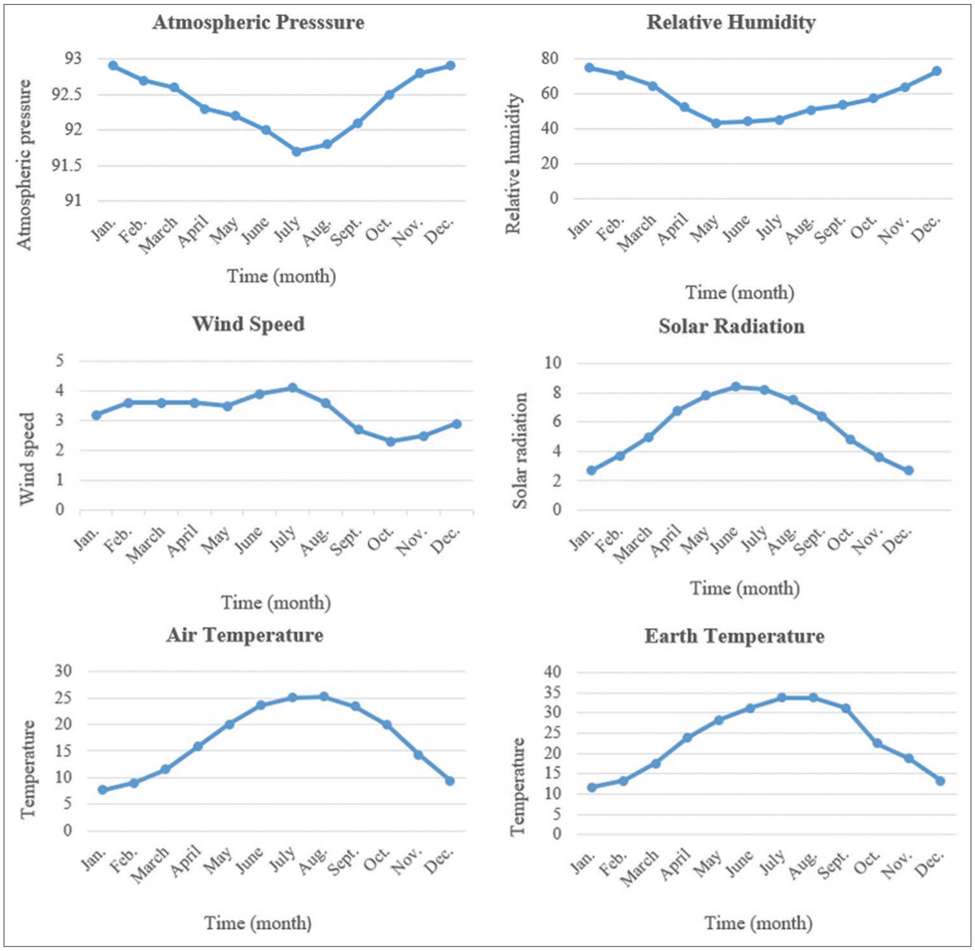


Figure 5: Power system proposed case used in the project

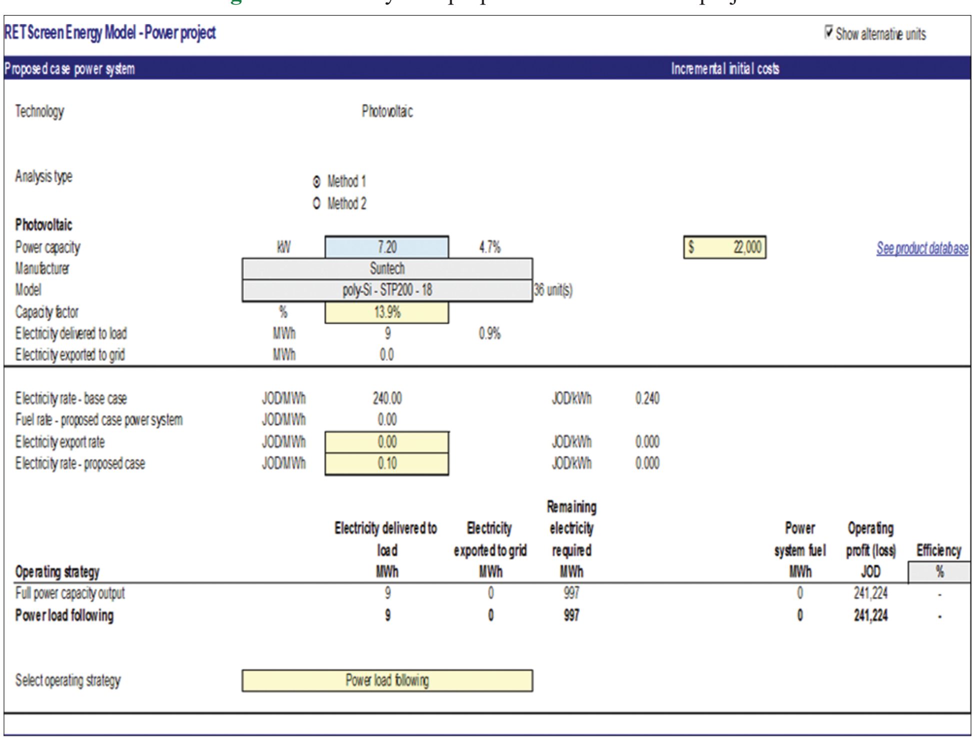


Figure 6: Emission analysis for the netherlands embassy, tons of CO_2

Emission Analysis					
Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor	
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh	
Jordan	Natural gas	0.896	3.0%	0.924	
GHG emission					
Base case	tCO2	9,288.1			
Proposed case	tCO2	925.9			
Gross annual GHG emission reduction	tCO2	8,362.1			
GHG credits transaction fee	%	0.0%			
Net annual GHG emission reduction	tCO2	8,362.1	is equivalent to	19,447	Barrels of crude oil not consumed
GHG reduction income					
GHG reduction credit rate	JOD/tCO2	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 CO_2, CH_4, and N_2O 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 CO_2 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 (tCO_2): 9,288
- Propose case (tCO_2): 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 tCO_2. In addition, the use of PV systems reduces electricity bills.

REFERENCES

Akram, M.W., Mohd Zublie, M.F., Hasanuzzaman, M., Rahim, N.A. (2022), Global prospects, advance technologies and policies of energy-saving and sustainable building systems: A review. Sustainability, 14(3), 1316.

Amponsah, N.Y., Troldborg, M., Kington, B., Aalders, I., Hough, R.L. (2014), Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations. Renewable and Sustainable Energy Reviews, 39, 461-475.

Bakos, G.C., Soursos, M. (2002), Technical feasibility and economic viability of a grid-connected PV installation for low-cost electricity production. Energy and Buildings, 34, 753-758.

Banos, R., Manzano-Agugliaro, F., Montoya, F.G., Gil, C., Alcayde, A., Gómez, J. (2011), Optimization methods applied to renewable and sustainable energy: A review. Renewable and Sustainable Energy Reviews, 15(4), 1753-1766.

Chauhan, A., Saini, R.P. (2016), Discrete harmony search based size optimization of Integrated Renewable Energy System for remote rural areas of Uttarakhand state in India. Renewable Energy, 94, 587-604.

Couture, T.D., Cory, K., Kreycik, C., Williams, E. (2010), Policymaker's Guide to feed-in Tariff Policy Design (No. NREL/TP-6A2-44849). United States: National Renewable Energy Lab.(NREL), Golden, CO.

Hernández-Moro, J., Martínez-Duart, J.M. (2013), Analytical model for solar PV and CSP electricity costs: Present LCOE values and their future evolution. Renewable and Sustainable Energy Reviews, 20, 119-132.

Jeffery, C., Kopp, R.J., Portney, P.R. (2006), Energy, Resources and Global Development. Science Magazine's State of the Planet 2006-2007. Washington, DC: American Association for the Advancement of Science, Island Press.

Liao, B., Li, L. (2022), How can green building development promote carbon emission reduction efficiency of the construction industry?--Based on the dual perspective of industry and space. Environmental Science and Pollution Research, 29(7), 9852-9866.

Liu, W., Chen, Y., Zhu, P., Tong, J. (2024), Can carbon reduction policies promote sustainable construction development? Evidence from China's green building market. PLos One, 19(5), 0303149.

Ma, Z., Awan, M.B., Lu, M., Li, S., Aziz, M.S., Zhou, X., Du, H., Sha, X., Li, Y. (2023), An overview of emerging and sustainable technologies for increased energy efficiency and carbon emission mitigation in buildings. Buildings, 13(10), 2658.

Markovic, D., Cvetkovic, D., Masic, B. (2011), Survey of software tools for energy efficiency in a community. Renewable and Sustainable Energy Reviews, 15, 4897-4903.

MNR Ministry of Natural Resources. (2005), RETScreen® Software Online User Manual. Minister of Natural Resources Canada, CANMET Energy Technology Centre. Varennes, Quebec, CANADA: Minister of Natural Resources Canada.

Obeidat, O. (2013), Jordan Reaches Out to Wealthy Arab States for Urgent Financial Aid. Jordan: The Jordanian Time.

Qu, X., Zhao, X. (2022), Carbon Emission Reduction Indicators in Green Building Evaluation System Based on Meta-analysis. In: International Symposium on Advancement of Construction Management and Real Estate. Singapore: Springer Nature Singapore. p1576-1584.

Rao, L. (2021), Green Building Analysis and Carbon Emission Calculation Based on BIM. In: Huang, C., Chan, YW., Yen, N., editors. 2020 International Conference on Data Processing Techniques and Applications for Cyber-Physical Systems. Advances in Intelligent Systems and Computing. Vol 1379. Singapore: Springer.

Scofield, J.H. (2013), Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emissions for large New York City office buildings. Energy and Buildings, 67, 517-524.

Sun, L., Wang, Q., Zhou, P., Cheng, F. (2016), Effects of carbon emission transfer on economic spillover and carbon emission reduction in China. Journal of Cleaner Production, 112, 1432-1442.

Thevenard, D., Leng, G., Martel, S. (2001), The RETScreen Model for Assessing Potential PV Projects. PV Horizon: Workshop on Photovoltaic Hybrid System. Montreal. p4.

Zheng, X., Yang, X., Miao, H., Liu, H., Yu, Y., Wang, Y., Zhang, H., You, S. (2022), A factor analysis and self-organizing map-based evaluation approach for the renewable energy heating potentials at county level: A case study in China. Renewable and Sustainable Energy Reviews, 165, 112597.