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Article

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Examining Power, GHG Emission and Financial Saving in Green Buildings: A Case Study of Jordan

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ABSTRACT

The purpose of this research is to explore the effect of reducing Green House Gas (GHG) emissions in a case study of green buildings in Jordan through the use of photovoltaic solar panels to generate electricity. It also examines the use of photovoltaic solar cells to generate electricity and supplement Jordan's national grid. The emission analysis is used to determine the case framework and the project's GHG emissions, which is the CO_2 project. The study's findings demonstrate that implementing photovoltaic (PV) plans is economically feasible for Jordan's electricity production. The annual energy savings are estimated to be 9315.61 kWh, which equates to a savings of over 3200 USD per year on the electricity bill. This is in addition to the annual reduction of GHG emissions by 920.7 tCO_2, indicating that the case study initiated a beneficial event. The study contributes to filling a gap in the existing literature on the energy savings and environmental benefits of green buildings, which is deficient in developing countries due to a lack of applied research. The findings are not unique to Jordan; they could easily be applied to other developing countries as well.

Keywords: CO_2 Emission, Green Building, GHG, PV, Solar Thermal Collector

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

1. INTRODUCTION

Jordan is entirely reliant on fossil fuels to meet its electricity needs. Jordan imports almost all its natural gas and heavy fuels, and as a result, the country is in a severe financial crisis. This is because imported fuels are subsidized for domestic use, the primary purpose of which is to generate electricity. These imports account for approximately 10% of the country's gross domestic product (GDP). Jordan receives an average daily solar radiation of around 8kWh/m^2 or more in the summer and 4 kWh/m^2 in the winter, making it one of the Sunbelt countries. Climate change on a global scale and the energy crisis have prompted this work approach, which involves investigating and analyzing how green buildings are designed to have the least environmental impact possible. The usefulness of using renewable energy as an origin of generating electricity has become much more eminent because of the increase in oil prices over the last decades well as, the awareness of the environmental effect of using fossil fuels, which has gained ground (Rehman et al., 2007). Furthermore, on a universal scale, the use of renewable energy presents more than 20% of electricity generation from the year 2010. This halt at 12.7% of the World's energy mix in the year 2011 in terms of direct renewable energy consumption. CO_2 gas is regarded as a trace gas in the atmosphere, with a current mean concentration of 385 ppm (parts per million), and by 582 ppm/volume mass. earth's atmosphere mass is 5.14×10^{18} kg, and thus the total mass of CO_2 is equal to 3.0×10^{15} kg (Saidan et al., 2016).

The photovoltaic (PV) arrays on the building roof are used to produce approximately 7200W power of electric energy for the lighting of the embassy's offices. Each solar panel provided 200W as a maximum. The PV solar system consists of 36 solar panels. Each panel generates 200W in maximum, with 36 panels encasement an area of 52 m^2. These PV panels (Suntech STP200

– 18/Ub) are linked to 3 inverters type SMA Sunny Boy 2500 to transform to direct current to an electric one. The panels' arrays are tilted with a south orientation at an angle of 35°. The photovoltaic panels supplied more output power because of the advanced texture and isolation of cell which lead to the improvement of low irradiance performance. The PV has also an excellent design of solid construction and drainage holes to protect the PV frame from breaking or damaging in freezing weather or because of other forces effects.

The solar thermal collectors mounted above the parking lots and the technical room in the garden are spread over a 75-square-meter roof surface. These solar collectors are used in conjunction with a thermal storage system that serves several purposes, including optimizing the ability of a generation system, as well as ensuring the efficient and reliable performance of other tasks such as water storage for firefighting. The advantages of thermal storage are the possibility of providing heated and chilled water during winter, autumn and spring. This is, also, to operate heat pumps joined to storage tanks at a constant load level throughout the whole day. The solar collectors supply heat during the winter period. The heat is either directly transferred to the heating water network of the building or stored in the thermal storage. Both PV solar panels and solar collectors supply the embassy with some of its energy needed, and their combination as onsite sources of renewable energy sources provide the embassy with its energy needs and share in the consumption of energy.

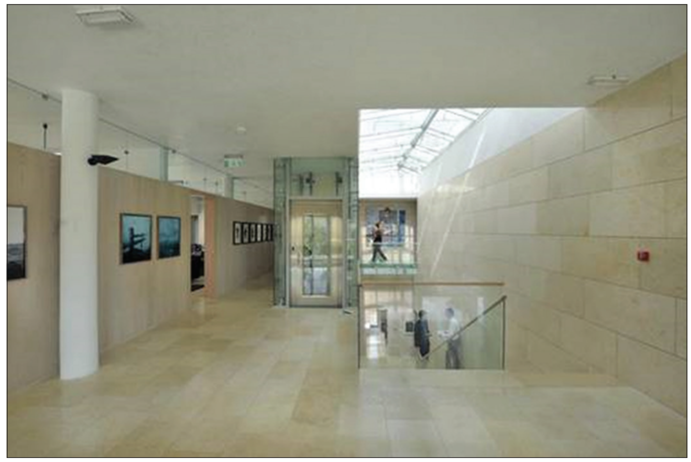
1.1. Energy in Jordan

Jordan's energy sector is heavily reliant on the importation of oil and its derivatives to meet the country's energy needs; as a result, the government has a plan to increase the use of renewable energy in the short and long term. Jordan is a "sun-belt country," with daily average solar radiation of approximately 8kWh/m^2 in the summer and 4kWh/m^2 in the winter, which is regarded as one of the primary reasons for the widespread use of solar energy in water heating (about 30%), primarily in the residential sector, (Greenpeace., 2013).

1.2. Green Building in Jordan

It is quite important to improve the infrastructure to reduce the dangerous effect on the environment, at the same time, decrease human impact on the earth, which may be regarded as one of the reasons for climate change. Green building is the originating of structures and using procedures that are environmentally in charge throughout the life cycle of the building from design and construction to the operation and maintenance, then to deconstruction. The Jordanian Green Building Council was first registered in 2009 as one of the non-government organizations, under law number 51, to increase awareness towards green buildings as well as sustainability. Since 2009, it has been strongly contributed to following national and international Green Building organizations. This was including the national committees for the technical review of green building codes at the JBC and the Construction and Urban Planning Cluster of the Royal Scientific Society in Amman. The buildings granted the LEED certificate in Amman is the World Health Organization with the gold medal, and the Netherlands embassy (the case study of this work) with the silver medal.

Figure 1: Central Hall (first floor)



1.3. The Building of the Netherlands Embassy

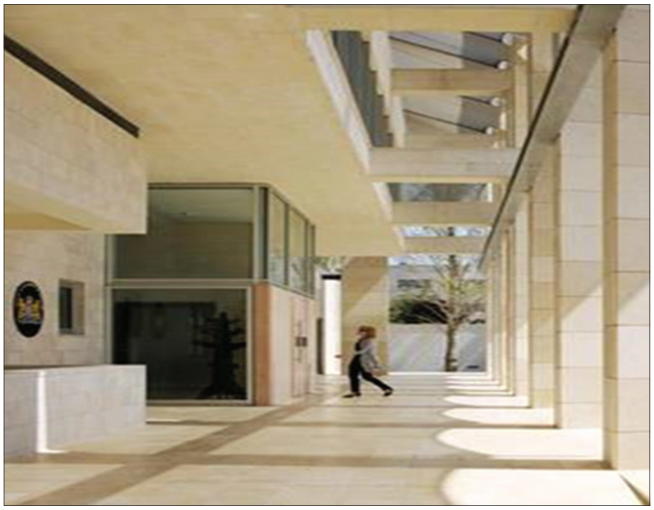
The Netherlands Embassy in Jordan is located in the capital of Amman. The embassy's architect is Rudy Uytenhak from the Netherlands, and the contractor was Abu Eisheh and Bros. Contracting. The area of the embassy is 1,253 square meters including the main building and its annex. The building planned and designed in the period from 2007 to 2008, and the construction was during the period 2008-2009, and it is completed in February 2010. The policy of Dutch Government Sustainability is that new and innovative technologies should be used to change the way we produce and consume things, and hence avoiding causing further harm to ecosystems and easing the pressure on the environment. The balance between ecology and the economy must be adjusted to engender a close connection between economic dynamism and ecological development. The Netherlands embassy in Jordan is the first building in Jordan granted the LEED certification.

- Comfort thermal conditions for all building's spaces
- Automatic control for all systems in the building such as controlling temperature, lighting, humidity, and airflow
- Daylight optimization for all building spaces. This is clearly shown in Figure 2 for the side view of the entrance and central hall of the embassy
- Increasing the visual access of the external environment, especially for offices and regularly used spaces
- Low Volatile Organic Compounds materials to be used in furniture and other indoor finishing products to reduce the effect of indoor contaminants
- The building itself is a non-smoking environment, contributing positively to the control of Environmental Tobacco Smoke.

1.4. The Building's Solar System

The photovoltaic effect is the conversion of light directly into electrical current through the use of semiconductors such as silicone. This can be achieved by the utilize of solar cell panels containing several solar cells. Different materials can be used in solar cells such as monocrystalline, polycrystalline, cadmium telluride, amorphous, etc. There is a growing demand for the use of solar cells as a renewable energy source unlike other resources of energy, this is due to the free power source (the sun), low maintenance during its life span, environment friendly (no pollution). The advancement in manufacturing and the technology

Figure 2: Side view of the entrance



of solar systems made them cost-effective. Most of these solar systems have a lifetime of more than 30 years, which makes them have a warranty of more than 20 years. The work in this study highlighted the following points;

1. The sunshine duration changes from 7.4 to 9.4 h, with a total of 8.89 h (annually 3425 h)
2. The total annual production of renewable energy is 5MW
3. An annual reduction of 8182 tons of the GHG.

The solar cell panels were assembled on the embassy's rooftop as shown in Figure 3 to generate the electric power, which is also provided by the national grid. These panels are used to provide approximately 7.2 kW (36 panels with 200 W ea.) of electrical power. These panels were connected to three inverters to transform DC to AC for building use. The tilt angle was set at 35^o in the south direction.

The solar thermal collector panels were placed on the rooftop of the technical room and car park in the garden (Figure 4), with 75 square meters of the total surface. The solar collectors supply heat during the winter period. The heat is either directly transferred to the building's heating water network or stored in the thermal storage.

- Number of occupants (used in mechanical and water calculations): 25
- Occupancy: 11 working hours in a day (07:00 am – 06:00 pm), 250 working days in a year
- Heating Load: the peak heating load of the building is 58 kW in extreme winter (December, January and February), 45 kW in winter (March) and 30kW in intermediate season (April and November)
- Cooling Load: the peak cooling load is about 82.20 kW.

Ventilation: Mechanical ventilation is applied to supply fresh air to the rooms, to extract used air and recover energy from the exhaust air. Fresh air is supplied to the rooms and used air flows to the central area. The central air handling unit extracts air from the central area. The same amount of air that is supplied as fresh air to the rooms flows to the central area through overflow grills. The remainder part of the supplied air to a room is recirculated to the fan coil units.

Figure 3: Solar panels implemented on the embassy's rooftop

Figure 4: Solar thermal panels for hot water in the garden of the embassy

2. REVIEW OF LITERATURE

In recent years, several studies have examined GHG emission, power and economic impact of Green Buildings that can help mitigate the impacts of buildings on the environment, society and economy. The rating systems or tools that have been developed worldwide to assess and certificate green buildings are varied. Reviewing the related and recent literature regarding this topic reveals different methodology and findings, mainly due to differences in design requirements and operating modes.

Gan et al. (2020) conducted a review of computer simulation and optimization studies for reducing life cycle energy use and carbon emissions in buildings, to determine current practices and future research needs in this area. Life cycle design optimisation with the consideration of production, operation and end-of-life of building systems has growing importance for the sustainable development of the future towards a resource-based circular economy. Besides, emerging digital technologies such as machine learning, data-driven design, and parametric 3D modelling allow further automation in early design exploration and advanced decision-making in design optimization. Using panel data from China's 30 provinces from 2000 to 2015, Huo et al. (2020)

attempted to develop a comprehensive framework for urbanization and systematically explore the multiple effects of urbanization on urban building carbon emissions from both quantity and structure dimensions using the STIRPAT model. The three dimensions of urbanization are population, economy, and land. The findings indicate that urban population and building floor space harm carbon emissions in the urban building market, while the added value of the tertiary industry has a positive impact on carbon emissions in the quantity dimension.

Geng et al. (2019) reviewed the published researches on the post-occupancy performance of green buildings in terms of energy use, indoor environment quality (IEQ) and occupant satisfaction. A total of 925 related papers were searched and 106 articles were screened for deep review. The study also compared the actual operating performance of green buildings in China and the United States, with information collected from previous research. A significant gap between the designed and operational energy consumption was found. Green buildings generally had a higher occupants' satisfaction level than conventional buildings, but subjective data from the U.S. did not support this inference. Bastida et al. (2019) explored the potential of ICT-based interventions in households to decrease electricity usage, improve energy efficiency and thus contribute to reducing GHG (greenhouse gas) emissions from this sector. They defined parameter values, which reflect the efficacy of ICT at changing household energy usage patterns, and ultimately decreasing GHG emissions from the electricity sector. It is found that ICT-based interventions in household energy use could contribute between 0.23% and 3.3% of the EU CO_2e reduction target from the energy sector that would keep warming under 1.5 °C, corresponding to 4.5–64.7 mio. tCO_2e abated per year. Also, Ghisellini et al. (2018) adopted an economic model to decrease waste generation, aiming to innovate the entire chain of production, consumption, distribution and recovery of materials and energy according to a cradle to cradle vision. The findings stress the need for increasing constraints on the availability of resources as well as the increasing demand for access to welfare and wellbeing by developing countries. The final goal of this study is to evaluate if the adoption of the circular economy framework is environmentally and economically sustainable, given that the recovery of waste materials requires investments of resources. Finally, several directions for future research have been proposed: increased the life cycle Assessment approach modelling for sustainability evaluation, a wider development of cleaner production strategies focused on circular design, and finally, the adoption of a comprehensive accounting of input and output flows, to assign appropriate weights to flows and benefits that are most often disregarded.

Another strand of the literature concentrated on reviewing the effects, and legal acts on the energy efficiency of civil buildings, to improve energy performance and sustainability, as is the case of Lee et al. (2019) to some Korean public buildings, Ma, Cai, and Wu (2019) in the case of China, Wuni et al. (2019) for global research trends on green buildings, Ma et al. (2019) in construction journals from 1992 to 2018. Zhang et al. (2019) investigated various approaches in a single building to enhance renewable energy evaluation. This study examines the renewable energy evaluation approaches used in green building and how they can be used to better understand and develop rating systems. Calculations relating to renewable energy types, building features, and energy conversion are all part of these approaches. Those other notable studies that dealt with energy savings, emission reductions, and health co-benefits of green building include MacNaughton et al. (2018), Song et al. (2018) and Uğur and Leblebici (2018). Similar studies to these with more concentration on the economic aspect include Neagu and Teodoru (2019) for the relationship between economic complexity, energy consumption structure and greenhouse gas emission, Rokhmawati and Gunardi (2017) for empirical evidence from listed manufacturing firms in Indonesia, Thanarak and Chiramakara (2019) for agricultural land used for PV Power Plant, Wang and Feng (2018) for the case of China's construction industry and Zhang et al. (2018).

For the MENA region, few studies have explored the effect of environmental variables on Green Buildings. Maku and Ikpuri (2020) investigated the relationship between renewable energy, carbon emission and economic growth for a group of eight MENA countries covering the period 1990-2018. The study adopted the Fully-Modified and the Dynamic OLS estimation technique to examine these relationships. The findings show that there is a significant relationship between CO_2 emissions and economic growth, as well as that renewable energy consumption has a significant impact on economic growth. However, although economic growth reacts positively to CO_2 emissions, CO_2 emissions react negatively to renewable energy consumption, in contrast to the positive outcome between renewable energy consumption and economic growth. This goes to show that most economies in this region have yet to develop appropriate policies to control the regulation of renewable energy prices, which can help take into account the stability of the economic growth structure while also mitigating the emission of Greenhouse Gases. Albaali et al. (2021) investigated the effects of construction and demolition of green buildings in Jordan, with a focus on the benefits that could be realized as a result of green building adoption in construction projects carried out by the construction sector. The study emphasizes the importance of reducing waste generated by construction projects, conserving water, electricity, and natural resources, and having a positive impact on the environment. The study utilizes a descriptive methodology based on survey analytical methods. It explores the several advantages that have been achieved in applying the building method in the construction of the WHO organization's building at the economic and environmental levels. The study suggests taking several steps to activate the proposed incentives to support Jordanian construction companies' adoption of the green building method, including encouraging engineering offices to consider green building specifications in the design and execution of buildings and projects, raising awareness about its positive environmental impact, and encouraging engineering offices to consider green building specifications in the design and execution of buildings and projects. Albaali et al. (2020)

investigated whether an increase in energy spending has had a negative or positive effect on the Jordanian economy, taking into account the difference between generated and consumed energy. According to the study, such rapid increases in public energy spending endangers Jordan's future generations. It also concluded that it is time to reduce the amount of funding that residential energy consumers need to invest in other energy projects such as hydroelectric, wind, or large solar farms. Saidan et al. (2016) investigated the impact of dust accumulation on photovoltaic solar modules in Baghdad city in Iraq. Three identical photovoltaic solar modules were subjected to an experiment to measure the losses incurred by dust accumulation on their surfaces. On a daily, weekly, and monthly basis, measurements of dust accumulation on modules were taken. The average rate of degradation of solar module efficiency when exposed to dust is high. The results of this study show that for exposure cycles of 1 day, 1 week, and 1 month, the average degradation rate of the efficiencies of solar modules exposed to dust is 6.24 per cent, 11.8 per cent, and 18.74 per cent, respectively.

The findings of the literature review can be summarized as follows:

First, except for a few special cases, green buildings outperformed their traditional counterparts in terms of energy efficiency under comparable climate conditions. Second, there was a major difference between the built and operational energy use, and many green buildings used less energy than predicted. Third, there was no discernible connection between real energy use and the degree of green building certification. Fourth, due to differences in design requirements and operating modes, the real IEQ conditions of green buildings were not comparable across countries. Finally, although the subjective evidence from several countries did not support this conclusion, green buildings typically had higher occupant satisfaction levels than traditional buildings.

3. METHODOLOGY AND DATA

3.1. Methodology

The increasing global importance of energy variables has attracted several research activities in the last few years. The building industry contributed to a large proportion of the global energy use and carbon emissions across material production, construction, operation and end-of-life. Along with this progress, utilizing computer simulation techniques to maximise the life cycle of green buildings and the associated environmental impacts have gained increasing attention. Based on a literature review on the subject, we suggest three models and apply them to the building of the Netherlands Embassy in Jordan. The building is used as a green building to estimate GHG emissions. It is the first green building project in Jordan to have the LEED certificate for a green building. The footprint of the case study is restricted existing structure boundaries to minimize the effect of the environment on the site, such as enlarging the open space. The embassy footprint is restricted to building structure boundaries to decrease the environmental influence of the project on the building site; enlarging the open space; closeness to public services, and minimization of the urban heat influence by using covered parking, and shading outdoors areas. Local materials were used for the construction of this new building, such as the typical Jerusalem stone used commonly for the architecture of Amman. The embassy garden The garden is reorganized with the characteristic of transforming and using a swimming pool as a storage tank of water and design a new, low water-intensive garden. The existing swimming pool is used for energy storage. The cold night breeze is apprehended in the swimming pool water and then pumping to the embassy through the day and it works as a natural cooling system. The solar collectors heating the water in the pool during the winter which can then be used in heating the building in the day. Moreover, one of the features of the building is collecting the rainwater in tanks to use in garden irrigation.

The software used in renewable energy technology analysis is RETScreen®, which can be used in energy production analysis, and calculations of GHG emission and life cycle cost for different technologies of renewable energy (Markovic et al., 2011). The software (RETScreen®) is a computerized analytical techno-economic general model. This software is regarded as an international clean energy software used in project analysis. It is used to carry out the analysis of energy production, financial, and emission of greenhouse gases, for the suggested PV-grid connected power plant (Bakos and Soursos, 2002). RETScreen® is a unique and innovative renewable energy/awareness, and decision support tool used in such cases (Bakos and Soursos, 2002). Hence, it is used to analyze the green building setup used in this case study (Embassy of the Netherlands in Jordan). It can be used for different types of technologies such as photovoltaic (PVs), wind energy, small hydro, heat and power joint, biomass heating, refrigeration and source for ground heat pumps. RETScreen® software consists of six steps for esteem the potential of specified installation of photovoltaic, such as site conditions regulations, energy model, in addition to the analysis of risk, cost finance, and emission (Markovic et al., 2011). The model energy used presents the summary of the suggested case system, which is the type and consumption of fuel, provided energy with its capacity, based on characteristics and calculations of the system in the network design, load, and equipment worksheets.

3.1.1. Energy model

The energy model worksheet is a part of RETScreen software to solve for the suggested case system. During the first step, the user selects the following:

- The currency in which the monetary data of the project will be reported: *Jordan Dinar*
- The units; Metric or Imperial units: *Metric*
- Heating value: *Lower heating value*
- The proposed project type: *Power, Technology: Photovoltaic, and Grid type: Isolated-grid and internal load*).

Where "Heating Value" is a measure of released energy when the fuel is burned. The lowest Heating Value (LHV) is calculated by assuming that the combustion product remains in a vapour form, which applies to the case study. For this reason, the setting in this project is based on LHV.

3.1.2. Emission model

RETScreen was used to calculate the amount of greenhouse gas (GHG) reductions. The analysis of energy project relevant to the Green House Gasses is CO_2, CH_4 and N_2O. This study was conducted to calculate the amount of CO_2, which is carried out by the software used for the analysis of the reduction in the emission of greenhouse gasses. Carbon dioxide values are varied from 204 t/MWh for natural gas to 329t/MWh of coal used in industry. The energy generated data and the saving in CO_2 emission according to the Embassy are shown in Figure 5.

The CO_2 emission values are varying from 329 tons/MWh of coals and 204 tons/MWh for natural gas used in industrial processing. The following variables and their values were used for the identified fuel type to perform the emission analysis on the software used, which are:

1. The fuel type
2. CO_2, CH_4 and N_2O emission factors
   - GHG emission factor excluding Transmission and Distributions (T and D) losses in Jordan used in this study equal to 0.895
   - GHG emission factor including Transmission and Distributions losses in Jordan used in this study equal to 0.924.
3. The electricity generation efficiency
4. The losses during T and D in (%) for the base case electricity system. The T and D losses used in this study is equal to 3.0%
5. The emission factor for the greenhouse gases excluding T and D losses for the base case electricity system specified
6. Annual percentage of credits to be paid.

The input was as follows: The greenhouse gases emission factor excluding transmission and distributions losses in Jordan is equal to 0.895; the greenhouse gases emission factor including transmission and distributions losses in Jordan is equal to 0.924, and Transmission and Distribution losses equal 3.0%. After the above-mentioned variables were identified and their values have been known, they were entered into the software and it was run to revolve the output. The results are summarized in the output list, as 9,288 tCO_2 for the base case, 925.9 tCO_2 for the proposed case, 8,632 tCO_2 for the annual reduction of greenhouse gasses emission, and finally the annual rate decrease in greenhouse gasses (tCO_2) is 8,362.1, which is equal to 19,450 barrel of oil. Note that in the units switch, there will be a selection to express the emission factor in $kgCO_2/kWh$ or tCO_2/MWh, and the model allows comparing the net annual decrease in the emission of GHG with units which are much easier to conceptualize, using the software dropdown list.

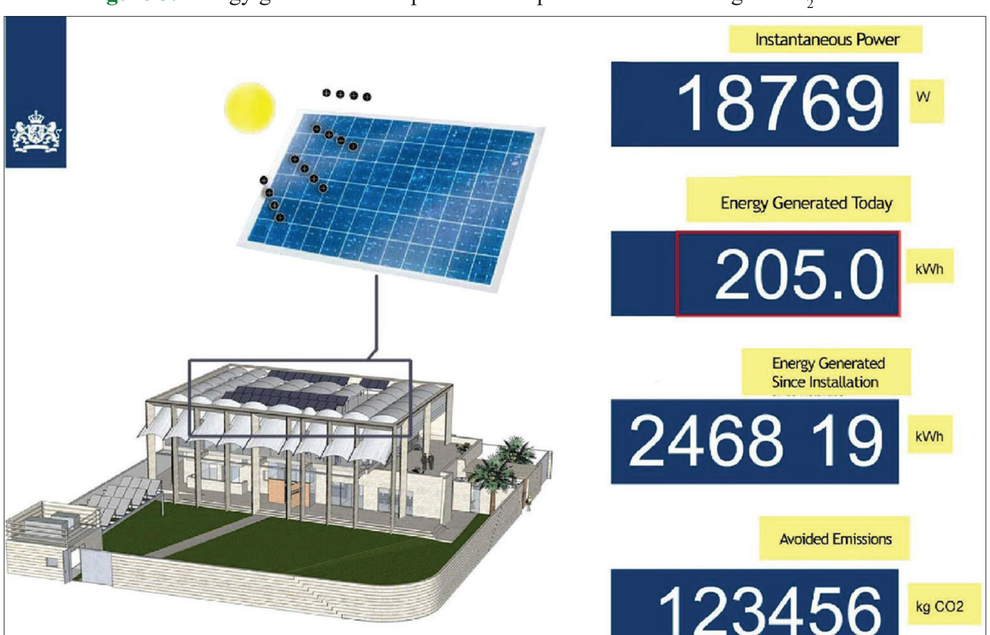
3.1.3. Financial model

The RETScreen is comprehensive software; it is capable to perform financial analysis. The parameters required and used in the financial analysis were 6.4 per cent for the inflation rate, the project life span and debt term is 25 years, the ratio of debt is 60%, and the rate of interest is 5.5%. These values are taken by the researcher from several resources. The other parameters implemented to the software are the cost of PV solar cell, cost of the invertor and its replacement, inverter lifetime, spare parts and system installation, annual operation and maintenance, in addition to the increase rate in the cost of energy and the inflation rate. The solar cell lifetime and period of the analysis are taken based on 25 years. Note that all the costs are taken from the suppliers. The financial analysis aims to calculate the annual saving cost and the payback period.

3.2. Data

There are seven proposed project types in the software used, but the setting used in this work is for power only. The site conditions associated with the software used in this work are to evaluate the annual production of energy for a PV project. Once the weather station location is specified, the total annual incident of solar radiation on the photovoltaic array (MWh/m²), and the

Figure 5: Energy generated from photovoltaic panels and the saving in CO_2 emission



annual mean of temperature (°C) is calculated by the model. The temperature of heating and cooling design, longitude, latitude, elevation, and amplitude of earth temperature is also defined. These data are shown in Table 1.

The temperature of air and earth in degree Celsius, relative humidity as a percentage, daily solar radiation measured in kWh/m^2/d, wind speed in m/s, horizontal atmosphere pressure in kPa, heating and cooling in °C/d is also introduced to the software used. The above-mentioned data can be loaded manually, or provided from the software built-in information as it is already linked with the NASA metrological data (Table 2). Metrological data are a function of time and elevation, therefore these metrological indices were measured at a constant elevation, and varied time. The time is defined on monthly basis; also it may be composed of smaller time interval, such as day, and hour.

These data are visualized in Figure 6, which consists of four charts; 2 histograms and 2 x-y scatter plots. The histograms visualized the air and earth temperature, while the x-y scatters plot air/earth temperature and cooling/heating temperature. The study constructs these charts from Table 2. The X-axis was set for the time monthly based, while the y-axis was set for the temperature variable. This gives a clear indication of the various temperatures every month.

The user constructs the following 4 charts, shown in Figure **7**. These charts are relative humidity, daily solar rad., atm. pressure and wind speed. The data were from Table 2. The variables measurement units are shown in the figure caption.

Metrological data are a function of time and elevation. Therefore, these metrological indices were measured at a constant elevation and varied time. The time is defined on monthly basis; also it may be composed of smaller time interval, such as day, and hour. The project settings were based on power generation that is converting sunshine directly to electricity. The application of photovoltaic in the worksheet of solar resources is automatically copied to the worksheet of the energy model. The type of grid (Central-grid" or Isolated-grid) was specified from the drop-down list. The size of the grid in the system is very large which means that all energy generated from the photovoltaic is used and thus it is recommended to use the central grid for such systems. The data were collected from two major sources, which are Netherlands Embassy in Jordan, whilst the remaining variables of the proposed case and electricity rate base are collected from the commission of electricity regulatory. The above statistics are presented below in Figure 8.

All data shown above are introduced to the suggested project. They are obtained from two major sources which are the embassy of the Netherlands in Jordan and the proposed case and electricity rate base taken from the commission of electricity regulatory.

The data below were also required to implement the RETScreen energy model, power model to get results, which are:
1. The technology of the project under investigation is power, the production of electricity from solar energy using a photovoltaic system
2. The expected power capacity (i.e. the capacity of the system) to generate electricity in its full operation. The power capacity of the system is 7.2 kW. It is calculated based on the number of cells multiplied by each cell power capacity. This represents the total power capacity expected if the system is run in its full power capacity, and with 100% efficiency
3. The manufacture of the solar system (Suntech). must be defined. The user can enter the manufacture manually The RETScreen software includes an internal database, and it is connected to an online database and the manufacture websites. Thus, the user could use any one of them; manually or as a database
4. The model of the photovoltaic solar cell in the project under investigation is Poly-Si-STP200-18
5. The capacity factor of the solar photovoltaic system must be defined. It was taken from the manufacture, which is 13.9%.

The energy model of The RETScreen® calculates the electricity supplied to the grid and the load. No electric power is supplied to the grid and only supplied to load, which is predestined with the value of 9 MWh (approx. 0.9% of needs from electric power). The estimated generated electricity used by the Netherlands Embassy in Jordan was based on monthly estimation. This is in addition to providing the software with the rate base of electricity measured in JOD/MWh. Fuel and electricity are fully governed by the government. The government alligate that it pays 550-600 Fils/KWh (1 Jordanian

Table 1: Site conditions used in the work

	Unit	Climate data location	Project location
Latitude	°N	32.0	32.0
Longitude	°E	36.0	36.0
Elevation	m	779	779
Heating design temperature	°C	2.1	
Cooling design temperature	°C	34.0	
Earth temperature amplitude	°C	23.1	

Table 2: Parameters introduced to the software used

Months	J	F	M	A	M	J	J	A	S	O	N	D	*A
Air temperature	7.7	9.0	11.6	15.8	20.0	23.6	25.1	25.2	23.4	19.9	14.3	9.40	17.1
Relative humidity	74.8	70.9	64.4	52.5	43.4	44.1	45.1	50.8	53.7	57.5	63.8	72.9	57.8
Daily solar radiation	2.7	3.7	5.0	6.8	7.8	8.4	8.2	7.5	6.4	4.8	3.6	2.7	5.64
Atm. Press	92.9	92.7	92.6	92.3	92.2	92.0	91.7	91.8	92.1	92.5	92.8	92.9	92.4
Wind speed	3.2	3.6	3.6	3.6	3.5	3.9	4.1	3.6	2.7	2.3	2.5	2.9	3.3
Temp of earth	11.7	13.3	17.5	23.9	28.3	31.2	33.7	33.8	31.2	25.5	18.8	13.3	23.6
Daily heating	319	252	198	66	0	0	0	0	0	0	111	267	1.213
Daily cooling	0	0	50	174	310	408	468	471	402	307	129	0	2.719

*A is the annual

Figure 6: Monthly temperatures

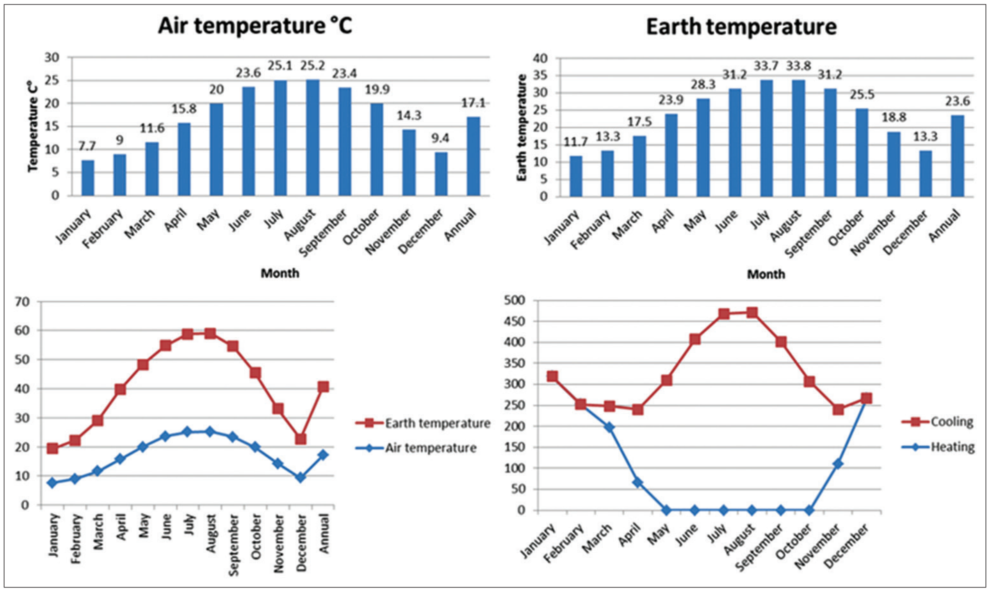
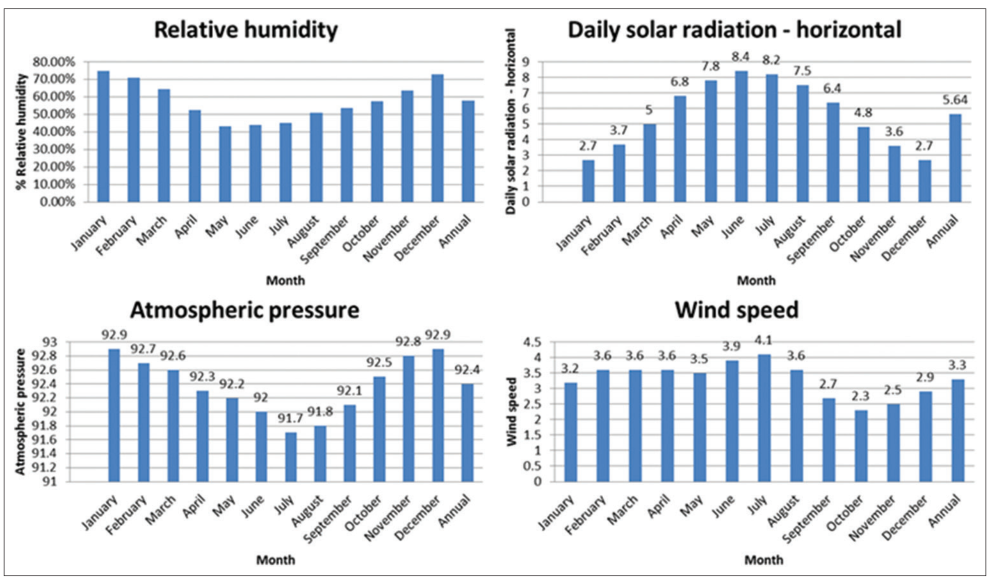


Figure 7: Relative humidity, daily solar radiation, atmospheric pressure and wind speed



Dinar equals 1,000 Fils), and sell it for less than its half price. As can be seen, from Figure 9, there was a steady increase in electricity generation cost, for the 5 years following 2007.

The electricity used by the embassy, based on monthly estimation is shown in Table 3.

The data mentioned above was required to load it to the RETScreen software, i.e. these data are the input of the software worksheet. Consequently, after that, the program was run to get the results.

4. RESULTS AND DISCUSSION

4.1. Energy Analysis

Upon inserting the data that was selected and mentioned earlier, the program ran successfully. Figures 10 and 11 show the base and proposed case power system of the embassy project.

The electricity delivered from the system to the load is 833 MWh, while the required total current is 1006 MWh, which represents 82% of the total power needed.

4.2. Emission Analysis

RETScreen has been used to calculate the amount of GHG reduction. The emissions reduction analysis is used to assess the GHG emissions of the suggested project. The inputs required were: country region, fuel type, the emission factor of greenhouse gasses, and the losses of transmission and distribution. The input of greenhouse gasses emission factor excluding transmission and distributions losses in Jordan is equalled to 0.896, while the GHG emission factor including transmission and distributions losses in Jordan equals 0.924, thus T and D losses are equal to 3.0%. Consequently, after running the program over the entered input data, the output information is GHG emission factor in tCO_2/MWh which equals 0.924. The GHG emission factor taken was used in

Figure 8: Power system (Proposed case) for Netherland embassy project

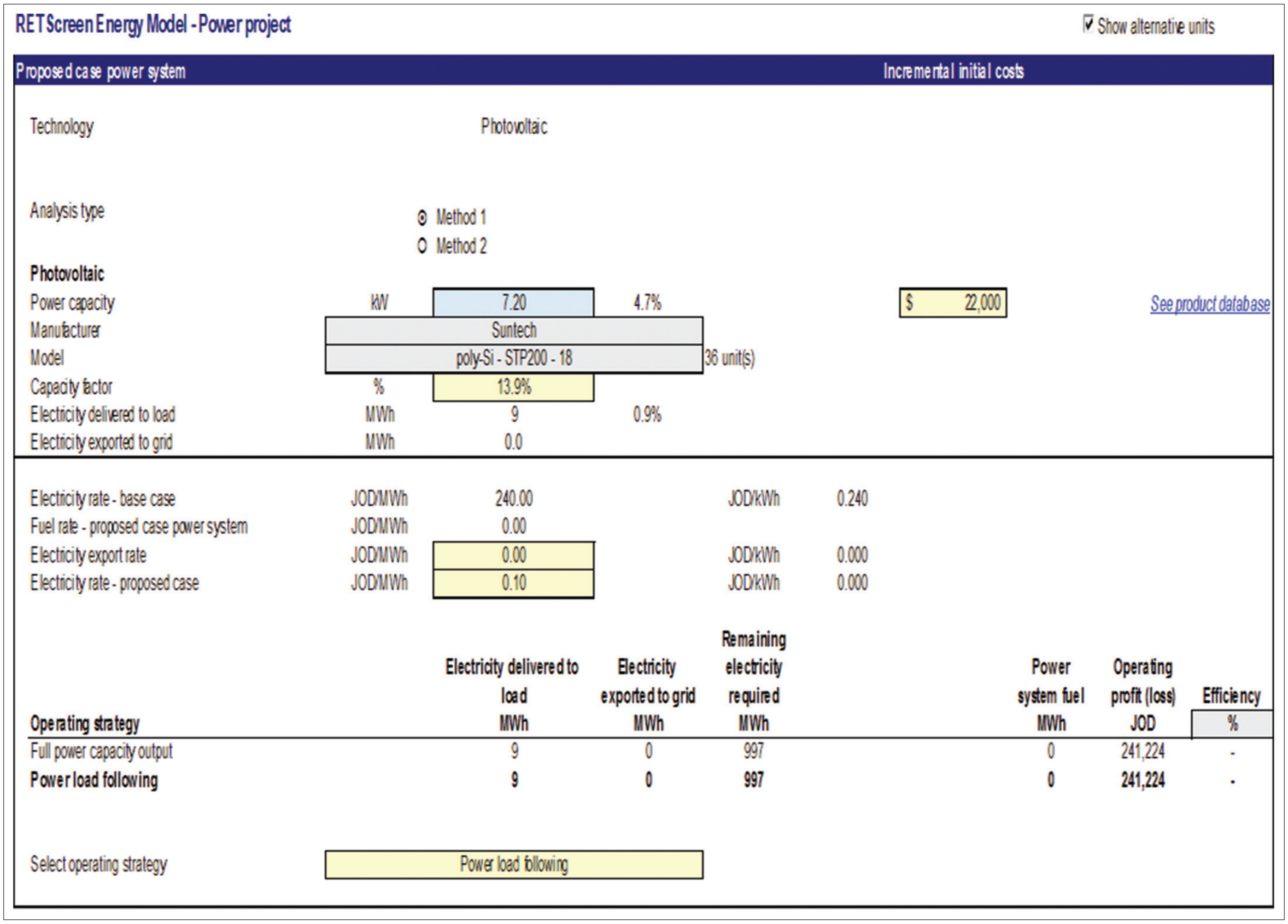


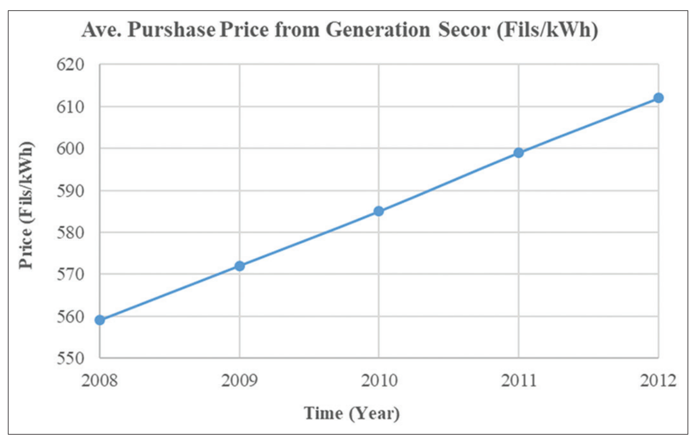
Table 3: Electricity used by the Netherland embassy based on monthly estimation

Date	No. of Days	No. of Days Without Holidays	Hours of Sunshine (angle 35)	Hours (with Holidays)	Hours (Without Holidays)
3/2010	31	22	5.6	1124.9	798.33
4/2010	30	19	6.1	1185.84	751
5/2010	31	20	6.5	1305.72	842.4
6/2010	30	20	7.1	1380.24	920.16
7/2010	31	21	7	1406.16	952.56
8/2010	31	23	7	1406.16	1043.28
9/2010	30	21	6.8	1321.92	925.34
10/2010	31	21	5.8	1165.1	789.264
11/2010	30	19	4.7	913.68	578.664
12/2010	31	21	4	803.5	544.32
1\2011	31	21	4	803.5	544.32
2\2011	29	21	4.6	864.43	625.97
Total	366	249		13681	9315.61

Source: Personal communication from employees in charge at the Netherlands Embassy, Amman, Jordan

input entered data to net annual GHG emission reduction. The results obtained were very interesting. The outputs are presented in equivalent tons of carbon dioxide avoided per year, and it was as follows: the base case is 9,288.1 tCO_2; the suggested case is 925.9 tCO_2; the gross annual reduction in the emission of GHG is 8,632.1 tCO_2; the net annual reduction in the emission of GHG is 8,362.1 tCO_2, which is equivalent to 19,447 barrels of crude oil (Figure 12).

Figure 9: Average purchase price from generation sectors, 2008-2011



4.3. Financial Analysis

The analysis used for the financial section contains six parts to provide details on the project's revenue, which includes the cost of the project, yearly income, summary of saving and income, annual and cumulative cash flow. Analytical calculations are used to assess the payback period and cost-saving, which is covered the

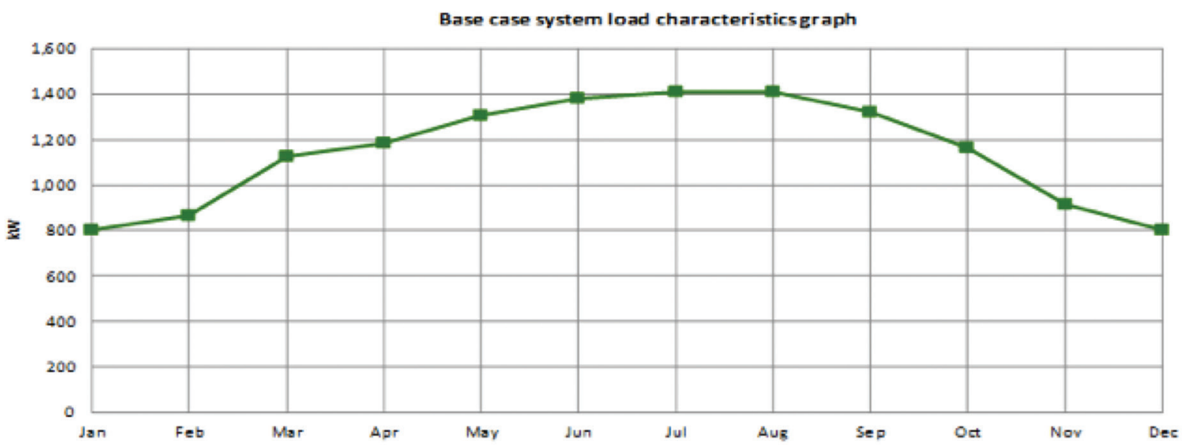
Figure 10: Base case power system of the embassy project

Power project	Unit	
Base case power system		
Grid type		Isolated-grid & internal load
Peak load - isolated-grid	kW	1,500
Minimum load - isolated-grid	kW	800

Base case load characteristics

Month	Power gross average load kW
January	803.5
February	864.43
March	1124.9
April	1185.84
May	1305.72
June	1380.24
July	1406.16
August	1406.16
September	1321.92
October	1165.1
November	913.68
December	803.5

System peak electricity load over max monthly average		8.0%
Peak load - annual		1,519
Electricity	MWh	10,055
Electricity rate - base case	JOD/kWh	0.240
Total electricity cost	$	2,413,237



Proposed case energy efficiency measures		
End-use energy efficiency measures	%	90%
Net peak electricity load	kW	152
Net electricity	MWh	1,006

Source: load and network worksheet, in specific it is the output screen of a power project, it includes based case power system variables and power project output. The table is a RETScreen screen.

period (02/2010 – 03/2011) of producing the electricity since the installation (427 Days). The total energy used was calculated based on total power (7.2 kW) x invertor's efficiency (90%) x number of days 366) x Ave. hours of sunshine (5.7), which means that the total energy used is equal to 13.682 kWh, as shown in Table 4.

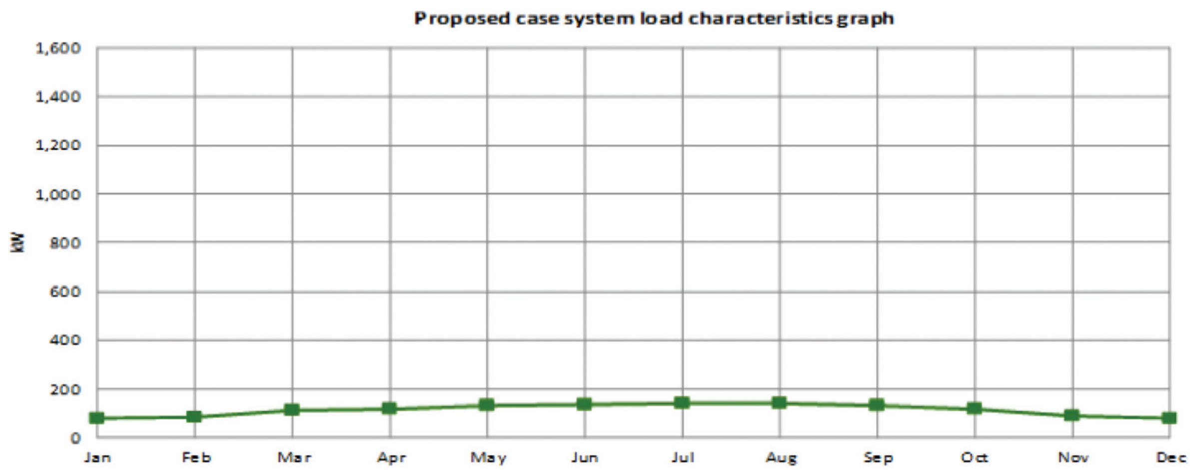
Based on the data in the above table:
- Total system cost is 24,330 Jordanian Dinars
- Yearly energy saving is 9,316.0 KWh
- The estimated electricity tariff from the grid is 240 Jordanian Fils/kWh
- Yearly cost saving is equal to 9,316.0*0.24 (electricity tariff rate) = 2,235.8 Jordanian Dinars
- Payback period 24,330/2,235.8 = Approximately 11 year.

The geographical location field study was defined and set by its longitude, latitude, and elevation. The physical parameters of location become constant and can delete it when making a comparison to the amount of solar radiation between two different geographical locations. Consequently, a doable comparison of solar radiation among different geographical locations would be by comparing just solar radiation indicators of a geographical

Figure 11: Proposed caseload characteristics

Proposed case load characteristics

Month	Power net average load kW
January	80
February	86
March	112
April	119
May	131
June	138
July	141
August	141
September	132
October	117
November	91
December	80
Peak load - annual	152



Proposed case load and energy		Power
System peak load	kW	152
System energy	MWh	1,006

location to others location with referring to its political site. Jordan has the highest solar radiation among others countries (300 sunny days, 2,080 kWh/m^2), which is a promising signal to use renewable energy on a wide range. This suggests that, by 2050, Jordan can provide more than 60 times of its electrical need through the use of wind and solar (Moser et al., 2011).

For the environmental section, unfortunately, there is no reference cost of GHG reduction in Jordan based on international conventions such as Kyoto; even it must be publicly released. Jordan sells its decrease of GHG to other developed countries and made this a national resource by returning it as cash to the treasury of Jordan. However, the unobtainable data lead to precisely estimate the importance of this study in Jordan. Thus, selling the reduction of GHG to the developed countries has a positive impact because it supports the electricity production cost in Jordan as a government and as a customer. Taking into consideration that a 30 USD is credited for every ton of CO_2 for point the advantages of the reduction in the emission of GHG (Mirzahosseini and Taheri, 2012). For the financial section, an analysis of a PV has been done to calculate the overall project cost, after taking into consideration and calculating all financial parameters related to the project. The study calculates the payback period which was 11 years, this shows the value of using PV projects to provide electricity in Jordan. The study also showed that the cost of installing such systems is less than producing electricity, after taking into account Jordan's tariff of electricity. Thus we can conclude that supporting such projects will lead by the end to minimize the electricity bill. For the economic section, the cash flow of the project was favourable for the 1st year of application i.e. the annual saving in electricity bill is more than the annual cost of the project. These results highly support the use of the PV small projects in the residential building on a large scale in Jordan

Figure 12: Base case power system of the embassy project

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor 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			

Table 4: Sunshine hours and energy saving

Date (month/year)	No. of Days	No. of Working Days Without Holidays	Sunshine Hours	Energy-saving (with Holidays)	Energy-saving (Without Holidays)
3/2010	31	22	5.6	1,124.9	798.33
4/2010	30	19	6.1	1,185.84	751
5/2010	31	20	6.5	1,305.72	842.4
6/2010	30	20	7.1	1,380.24	920.16
7/2010	31	21	7	1,406.16	952.56
8/2010	31	23	7	1,406.16	1,043.28
9/2010	30	21	6.8	1,321.92	925.34
10/2010	31	21	5.8	1,165.1	789.264
11/2010	30	19	4.7	913.68	578.664
12/2010	31	21	4	803.5	544.32
1/2011	31	21	4	803.5	544.32
2/2011	29	21	4.6	864.43	625.97
Total (Average)	366.0	249.0	(5.7)	13,682.0	9,316.0

5. CONCLUSION

Photovoltaic is proved financially effective, due to the decrease in photovoltaic technology cost, this is in addition to the geographical situation of Jordan which is found applicable and promising to generate electricity from PV cells, and the increasing prices of oil and natural gas. This is also that these cells are environmentally friendly and it minimizes the emission of GHG, which results to lower the effect of greenhouse gasses on climate change. The implements of PV plans are considered economically reasonable for Jordan to produce electricity. The annual saving of energy is found to be 9,315.61 kWh, which will, in turn, reduce the electricity bill by over 3,200 USD per year. This is in addition to the elimination of GHG by 920.7 tCO2 annually, which means that the case study inaugurated a good event.

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