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Feasibility of residential grid connected PV system under the Jordanian net metering renewable energy law

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Abstract

Jordan is very rich in renewable energy resources especially with solar energy, with an average daily peak sun hours of 5.8, on the other hand it is not an oil producing country and imports 96% of the energy used, in this paper the economic feasibility of a 3.0 kWp PV system is analyzed for three residential scenarios with low, medium and high electrical energy demand the payback period for the three scenarios are compared and the effect of the electrical tariff structure is studied, the study showed that the 3rd scenario with the higest consumption resulted with a much lower payback period of 3.42 years.

Introduction

Jordan is a very rich country in renewable resources, especially solar the average peak sun hours are estimated to be around 5.8 hours which is amongst the highest in the world, furthermore the temperatures are not very high which is beneficial for the panels efficiency.

Jordan is a non-oil-producing country and imports 96% of the energy used. As a consequence, energy imports accounts for roughly 22% of the GDP. The population's growth rate is high; about 2.3% per year. This causes the demand on energy sources, mainly oil products to increase rapidly. Implementation of renewable energy resources such as solar energy, will lead to economical, social and environmental benefits [1].

The Jordanian market is currently witnessing a huge increase in photovoltaic energy projects demand and that's due to the increase in electricity bill costs and due to the introduction of the renewable energy law which has included the net metering application [2].

Extensive research has been made in the field of photovoltaic energy projects and the economic feasibility of the renewable energy systems, in a recent paper Yousef El-Tous [3] compared the feasibility study of two identical systems one in Jordan and the other in Italy and took into account the effect of the Italian feed in tariff [4], the study resulted in a clear advantage for the system located in Italy, with an annual income of $ 2445.

Education sector has experience a great interest in photovoltaic project due to the high energy bill, Ma'en Al-Sayed Ahmad et al. [5] proposed a system to provide 50% of the electric energy of the University of Jordan and found the optimal angel to be 30 degrees, Matlab/ Simulink simulation program was used, the system payback period resulted to be 12 years. Issa Etier et al. [6] proposed a project of about 3.5 MW to cover the energy demand of the Hashemite University of Jordan, the research resulted an LCOE of 0.18 $/kWh. Ibrahim M. Al-Adwan [7], studied the performance of the first grid connected residential PV system in Jordan and effects of the system on the voltage levels and power quality.

And in the field of stand-alone PV systems, Marwan M. Mahmoud et al. [8] compared the feasibility of supplying remote villages in Palestine by PV, Diesel generators and conventional grid, and showed that the payback period for supplying the remote villages with PV energy is less compared with diesel and electrical grid expansions.

This paper will present three scenarios with identical PV systems but with different electrical loads the three scenarios will be 510 kWh / Month (scenario 1), 990 kWh / Month (scenario 2) and 1500 kWh / Month (scenario 3). The feasibility study for a 3.0 kW system is then evaluated for each of the three scenarios, and the effect of the electrical tariff structure is analyzed, the different scenarios are simulated using the Hybrid Optimization Model for Electric Renewables (HOMER), the software is used evaluate the energy production of the PV system.

Electrical Bill tariff structure

The Jordanian electric tariff structure is divided into 7 segments as shown in table 1[9].

Table 1: Jordanian electricity bill structure

Electrical consumption [kWh]	Structure [kWh]	Cost [USD/kWh]	structure cost [USD]
1 - 160	160	0.046	7.43
161 - 300	140	0.101	14.19
301 - 500	200	0.121	24.23
501 - 600	100	0.16	16.08
601 - 750	150	0.20	29.75
751 - 1000	250	0.24	60
More than 1000	-	0.33	-

It can be readily seen from table 1 that as the consumption goes up the electricity bill increases exponentially, Table 2 shows the total consumption Vs cost for a supposed consumption equal to each of the segments.

Table 2: consumption Vs cost

Consumption [kWh]	Cost [USD]
160	7.43
300	21.62
500	45.85
600	61.93
750	91.68
1000	151.68

Figure 1 shows the graphical representation of the data given in table 2.

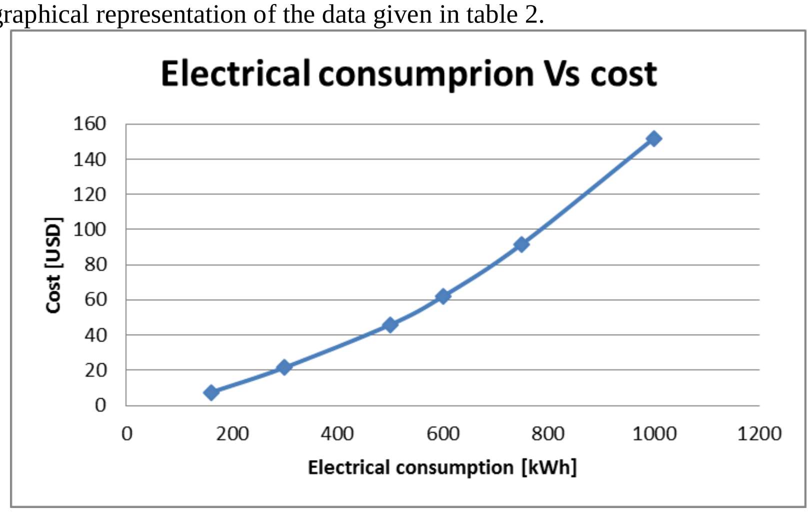


Figure 1: Electrical consumption Vs cost

It is clear from figure 1 that above 1000 kWh consumption the cost per kWh triples and that shows the saving potential of photovoltaic systems for consumers with higher electricity demands.

Solar irradiation

Solar irradiance data for Amman location were obtained from different sources [10, 11 and 12] the data obtained is shown in table 1, the average solar radiation is about 5800 (Wh/m^2. Day), which is a very high value suitable for electrical power generation.

Figure 4 shows the average daily solar radiation incident on one square meter area (Wh/m^2. Day) for the year 2010.

Table 1 The average daily solar radiation incident on one square meter area (Wh/m^2. Day).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
2004	2970	3861	5352	6341	7596	8188	8154	7428	6313	5003	3764	3169	5678
2005	3072	4022	5469	6187	7461	8119	7963	7164	6418	5188	3641	3117	5652
2006	3106	3445	5993	6595	7882	8341	8314	7488	6238	4857	3608	3084	5746
2007	3402	4026	5524	6634	7495	8420	8204	7348	6488	4905	3846	3214	5792
2008	2976	4264	5970	6961	7877	8334	8327	7483	6219	4809	3632	3066	5826
2009	3535	4415	5952	6670	7638	8446	8397	7532	6507	4927	3603	3007	5886
2010	3562	4483	5978	6751	7981	8368	8084	7442	6142	5032	3638	3204	5889

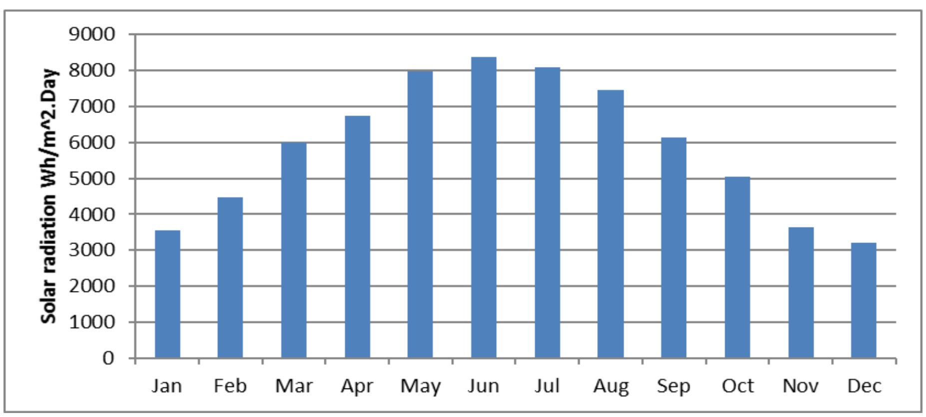


Figure 4: The average daily solar radiation incident on one square meter area (Wh/m^2. Day) for the year 2010

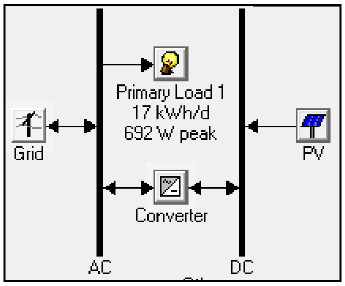
PV system model

This paper will present three scenarios with identical PV systems but with different electrical loads the three scenarios will be 510 kWh / Month (scenario 1), 990 kWh / Month (scenario 2) and 1500 kWh / Month (scenario 3). These three scenario cover the main consumer categories in Jordan low, medium and high demand,The system model was build using HOMER (hybrid optimization model for electric renewables) [], the system components and quantities are identical for the three scenarios the component specifications are shown in table 2.

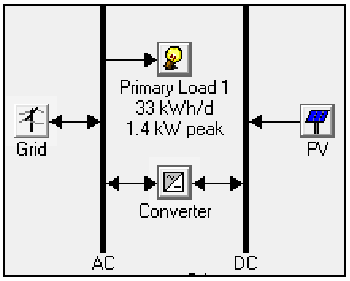
Table 2: PV system component specifications

PV system	
Size [kW]	3.0
Tilt [Degrees]	26
Azimuth [Degrees]	0
Temperature coefficient Of power [%/C^o]	-0.45
Nominal operating cell temperature [C^o]	46
Panel efficiency at STC [%]	15.3
Inverter	
Size [kW]	3.5
Efficiency [%]	97
Total system cost [USD]	6300

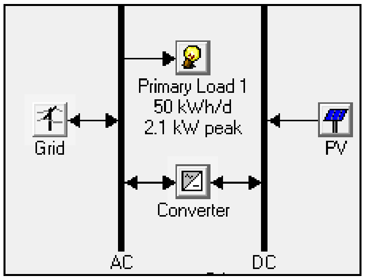
Figure 2 shows the homer layout for the three scenarios, the three PV systems are identical except for the load demand.



Scenario 1



Scenario 2



Scenario 3

Figure 2: PV system scenarios (1, 2, and 3).

Results

The simulation results obtained from the simulation program are shown in table 3

Table 3: PV system simulation results

Quantity	Value	Units
Rated capacity	3.00	kW
Mean output	0.65	kW
Mean output	15.7	kWh/d
Capacity factor	21.8	%
Total production	5,564	kWh/yr

The total annual energy production from the PV system is 5737 kWh which is translated to a monthly value of about 464 kWh which is a very attractive number, the daily output suggest that the average peak sun hours are 5.16 this is less than the mentioned 5.8 due to the inefficiencies due to temperature, dust, clouds, electrical losses, etc.

Figure 3 shows the monthly electrical energy production of the 3.0 kWp system. The data is given in Table 4.

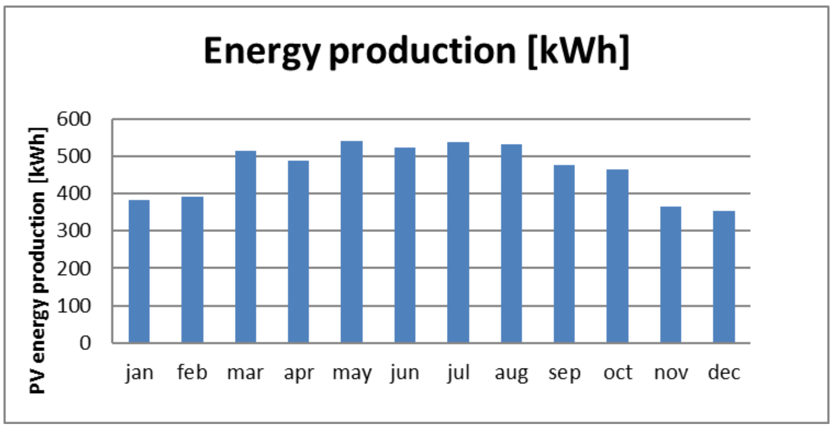


Figure 3: monthly electrical energy production of the 3.0 kWp system

It is clear from figure 3 that the energy production peaks during the summer months and that's due to higher irradiation and longer days.

Table 4: monthly electrical energy production of the 3.0 kWp system

Month	Energy Yield [kWh]
Jan	383
Feb	390
Mar	514
Apr	489
May	540
Jun	523
Jul	536
Aug	532
Sep	477
Oct	464
Nov	364
Dec	352
Annual	5564
Avg. Monthly	464

Table 5 shows the economic feasibility of the three scenarios and the comparisons of the electricity bill before and after the PV system, the electricity bill was calculated according to the electric tariff structure mentioned earlier.

Table 5: Economic analysis of the three scenarios

Consumption before PV [kWh]	Cost before PV [USD]	PV production	Consumption after PV [kWh]	Cost after PV [USD]	Total monthly Saving [USD]	Annual saving [USD]	Payback period [Years]
510	47.5	463	47	2.2	45.3	543.4	11.59
990	148.5	463	527	50.2	98.3	1179.6	5.34
1500	316.3	463	1037	163.1	153.2	1838.9	3.43

It can be readily seen from table 5 that the higher the consumption the greater the savings which is due the exponential increase in the energy costs with the increase of consumption, which directly affects the payback period of the project.

In the case of scenario 3 the payback period is 3.43 which is extremely attractive, it is also noteworthy mentioning that the Jordanian electric energy tariff are in constant increase.

Conclusion

In this paper the economic feasibility of a 3.0 kWp PV system was compared for three load scenarios. The first scenario with a monthly consumption of 510 kWh resulted an annual saving of $ 45.3 and a payback period of 11.59 years which is very high and can be considered not feasible, in Scenario 2 the monthly consumption was 990 kWh, the annual savings resulted to be $ 1179.6 and the payback period 5.34, finally the most attractive case was seen in Scenario 3 with the highest monthly energy consumption of 1500 kWh, the annual savings resulted to be $ 1838.9 and the payback period 3.43.

It is clear that the best payback period is obtained in systems with an energy consumption of more than 1000 kWh, nonetheless a good payback period is obtained for systems with medium consumptions (800 – 1000) kWh.

The payback periods could be greatly improved by providing feed in tariffs and incentives on the PV systems.

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