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Using computer simulation in the analysis of energy saving in green building; a case study

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Abstract

The implementation of solar panels for a green building in Jordan to generate solar energy and to support the electricity supplied by the national grid is presented in this study. The photovoltaic panels used generate approximately 7.2 kW of electrical power, which is used for office lighting. RETScreen software and computer simulation is used for the analysis of renewable energy technologies. The Energy Model worksheet is used to evaluate the proposed case system, which is the photovoltaic one. The result showed that the project cash flow is positive. The annual energy saving is found of 9315.61 kWh, which will annually eliminate 920.7 tCO_2 of GHG. These findings support strongly the implementation of a local residential photovoltaic small project in Jordan, taking into consideration the escalating oil and natural gas price, and the decrease in photovoltaic technology cost.

Keywords: Green building, energy model, RETScreen software

1. Introduction

Photovoltaic (PV) technology is proven and easy to use solar energy to generate electricity. The PV sector is projected to continue to grow, in part due to feed in tariff support as well, due to grid parity economics in much countries.Another aspect is the necessity to deliver environmentally sound and sustainable solutions to the built environment. The global climate change and energy crisis demands lead to the approach of this work, which is studying the way buildings are designed, constructed and operated in order to reduce their impact on the natural environment.

The choice of the building has been the Embassy of the Netherlands as it integrates many “green building” technologies and it is the first building in Jordan to receive the prestigious international LEED (Leadership in Energy and Environmental Design) certification for green building, which is rated from the US Green Building Council (USGBC). RETScreen software has been used for the analysis of the renewable energy technologies, and the aspect subject to the analysis is the proposed case power system.The Energy Model worksheet is used to evaluate the proposed case system, which is the photovoltaic one.

2. Energy Consumption and Electricity Outlook

Around 1.5 billion people or more than a fifth of the world's population mostly in rural areas of developing countries have no access to electricity and further 2 billion are severely undersupplied [1].Of the people without electricity, 85% live in rural areas or on the fringes of cities. Total global energy use exceeds 102 Trillion kWh per year, which is equivalent to over 170 million barrels of oil each day [2]. Global energy consumption draws from six primary sources: 44% petroleum, 26% natural gas, 25% coal, 2.4% hydroelectric power, 2.2% nuclear power, and 0.2% non-hydro renewable energy. As the prices of oil and gas have been rising since the past decade, as well as, the awareness of the environmental impact of fossil fuels, the importance of renewable energy as a source of power has become more prominent [3]. On the global scale, renewable energy made up to 20.1% of electricity production, up by 1.4% from 2010’s energy mix. In terms of direct consumption of renewable energy, this stood at 12.7% of the global

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energy mix in 2011 [4].

The energy in Jordan is heavily dependent on imported crude oil and oil products to cover the energy needs. Energy imports account for nearly 10% of Growth Domestic Product GDP. According to international classifications, Jordan is one of the "sun-belt countries" with average daily solar radiation of 4kWh/m^2 in winter and more than 8kWh/m^2 in summer. This is why the solar energy is mainly used for domestic solar water heating for about 30% of residential units in the country [5].The annual primary energy consumption (1000 toe) during 1997-2004 in Jordan is shown in Table (1).

Table 1. Annual primary energy consumption (1000 toe), during 1997-2004 in Jordan [6]

Year	Primary Energy Type				Total
	Crude Oil and Oil Products	Natural Gas in billion ft^3	Renewable Energy	Imported Electricity	
1997	4385	10.7	65		4673
1998	4491	10.9	67		4784
1999	4471	10.8	68		7450
2000	4815	10.3	75	11	5114
2001	4803	9.9	76	65	5150
2002	4954	9.0	79	78	5299
2003	5031	43.2	77	235	5774
2004	0	49.2	82	199	6489

2.1. Green Building

Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. The sustainable design would streamline the industry towards both environmentally and socially responsible solutions to the built environment

2.2. Embassy of the Kingdom of Netherlands

The new Embassy building has onsite renewable energy generation and utilization through photovoltaic panels and solar thermal panels for hot water; high spec glazing on both floors to enhance the building's energy performance. This is in addition to the use of energy efficient lighting and electrical equipment. The indoor environmental qualities were:

- Design and verification for thermal comfort conditions for all spaces.
- Automatic and occupant controllability of building systems, including lighting, temperature, humidity and airflow.
- Optimization of daylight as a design strategy for most of the building spaces.
- Low Volatile Organic Compounds (VOC) materials to be used in furniture and other indoor finishing products to reduce the effect of indoor contaminants.

2.3. The Photovoltaic Panels

The photovoltaic panels on the roof are used to generate approximately 7.2 kW of electrical power, which is used for offices lighting. Each panel produces up to 200 W and there are 36 panels covering an area of up to 52 m2. The panels are connected to 3 inverters that transform the 17V DC to 230V alternating current. The tilt angle is 35 degrees with south orientation. The used panels can be used in different applications such as: on-grid utility systems, on-grid commercial systems, and on-grid ground mounted systems. The panel provides more field power output through advanced cell texturing and isolation process, which improves low irradiance performance [7].To get the optimum match between the solar generators' output power and the inverter's input power, an inverter type Sunny Boy 2500 has been used.

2.4. The Solar Thermal Panels

The solar collectors are placed with the total collector surface amounts to 75 m ².The solar thermal panels are used in conjunction with the thermal storage system, which serves a number of purposes including increasing system generation capacity, efficiency and reliability with the possibility of integration with other functions such as water storage for fire application. The existing swimming pool is insulated with 70mm insulation material which is covered with a reinforced watertight sheet.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 [8]. The data for the panels used in the case study are summarizing as follows:

- 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 (Dec., Jan. & Feb.), 45 kW in winter (March) and 30kW in intermediate season (April & Nov.).
- Cooling Load: the peak cooling load is about 82.20 kW.

As a result, the embassy building is less dependent on fossil fuels, the emission of greenhouse gasses will be reduced and less electricity will have to be withdrawn from the power company resulting in lower costs and energy savings.

3. Methodology

In this study, the available software for the analysis of renewable energy technologies has been used. It is used to perform energy production analysis for a proposed photovoltaic-grid connected power plant for the Netherland embassy project [9]. The RETScreen computer program consists of 6 steps procedure for evaluating the potential of the specific PV installation, which are setting site conditions, energy model, cost analysis, emission analysis, financial analysis and sensitivity and risk analysis. In the analysis of ‘‘energy model’’, the basic information of the site conditions; solar radiation, latitude of project location, annual average temperature, system characteristics, PV array technical information and power conditioning are loaded. This is in addition to the information on the local electric utility such as the demanded peak electrical load, and annual energy consumption demand in order to estimate the amount of energy coming from conventional sources that PV system will be able to replace. The energy model worksheet presents the proposed case system summary, fuel types, fuel consumption, capacity and energy delivered, based upon system characteristics and calculations in the Load and Network Design and Equipment Selection Worksheets [10] and [11]. The selected language is English; the currency in which the monetary data of the project is the Jordan Dinar; the units; Metric or Imperial units: Metric; the defined project location: Amman/King Abdullah; heating value: Lower heating value; and finally, the proposed project type: Power, Technology: Photovoltaic, and Grid type: Isolated-grid & internal load). The two points to explain are:

1. The heating value, which is a measure of energy released when a fuel is completely burned. It is classified into; Higher Heating Value (HHV) and Lower Heating Value (LHV). HHV is calculated assuming that the combustion product is condensed and the steam is converted to water, while LHV is calculated assuming the combustion product stays in a vapor form [10]. The setting in this project is based on LHV.

2. The seven proposed project types [10] are: heating, power, cooling, combined heating and power, combined cooling and power, combined heating and cooling, and combined cooling, heating and power.

In this study, the setting used is for power only. In RETScreen software used in this work, the user entered the weather station location in the Solar Resource and System Load (SR&SL) worksheet, which is copied automatically to the energy model worksheet. The model calculated the total annual solar radiation incident on the PV array (in MWh/m ²), and the annual average temperature (in ℃). Both measurements were calculated from monthly data entered by the user in the SR & SL worksheet. The site reference details used in the project conducted herein. The user identified these data based on the offline database and online database connect-in RETScreen software (Table 2).

Table 2.The site reference data used in the study

	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	

In addition to all above, the software needs to identify the months, air temperature (^{o}C), relative humidity (%), daily solar radiation (kWh/m^2/d), horizontal, atmospheric pressure (kPa), wind speed (m/s), earth temperature (^{o}C), heating (^{o}C/d), and cooling (^{o}C/d). The data could be entered manually, if it's available, or it could be obtained from the software itself, since as mentioned above it is connected to NASA metrological data. These data are shown in Table 3.

Metrological data are function of time and elevation, therefore, these metrological indices are measured at constant elevation, and varied time. The study conducted in this work is based on power generation that is converting sunshine directly to electricity. The user also selects the type of grid from the two options in the drop-down list: "Central-grid" and "Isolated-grid". In this case the "PV energy absorption rate" should be specified [10]. The user has to define also the following: Power capacity; PV system manufacture; Model; Capacity factor; Electricity delivered to load; Electricity rate–base rate; and Electricity rate–proposed case.

Table 3.The Site data and weather parameters used in the study

Months	AT*	RH*	DS*	AP*	W*	ET*	H*	C*
Jan	7.7	74.80	2.7	92.9	3.2	11.7	319	0
Feb.	9	70.90	3.7	92.7	3.6	13.3	252	0
March	11.6	64.40	5	92.6	3.6	17.5	198	50
April	15.8	52.50	6.8	92.3	3.6	23.9	66	174
May	20	43.40	7.8	92.2	3.5	28.3	0	310
June	23.6	44.10	8.4	92	3.9	31.2	0	408
July	25.1	45.10	8.2	91.7	4.1	33.7	0	468
Aug.	25.2	50.80	7.5	91.8	3.6	33.8	0	471
Sept.	23.4	53.70	6.4	92.1	2.7	31.2	0	402
Oct.	19.9	57.50	4.8	92.5	2.3	25.5	0	307
Nov.	14.3	63.80	3.6	92.8	2.5	18.8	111	129
Dec.	9.4	72.90	2.7	92.9	2.9	13.3	267	0
Annual	17.1	57.80	5.64	92.4	3.3	23.6	1,213	2,719

Where AT=Air Temperature (℃), ET=Earth Temperature (℃), RH=Relative Humidity (%), DSR=Daily Solar Radiation (kWh/m^2/d), AP=Atmospheric Pressure (kPa), WS=Wind Speed (m/s), H=Heating (℃-d), and C=Cooling (℃-d).

The above data are specifically defined for the proposed project. They were taken from two main sources, which are the Netherland embassy (the official owner of the project), while the rest variables such as electricity rate–base rate, and electricity rate–proposed case were taken from Electricity Regularity Commission [12].

The RETScreen energy model calculates the electricity delivered to load and the grid. In this project, no electricity will be delivered to grid, but only to load. Moreover, the user enters the electricity rate–base case in JOD/MWh. The government official department defined the electricity tariff to domestic sectors [13]. However, in Jordan there are two different electricity tariffs; these are: the average purchase price from generation sectors and the electricity tariffs to domestics sectors. The government claims that it pays about 550 Fils/kWh, while sell it to domestics by less than 50% of that cost.

In this study, the estimated of the electricity tariff to the Netherlands embassy is assumed to be 240 Jordanian Fils/kWh. This tariff is less than half of the average purchase price from generation sectors as the government claimed, as well as it is within the announcement tariffs of electricity rate for different domestic sectors regarding its consumption level. The estimated electricity equities consumed by the Netherland embassy in Jordan, based on monthly estimation are shown in Table (4).

Table 4. Monthly based estimation of electricity equities by the Netherland embassy in Jordan

Date	ND*	NDWH*	HS*	HH*	HWH*
03/2010	31	22	5.6	1124.9	798.33
04/2010	30	19	6.1	1185.84	751
05/2010	31	20	6.5	1305.72	842.4
06/2010	30	20	7.1	1380.24	920.16
07/2010	31	21	7	1406.16	952.56
08/2010	31	23	7	1406.16	1043.28
09/2010	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
01/2011	31	21	4	803.5	544.32
02/2011	29	21	4.6	864.43	625.97
Total	366	249		13681	9315.61

Where ND=Number of Days, NDWH=Number of Days without Holiday, HS=Hours of Sunshine (angle 35), HH=Hours with Holiday, and HWH=Hours without Holiday

Source: Personal communication from employees in charge at the Netherlands embassy, Amman-Jordan.

4. Results of the Energy Model Analysis

The obtained results are shown in Tables (5), and (6).

Table 5.Base case power system Proposed case load characteristics of the study

(a) Base case power system

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

(b)Proposed case load 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

The main input parameters identified to be feed into the first method (analysis technique) are: power capacity, manufacturer, model, capacity factor, electricity delivered to load, and electricity exported to grid (Table 6). Also, it need other parameters, those are: electricity rate - base case, fuel rate - proposed case power system, electricity export rate, and electricity rate - proposed case (Table 7).

Table 7. Proposed case power system conducted of the study

Proposed Case power system				Incremental initial costs		
Technology		Photovoltaic				
Analysis type		Method 1				
	‘	Method 2				
Photovoltaic						
Power capacity	kW	7.20	4.7%		14,331 JD	
Manufacturer		Suntech				
Model		poly-Si - STP200 - 18		36 unit(s)		
Capacity factor	%	1390.0%				
Electricity delivered to load	MWh	833	82.8%			
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	0.00		JOD/kWh	0.000	

Operating strategy	Elec. delivered to load MWh	Elec. exported to grid MWh	Remaining elec. required MWh	Power system fuel MWh	Operating profit (loss) JOD
Full power capacity output	833	44	173	0	241,334
Power load following	833	0	173	0	241,334

The solar system delivered 833 MWh of electricity to load while the total amount of required current is 1006 MWh. This is equivalent to 82% of the whole electricity needed.

Based on the data mentioned in Tables 6: The total cost of this system is 14331 JOD ($20000); the annual energy saved is 9315.61 kWh; the estimated electricity tariff from the grid is 240JDFils/kWh; the annual cost saving is 9315.61*0.24= 2236JOD/year; the payback period is 14330/2235= 6.4 year

5. Discussion of Results

The results of this study in comparisons with other previously published studies worldwide are discussed in the following sections:

5.1. Geographical feasibility

The electricity generation form PV panels relies on the quantity of solar radiation hits the photovoltaic panel. Thus, geographical feasibility of a location is most influential point [14]. The geographical location is determined by its; latitude, longitude, and elevation above the sea level. Based on the solar radiation in Jordan, 2080 kWh/m2, and its 300 sunny days yearly, it is concluded that Jordan has an excellent and promising potential power generation from solar energy, which basically constitutes a national promising resource that needs to be invested to the full extent [15].

5.2. Environmental feasibility

In fact, Jordan is one of developing countries that scour transparency in energy sector. Jordan sells its reduction of GHG to others developed countries such as Germany, which made it a national resource that returns direct cash flow to the Jordan treasury. As mentioned above the selling of GHG reduction to other developed countries has an effect on the real cost of electricity production and consequently on the prices given to the customers. On the other hand, it is proven by this study and other previously published studies worldwide, that the ability and effectiveness of renewable energy projects, including solar ones decrease the GHG emissions into a national and international scale.

5.3. Economic feasibility

Due to the country’s dependence on subsidized and low cost natural gas imported from Egypt, Jordan’s government had failed to initiate any meaningful progress in renewable energy and energy efficiency despite the obvious strategic importance in providing energy security and establishing the basis for economic development [16] and [17]. This has resulted in a shift to imported oil derivatives that have come at a much greater cost to the government. The cost of PV has come down dramatically in the last few years. In Jordan, PV has already attained grid parity today; i.e., it is well below today’s cost of electricity of production of $0.25/kWh, and below what some consumers pay (above $0.15/kWh) [18] and [19].The results of the project cash flow are positive; the annual saving in electricity bill is more than the annual cost of the project. These findings support strongly the implementation of a local residential photovoltaic in Amman specifically, and in Jordan on a large scale.

6. Conclusions

Jordan is geographically suitable and promise to produce electricity from photovoltaic cell on a wide range scale. Due to high and escalating oil and natural gas price, and the decrease in photovoltaic technology cost, photovoltaic plans are economical reasonable solution to Jordan to produce electricity. This is in addition to the other important reasons as these cells are environmental friend and it decreases the GHG emission. It has been found in this study that, setting and running-on photovoltaic cell will reduce the electricity bill of the case study by 2236 JOD ($3130) per year, with annual energy saving of 9315.61 kWh. This will annually eliminate 920.7 tCO_2 of GHG, and it inaugurated a good event, that may enhance others embassies, international, and national agencies to follow.

References

[1] Anoopa S. Energy and environment: A framework for action in the Arab region. *Environment & Energy Conference & Exhibition*, UNEP, 2003.

[2] Jeffery C, Raymond JK, Paul RP. *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, 2006.

[3] Rehman S, Bader MA, Al-Moallem SA. Cost of solar energy generated using PV panels. *Renewable and Sustainable Energy Reviews*. 11: 1843–1857.

[4] Khammash T. CFA, CVA. (2012). The Jordanian Energy Sector, Jordinvest, Jordan Investment Trust P.L.C.

[5] Greenpeace International (2013). Jordan’s Future Energy. Amman: Greenpeace International.

[6] Chedid R. Jordan Baseline Study, MED-ENEC Project, Energy Efficiency in the Construction Sector in the Mediterranean, Beirut, 2006.

[7] Nelson J. *Solar Cells*. Imperial College Press, 2003.

[8] The Netherlands Embassy in Amman Jordan (2011).

[9] Bakos GC, Soursos M. Technical feasibility and economic viability of a grid-connected PV installation for low cost electricity production. *Energy and Buildings*. 2002; 34: 753–758.

[10] MNR Ministry of Natural Resources. RETScreen Software Online User Manual. Minister of Natural Resources Canada, CANMET Energy Technology Centre. Varennes, Quebec, CANADA: Minister of Natural Resources Canada, 2005.

[11] Markovic D, Cvetkovic D, Masic B. Survey of software tools for energy efficiency in a community. *Renewable and Sustainable Energy Reviews*. 2011; 15: 4897– 4903.

[12] Electricity Regularity Commission ERC. (2008). General Indicators for Economy and Energy.From Electricity Regularity Commission.

[13] Electricity Regularity Commission ERC. (2008a). Electricity Tariff.From Electricity Regularity Commission.

[14] USDEG United States Department of Energy (2013). Energy efficiency and renewable energy.

[15] Etier I, Al Tarabsheh A, Ababneh A. Analysis of solar radiation in Jordan. *Jordan Journal of Mechanical and Industrial Engineering*, 2010; 4(6): 733 – 738.

[16] Hoshberg M. *Jordan’s Energy Future: A Path Forward*. Middle East Institute, 2015.

[17] JREF Jordan’s Renewable Energy Future (2013).

[18] Fu R, Feldman D, Margolis R. US solar PV system cost benchmark. National Renewable Energy Laboratory. Technical Report NREL/TP-6A20-68925, 2017.

[19] Feldman D, Margolis R, James T, Weaver S, Dargouth N, Fu R, Davidson C, Booth S, Wiser R. PV system pricing trends. Sun Shot, US Dept. of Energy NREL/PR-6A20-62558, 2014.