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Viewpoint

A photovoltaic proposed generation promotion policy—The case of Jordan

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HIGHLIGHTS

- ► Encourage usage of solar and wind resources in Jordan through proper regulations.
- ► Investigate the role of parameters controlling the policy to reach a robust policy.
- ► Design a win–win PV promotion policy for both the consumer and the government.
- ► Recommend implementation of the policy on potential tariff categories.

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ABSTRACT

Jordan has scarce petroleum resources and hence depends to a large extent on imported crude oil, and natural gas to cover its energy needs and to generate electricity in order to cope with the growing demand. The escalating fuel prices associated with the global economic crisis have negative impacts on the economy of Jordan. However, the availability of renewable energy resources (mainly solar, and wind) supported by well-designed and ambitious incentive schemes that runs in parallel with an energy efficiency program, can contribute positively in solving the current problems. This may result in a dramatic reduction in energy bill cost for both short and long terms. Moreover, it shall result in a better and cleaner environment. In this paper an incentive policy is proposed by the Electricity Regulatory Commission (ERC) based on supporting the installation of PV generating units. ERC plays a major role in this effort which aids decision makers to adopt the proper policies in the electricity sector. It is anticipated that the implementation of this proposed policy will result in a win–win situation for both consumers and government, and will lead to increasing the energy security level in general, and electricity security in particular, within Jordan.

1. Introduction

Energy represents a significant factor in the economic development process for any country, including Jordan. The facts that (a) there are a limited fossil resources, (b) there environmental problems which are associated with these resources, and (c) the non-stoppable worldwide effort of searching for sustainable energy supply options lead to the growing use renewable energies. In the context of electricity generation, solar photovoltaic (PV) is potential renewable energy technology. PV modules and concentrating solar power (CSP) systems can generate electricity on a small or large scale.

There are various barriers that stand in the way of promoting renewable energies in general, and PV generation in particular, these include (Beck and Martinot, 2004; Cook and Karelas, 2009; REN21, 2009; Elkarmi and Abu Shikhah, 2012)

a) costs and pricing involving subsidies for competing fuels, high initial capital costs, difficulty of fuel price risk assessment, unfavorable power pricing rules, transaction costs, and environmental externalities,
b) legal and regulatory including lack of legal framework for independent power producers, restrictions on siting and construction (especially for wind), transmission access, utility interconnection requirements, and liability insurance requirements, and
c) market performance which is affected by lack of access to credit, perceived technology performance uncertainty and risk, and lack of technical or commercial skills and information.

In practice, several countries have adopted or are proposing national renewable energy targets, e.g. “Germany has more than doubled its renewable electricity production since 2000 and has already significantly exceeded its minimum target of 12.5% set for

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2010" (Frondel et al., 2009). The Ministry of Energy and Mineral Resources (MEMR) set the renewable target in Jordan to reach 10% by 2020, as compared to less than current 1% ratio (MEMR, 2007).

Actions are required to stimulate market expansion in the direction of renewable energy systems. Such expansion can be achieved by implementing the following measures: (a) reducing relative cost of new renewable technology, (b) making use of the economic efficiencies of the marketplace, (c) devising a pricing mechanism(s) that make renewables more competitive to conventional energy sources (e.g. phasing out subsidies and internalizing externalities). It should be stated, however, that such measures remain controversial as many practical barriers stand in the way of the accelerated development of renewable technologies. Such barriers can be overcome by appropriate frameworks and policies (Aßmann et al., 2006).

The promotion of renewable energy requires raising the choice awareness. This can be achieved through four key strategies (Lund, 2010): (a) description and promotion of concrete alternatives, (b) consideration of the relevant economic objectives of the society in question, (c) proposing concrete public regulation measures, and (d) isolating public decision making from political vacuum.

There are several benefits that can be gained in Jordan due to the promotion of renewable energy, solar and wind. These include (a) achieving the national target share of RE in the overall energy mix in the electricity sector anticipated to be 10% by 2020 (MEMR, 2007), (b) creation of jobs in the field, and hence lowering the unemployment rate, (c) enhancing energy security of supply through implementing distributed generation (DG) over larger areas, (d) reducing global CO_2 emission that leads to rewarding of the international rewarding of the Jordanian government.

It should be also remarked that the Jordanian government can financially support a promotion policy by activating the RE fund (as per RE law), and the initiation of soft loans facilitation, in addition to other means. Moreover, the usage of the abovementioned international rewards in the promotion process shall encourage the investment in the PV and other renewable energy technology.

Investigation focus of this research shall be on economical and cost aspects of the promotion of renewable energy, particularly PV, in Jordan. The rationale being that electrical energy produced by PV has a potential in supporting the morning peak (particularly in summer time). The installation of energy storage will make PV generation supportive to both morning and evening peak periods.

The target of this research is to get an overview of the economical effect of installing PV electricity generating systems supported by an incentive promotional policy to be adopted by the government of Jordan. As such, the proposed policy is based on promoting the installation of PV modules with capacities related to some of the categories defined in the existing tariff scheme. The main objective of the proposed policy is to reduce, or even cancel, the subsidies given to the categories representing the consumers with lower electricity consumption (who get the highest subsidy). The proposition is that the government will install a PV generating unit at consumer premises at no charge; however, the incurred costs are recovered through monthly bills paid by the consumer. The consumer is supposed to fully utilize the energy produced by the PV generating unit for own electricity consumption, and hence reduces electricity consumption from the network. The benefit to the consumer is apparent, however, the benefit to the government comes from lowering or even canceling the subsidy in the electricity tariff. It should be emphasized that if the PV generating unit has storage batteries installed, then this configuration enables storing the energy produced during sun and using this energy during peak load times. Of course this will add extra costs to the PV generating unit due to the installation of energy storage equipment.

In this paper Section 2 defines the consumer categories targeted by the proposed policy. The rationale of the proposed policy and the metrics used for evaluating different alternatives are discussed in Section 3. The proposed methodology is presented in Section 4. In Section 5, the parameters used in the investigation for the base case and the best case scenarios for different categories are defined. Investigation results for different scenarios are demonstrated in Section 6. This is followed in Section 7 by explaining the main outline of the recommended policy. Finally, Section 8 presents the conclusions and recommendations of this paper.

2. Consumers categories

The majority of consumers within Jordan pay a flat rate that varies between different categories. Industrial, large commercial, hotels, and water pumping categories are subject to non-flat tariff. The governmental provides a tariff subsidy for many tariff categories. This subsidy is the difference between the actual fuel costs spent to generate electrical energy (which is about 22.278 ¢/kWh) and the category imposed tariff rate.

The tariff categories covered by the proposed policy include (ERC Tariff Guide, 2012)

A. Residential consumers
   In this paper three residential tariff categories are considered:
   - R1: (0–160 kWh/month),
   - R2: (160–300 kWh/month), and
   - R3: (300–750 kWh/month).

B. Commercial consumers
   The commercial tariff category included is
   - C: (1–2000 kWh/month).

C. Street lighting
   - S: (1–36 kWh per month), where it is assumed that every street lighting post has only one halogen lamp.

Table 1 shows the electricity cost and governmental subsidies (assuming that the estimated average electricity cost is 22.278 ¢/kWh) for all considered categories. The policy is based on the installation of PV generating units with capacities of

- 1.1 kW, 2.055 kW, 5.13 kW for the categories R1, R2, and R3, respectively,
- 13.7 kW for categories C, and
- 0.25 kW for category S.

Table 1
Electricity tariff related costs and subsidies all categories.

Sector	Category	Consumption of kWh per month		Tariff	Cumulative charge	Cumulative subsidy
		From	To	¢*/kWh	($)	($)
Residential	**R1**	1	160	4.653	7.445	28.2
	R2	161	300	10.152	21.658	45.176
	R3	301	500	12.126	45.91	65.48
		501	750	16.074	86.038	80.99
Commercial	**C**	1	2000	12.831	256.62	188.94
Street lighting	**S**	1	50	9.024	4.512	6.627

The values in cumulative charge column of Table 1, were found by multiplying the flat rate tariff of the particular category with the maximum consumption, e.g. for category R1, this value is $160 \times 4.653 = \$7.445$. On the other hand, the values in the Cumulative Subsidy column are found to be the difference of the actual cost of the kWh and the tariff price of the particular category, e.g. for R1 this value is $160 \times (22.278-4.654) = \$\ 28.2$. It should be remarked that the currency in Jordan is the Jordanian Dinars (JD) which comprises 1000 Fils, and the exchange rate is $1=JD 0.709.

3. Policy rationale and metrics

This research aims to investigate alternatives that can be implemented to reduce the governmental support for certain tariff categories. The resulting savings are suggested to be used in the promotion and financing of PV technology installation.

The rationale behind the proposed methodology is based on the following facts:

a. The consumer who agrees to install a PV generating unit that produces an equal amount of his monthly electricity consumption will
   - get a free PV generating unit (i.e. at zero cost), and
   - be charged a percentage of the cumulative charge of his category as in Table 1, e.g. if the charging rate is 50%, then a consumer in category R1 will pay half of $ 7.445, i.e. $ 3.7224.

b. The government benefits come from the following:
   - receive an income that is equal to the consumer paid charges as given in (a) above,
   - reduce its subsidy to a large extent, which may become zero, as consumers will serve themselves in the context of electricity consumption. For example, see Table 1, the governmental savings for a consumer in category R1 will be $ 28.2,
   - reduction of CO_2 emission levels, and be internationally awarded.

The above items (a and b) will lead a win–win situation for both the consumers and the government over the assumed life time (or life span) of the PV generating unit. The benefits attained may be economically computed using the following metrics (Blank and Tarquin, 2005):

1. The net present value (NPV) of the alternative based on a defined discount rate.
2. The internal rate of return (IRR) of the alternative.
3. The payback period (PB).
4. The benefit/cost ratio (BCR) for a specified discount rate.

These metrics are evaluated for different studied scenarios which will help in deciding the best policy that the Jordanian government must follow to (a) achieve an optimum and efficient return on its investment, (b) provide acceptable and practical incentives to electricity energy consumers, and (c) contribute to cleaner environment.

4. Methodology

The methodology proposed in this paper investigates the role of different parameters that affect the incentives policy, in promoting renewable energy. The methodology steps are developed using the parameters related to the implemented tariff scheme shown in Table 1, in addition to the parameters related to the PV generating unit presented in Table 2. The values shown in Table 2 were derived from actual PV operating projects and PV specialized companies in Jordan.

Table 2
Parameters of PV generating unit.

Item	Value
Life time	20 years
Installation cost	$ 2.4675/W
Capacity factor	20%
Bill charge incentive (%)	50%
O&M cost factor	2% of installation cost/year

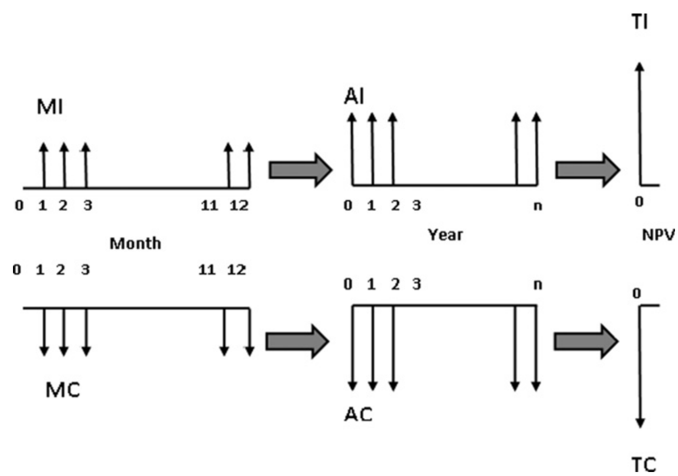

Fig. 1. Cash flows showing the relationship between different income and cost types.

The following steps are implemented using excel spreadsheets for each tariff category of consumers in the Jordanian system. The implantation steps include the computation of the (a) NPV for income and cost components, (b) the IRR, (c) the PB period, and (d) the BCR for each case.

The cash flows needed for the assessment of the abovementioned metrics are discussed in more detail in Appendix A. The cash flow elements used in the following section are those defined in Appendix A. These are IC=installation cost, MI=monthly income, AI=annual income, TI=total income at present time, MC=monthly cost, AC=annual cost, TC=total cost at present time, MS=monthly savings, AS=annual savings, and TI=total savings at present time.

The related cash flow diagrams of income and costs elements are illustrated in Fig. 1. The discount rate used in this research is assumed to be 10%.

Based on these cash flows, the required metrics are assessed as follows:

A. IRR computation
   For each case the IRR is found as the discount rate that causes the overall NPV (i.e. TS) goes to zero.

B. Pay back (BP) period computation
   The payback period is found using the following formula:

$$PB = \frac{IC}{AI - O\,\&\,M\ cost} \quad (3)$$

C. Benefit to cost ratio (BCR) computation
   This is found for each case from the NPV over the life time of the PV generating unit and is given by:

$$BCR = \frac{TI}{TC} \quad (4)$$

5. Investigated scenarios

5.1. Base case scenario

The main economical parameters affecting the results of the feasibility of the proposed policy are implemented for the base cases of all considered categories as per Table 2. The values shown in this table represent the modest values of the parameters considered in the analysis which are used at the present time (year 2012). The base case studies for residential, commercial, and street lighting consumption categories uses the values given in Table 2 to produce the values shown in Table 3 which are used in the investigation.

Table 3
Base case scenario—installed PV generation unit for different categories.

Item	Residential categories			Commercial category	Street lighting category
	R1	R2	R3	C	S
Installed capacity (kW)	1.1	2.055	5.137	13.7	0.25
Energy generated (kWh/month)	160.6	300	750	2000.2	36.5
Installation cost ($)	2714.25	5070.36	12,675.55	33,804.75	616.45
Annual O&M cost ($/year)	54.29	101.38	253.51	676.1	12.34
Consumer—bill charge ($)	3.72	10.83	43.05	128.31	2.93
Government—subsidy savings ($)	28.2	45.18	81.0	188.94	5.29

5.2. Best case scenario

This case represents the change of the PV generating unit parameters in accordance to Table 4, while keeping the categories definition as in Table 1. It represents an optimistic view based on the anticipated future trends in PV technology in the local Jordanian market.

Table 4 is used to compute the values presented in Table 5 that are used in the assessment of the best case studies for residential, commercial, and street lighting consumption categories.

Table 4
Best case scenario values of factors related to PV generating unit.

Item	Value
Life time	25 years
Installation cost	1.41 $/W
Capacity factor	20%
Bill charge incentive (%)	70%
O&M cost factor	1% of installation cost/year

6. Implementation and results

6.1. Base case scenario

6.1.1. Residential categories

For the assumptions shown in Tables 1 and 2, and taking various discount rates, for different categories, the results for applying the proposed methodology are illustrated in Table 6.

This table shows that as the discount rate increases then the NPV decreases. This is logical as the government will pay more interest to the investors (i.e. banks). The IRR decreases as governmental subsidy reduces with a value of about 4.86% for category R1. This suggests that the government must try to push on the banks to reduce discount rate to contribute in RE promotion campaign, including the PV generation.

Table 6 highlights the metrics for the 7% discount rate mark for categories R1, R2, and R3. It can be seen that for category R1 consumers, the government will be able to recover its expenses within 9 years and makes a NPV profit of $ 798.06, and the associated BCR is about 1.24. On the other hand, the NPV for category R2 is $ 1020.84, with a payback period of 9.3 years and BCR of 1.16. Category R3 will provide a NPV profit of about

Table 5
Best case scenario—installed PV generation unit for different categories.

Item	Residential categories			Commercial category	Street lighting category
	R1	R2	R3	C	S
Installed capacity (kW)	1.1	2.055	5.137	13.7	0.25
Energy generated (kWh/month)	160.6	300	750	2000.2	36.5
Installation cost ($)	1551	2897.55	7243.17	19,317	352.5
Annual O&M cost ($/Year)	15.51	28.98	72.43	193.17	3.53
Consumer—bill charge ($)	5.21	15.16	60.27	179.63	3.16
Government—subsidy savings ($)	28.2	45.18	80.99	188.94	6.63

Table 6
Base case scenario-metrics for *residential* categories at different discount rates.

Category	6.5%			7%			7.25%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
R1	4281.61	3342.55	939.6	4117.42	3320.13	797.36	4038.95	3309.27	729.68	
R2	7511.78	6244.61	1267.17	7223.71	6202.59	1021.12	7085.96	6182.43	903.53	
R3	16,636.59	15,609.83	1026.76	15,998.71	15,504.78	493.92	15,693.58	15,454.59	239.00	
	NPV ($)	BCR	PB (years)	NPV ($)	BCR (%)	PB (years)	NPV ($)	BCR (%)	PB (years)	
R1	**939.06**	**1.28**	**8.6**	797.36	1.24	8.63	729.68	1.22	8.64	**10.5**
R2	**1267.17**	**1.2**	**9.26**	1021.12	1.16	9.29	903.53	1.15	9.3	**9.5**
R3	**1026.76**	**1.066**	**10.71**	493.92	1.03	10.74	239.00	1.015	10.76	**7.5**

$838.95, however, its payback period is about 10.3 years with BCR of about 1.07. It is clear that the BCR values for categories R1 and R2 are economically more attractive than category R3. This can be justified based on the fact that more investment is needed for category R3, while the government subsidy for this category is less than that offered to the other two categories.

It can be concluded that all the first two categories, from an economical point of view, are marginally attractive, while category R3 is not. This implies that the PV generation promotion may face financing barriers, as financial institutions may not be interested in investing at such discount rates.

6.1.2. Commercial categories

Table 7 shows the estimation of the metrics for different discount rates, and the IRR for each category.

It is clear that given the current prices level of electricity and of the PV generating units, these categories are not economically attractive from an investment point of view.

6.1.3. Street lighting category

Table 8 shows the estimation of the metrics for different discount rates. The IRR for this category is estimated to be 14.23% which makes it attractive from an economical point of view. This means that the government has the motivation to start promoting PV technology to this category immediately.

The highlighted area in Table 8 for the 11% discount rate case shows that the NPV is about $ 138, and the associated BCR is 1.19 while the payback period is estimated to be 7 years.

6.2. Best case scenario

6.2.1. Residential

The parameters of Table 5 were considered for the residential categories R1, R2, and R3. The results obtained for these categories for different discount rates are presented in Table 9.

Table 9 shows that for category R1, the IRR is about 24.7%. This suggests that the government must try to push on the banks in its RE promotion campaign, including the PV generation. On the other hand, results assessed for category R2 and category R3 demonstrate that the IRR values for category R2 and category R3 are 23.8% and 22.2%, respectively. The metrics estimation for the 20% discount rate mark is highlighted in Table 9, and show that the payback period for different categories is about 5 years. This shall give the government a larger negotiation margin with financial institutes in the context of discount rate reduction.

6.2.2. Commercial

Similarly, the parameters of Table 5 were considered for the commercial category C. Results obtained for these categories for different discount rates are presented in Table 10. It can be seen that the IRR value for this category is above 21%. The payback period is about 5 years for these categories. Table 10 shows the

Table 7
Base case scenario-metrics for *commercial* categories at different discount rates.

Category	5%			6%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
C	48,071.41	42,574.81	5496.60	44,282.04	41,926.77	2355.26	
	NPV ($)	**BCR**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	
C	**5496.60**	**1.13**	**11.16**	2355.26	1.06	11.23	**6.8**

Table 8
Base case scenario-metrics for *street lighting* category at different discount rates.

Category	11%			12%			13%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
S	860.66	722.48	138.18	806.80	716.42	90.38	758.16	710.92	47.24	
	NPV ($)	**BCR**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	
S	**138.18**	**1.19**	**7**	90.38	1.13	7.04	47.24	1.07	7.08	**14.2**

Table 9
Best case scenario-metrics for *residential* categories at different discount rates.

Category	20%			21%			22%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
R1	1990.64	1636.59	354.05	1898.71	3184.06	265.64	1814.67	1629.82	184.85	
R2	3594.80	3057.44	537.35	3428.84	3050.82	378.02	3276.98	3044.90	232.09	
R3	8415.87	7642.91	772.96	8027.55	7626.41	401.15	7671.81	7611.32	60.49	
	NPV ($)	**BCR**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	
R1	**354.05**	**1.22**	**4.5**	265.64	1.16	4.52	184.85	1.11	4.54	**24.7**
R2	**537.35**	**1.18**	**4.66**	378.02	1.12	4.68	232.09	1.08	4.71	**23.8**
R3	**772.96**	**1.10**	**4.99**	401.15	1.05	5.01	60.49	1.01	5.04	**22.2**

Table 10
Best case scenario-metrics for *commercial* categories at different discount rates.

Category	18%			19%			20%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
C	24,289.37	20,484.06	3805.31	23,069.29	20,431.18	2638.11	21,959.2	20,383.1	1576.1	
	NPV ($)	**BCR**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	
C	**3805.31**	**1.19**	**5.05**	**2638.11**	**1.13**	**5.08**	**1576.1**	**1.08**	**5.1**	**21.7**

Table 11
Best case scenario-metrics for *street lighting* category at different discount rates.

Category	28%			30%			32%			IRR (%)
	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	TI ($)	TC ($)	TS ($)	
S	418.91	367.02	51.89	391.13	366.18	24.96	366.88	365.47	1.41	
	NPV ($)	**BCR**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	**NPV ($)**	**BCR (%)**	**PB (years)**	
S	**51.89**	**1.14**	**3.6**	24.96	1.07	3. 64	1.41	1.00	3.68	**32.1**

Table 12
Computed IRR vs. life time variations.

Sector	Category	Life time [years]—base case scenario					Life time [years]—best case scenario				
		20	22	25	28	30	20	22	25	28	30
Residential	**R1**	10.5	10.9	11.3	11.5	11.6	24.5	24.6	24.7	24.7	24.7
	R2	9.5	9.9	10.3	10.6	10.7	23.6	23.7	23.8	23.8	23.8
	R3	7.5	8.0	8.5	8.8	9.0	22.0	22.1	22.2	22.23	22.25
Commercial	**C**	6.8	7.4	7.9	8.3	8.4	21.5	21.6	21.7	21.72	21.74
Street lighting	**S**	14.2	14.5	14.7	14.9	14.94	32.07	32.1	32.12	32.125	32.13

estimation of the metrics for the 18–20% discount rates for category C.

Once again, the results of Table 10 indicate that category C is economically attractive, and hence more negotiation power is given to the government, as indicated earlier.

6.2.3. Street lighting category

The parameters of Table 5 were considered for the street lighting category S. Results are shown in Table 11. It can be seen that the anticipated IIR is very attractive and it exceeds the 30% mark. This means that the government is able to promote PV technology for this category without hesitation.

Note that if the 28% discount rate is considered, the NPV is about $ 51.9, and the associated BCR is 1.14 while the payback period is estimated to be 3.6 years.

6.3. Effect of parameters variations

In this section, the effect of varying one of the parameters of Table 2 or 4 while fixing the values of other parameters is investigated for both the ‘Base case’ and ‘Best case’ scenarios. This will illustrate the effect of individual parameters on the promotion policy, and is considered as a sort of sensitivity analysis. The used metric will be the IRR as it provides an indication of the return on the investment and is widely accepted. The parameters covered are (a) life time of the PV generating unit (in years), (b) installation cost of the PV generating unit (in $), (c) capacity factor (in percentage), (d) average electricity cost (in $), (e) bill charge incentive (in percentage), and (f) O&M cost factor (in percentage). Results of the investigation are discussed in the following.

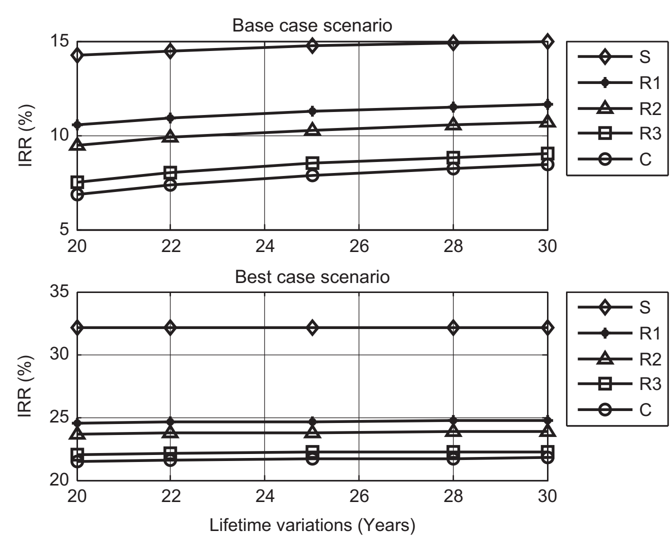

Fig. 2. Effect of PV lifetime (years) variations on IRR for different categories.

6.3.1. PV generating unit life time variations

The life time of the PV generating unit is assumed to vary between 20 and 30 years, and the effect on IRR is computed by fixing the other parameters of the base case and the best case scenarios. Table 12 shows the obtained results for selected life times, and Fig. 2 displays these results graphically.

These results indicate that the life time has minor effect on IRR for both scenarios leading to the conclusion that for any given category, IRR changes slightly when the estimated life time varies between 20 and 30 years. These lifetimes are viewed to be practical for different renewable energy technologies including the PV technology.

6.3.2. PV generating installation cost variations

The effect of the PV installation cost variations on IRR was investigated by assuming that such variations occur in the range between $ 1.06/W and $ 3.53/W of the installed capacity. Table 13 presents the results obtained for the base and best case scenarios scenario. Fig. 3 displays these results.

It is evident from Table 13 and Fig. 3 that as the installation cost goes down then the categories become more economically attractive (the IRR increases), and vice versa. The **$2.12**/W price (encircled in the figure, and highlighted in the table) is a good starting point for the promotion policy of PV generation that is applicable for all categories and for the base case and Best case scenarios.

6.3.3. PV generating unit capacity factor variations

The capacity factor effect is not included in the assessment due to the initial assumption set requiring that the installed PV generation must serve the category electricity requirement. So, the reduction of the factor means that more units are needed to be installed. On the other hand, the increase in this factor will benefit the consumer, as he shall have excess generation and hence representing free extra energy. The IRR for either case will not change based on the initial assumption set for the category based on base case or best case scenarios.

6.3.4. Average electricity cost variations

The effect of variations of the average electricity cost was investigated. It is assumed that the variations will cover the range −10% to +30%, for the base case and best case scenario. Results are presented in Table 14, and displayed in Fig. 4.

It is important to note that, for the base case scenario, if the average electricity cost goes up by 20% or more, then the PV technology becomes more feasible to implement and promote for all categories. On the other hand, given the best case scenario the current prices are in favor of encouraging promotion of the PV generation.

When the above results are further processed using linear regression, and the optimum linear fit for each category between IRR and P (the percentage of price change) is displayed in Table 15. P will range between −10 and +30 for the base case and the best case scenarios.

It is obvious, from Fig. 4, and Table 15, that the slope for all categories (except for category S) is almost equal. This means that the effect on IRR is the same for these categories. However, category S demonstrates a larger slope indicating that this category is more sensitive to price variations compared to other categories.

The relatively accepted IRR current values for category S, suggest that the government may wish to adopt the immediate installation of PV technology to this category.

6.3.5. Bill charge incentive variations

Here, the effect of the bill charge incentive is investigated. It is assumed that the variations will range between 40% and 80%. Results are shown in Table 16, and are displayed in Fig. 5.

It is evident that category S is economically attractive for all investigated values of the bill charge incentive variations. This is true for the base case and best case scenarios. On the other hand, category R1 is marginally attractive for the base case scenario. It can be concluded that all the categories will become economically attractive at the 40% mark (encircled in the figure) and over.

6.3.6. O&M cost factor variations

The annual O&M cost factor is assumed to vary between 0.5% and 4% of the PV generation installation cost. Results are demonstrated in Table 17 and Fig. 6.

It can be noted from these results that the increase of O&M cost will contribute in reducing the attractiveness of the PV technology at current installation prices. To promote PV technology, the current O&M costs must not exceed the 1% mark. However, as the PV technology installation prices goes down then O&M cost will reduce. This will serve in increasing the attractiveness for all categories, even at the 4% O&M cost level.

It is also noted that PV promotion can be applied at the present time to categories S, R1, and R2 as their IRR is around 10%.

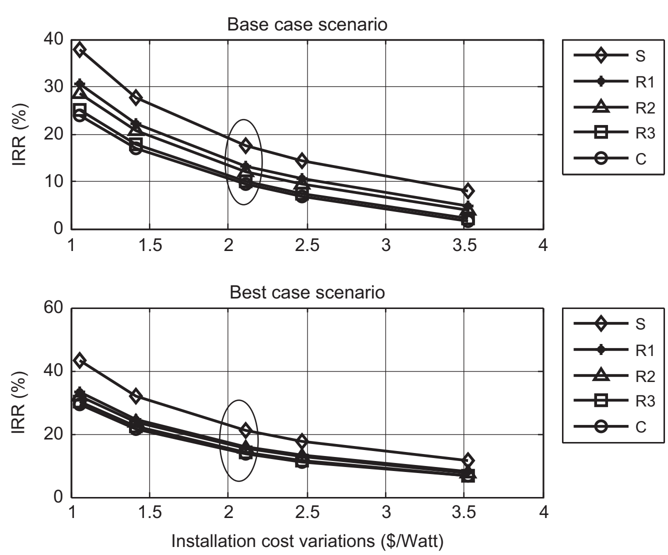

Fig. 3. Effect of PV installation cost variations on IRR for different categories.

Table 13
Computed IRR vs. installation cost variations.

Sector	Category	Installation cost [$/W]—base case scenario					Installation cost [$/W]—best case scenario				
		1.06	1.41	2.12	2.47	3.53	1.06	1.41	2.12	2.47	3.53
Residential	**R1**	30.5	22.2	**13.3**	10.5	4.9	33.3	24.7	**15.8**	13.2	8.0
	R2	28.5	20.6	**12.1**	9.5	3.9	32.1	23.8	**15.2**	12.6	7.6
	R3	24.9	17.8	**10.0**	7.5	2.2	30.0	22.2	**14.1**	11.6	6.8
Commercial	**C**	23.8	16.9	**9.3**	6.8	1.6	29.3	21.7	**13.7**	11.3	6.5
Street lighting	**S**	37.9	27.8	**17.4**	14.2	8.0	43.2	32.1	**21.0**	17.7	11.6

Table 14
Computed IRR vs. price variations for *Base case* and *Best case* scenarios.

Sector	Category	Average cost change [from 22.278 ¢/kWh]—base case					Average cost change [from 22.278 ¢/kWh]—best case				
		−10%	0%	10%	20%	30%	−10%	0%	10%	20%	30%
Residential	**R1**	8.5	10.5	12.4	14.2	16	21.9	24.7	27.4	30.2	32.9
	R2	7.4	9.5	11.4	13.3	15.0	21.0	23.8	26.6	29.3	32.1
	R3	5.3	7.5	9.5	11.5	13.3	19.0	22.2	25.0	27.8	30.5
Commercial	**C**	4.6	6.8	8.9	10.9	12.8	18.9	21.7	24.5	27.3	30.0
Street lighting	**S**	11.7	14.2	16.6	19.0	21.2	28.3	32.1	35.9	39.7	43.4

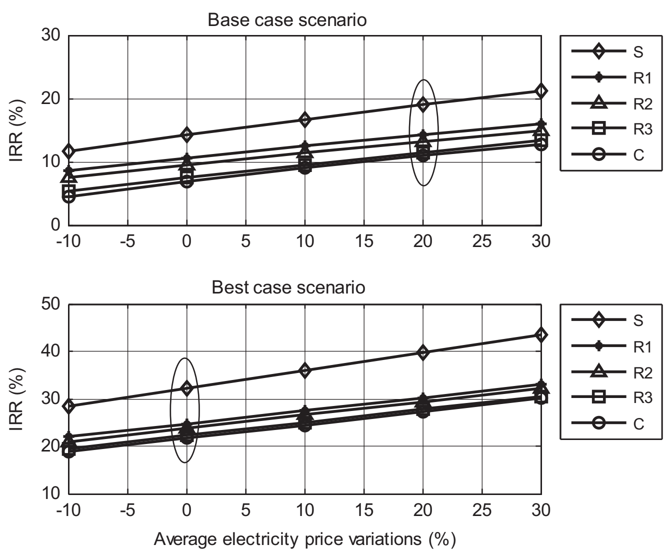

Fig. 4. Effect of PV installation cost variations on IRR for different categories.

Table 15
IRR linear regression equations for different categories.

	Base case	Best case
R1	0.187 P+10.45	0.275 P+24.67
R2	0.19 P+9.42	0.27 P+23.79
R3	0.201 P+7.42	0.279 P+22.18
C	0.205 P+6.75	0.279 P+21.66
S	0.24 P+14.18	0.378 P+32.113

7. Recommended policy

In this section, the main guidelines for the proposed policy, to be implemented at the present time, are presented based on the results obtained in this research. These are

a. start the PV installation with category S, street lighting,
b. assign the penetration rate for each category in the overall PV generation planning. Studies must be conducted by ERC and MEMR to assess the market and lead to the estimation of relevant penetration rate for each category,
c. as PV technology installation prices declines below $ 2.47 per W installed, then promote PV generation to category R1 first and then to category R2,
d. further decline of the PV technology installation below $1.76 per watt installed level will encourage the promotion to categories R3 and C,
e. if the average electricity cost increases by 20% of the assumed 22.278 ¢/kWh, then promote PV to categories R1 and R2,
f. further increase of average electricity cost of 30% or more (i.e. around 29 ¢/kWh) will encourage promoting PV technology to the remaining categories,
g. a 50% bill charge incentive can be currently adopted for category S. However, the promotion of this incentive for other categories is applicable when the PV installation costs decline below $ 2.12 per W installed. At that price level a 40% bill incentive can be adopted.

It should be mentioned that the inclusion of storage batteries option was not considered in this research. This will serve in adding extra costs on the PV installation cost; however, it can lead to feeding the grid with electricity at peak times, and will enable consumers to use their extra energy at other times (e.g. peak consumption times). This is expected to have minor negative effect on the proposed policy, however, it requires more investigation. Finally, it is highly recommended that the promotion policy, once implemented, must be monitored and reviewed and updated whenever a need arise.

8. Conclusions

There is a negative impact of escalating fuel prices on the economy of Jordan, and on its energy and electricity security. The fact that there are abundant solar, and wind resources can serve in overcoming such situation. The harnessing of such resources must be supported by a robust and ambitious incentive schemes which runs in parallel with an up-to-date energy efficiency program. This will surely contribute in a positive way to solve the current problems of the electricity sector. In this research the solar energy was the focus. As such, the role of the installation of PV generating units to enhance the Jordanian power system in terms of security and economy was investigated. It can be stated with confidence that there is a need to start the implementation of renewable based generation, in general, and PV generation in particular, as soon as possible. However, this must be accompanied with well defined and publicized policies that will promote this movement. In this paper, incentives policy to promote PV technology in Jordan was proposed and investigated taking into account different controlling parameters. Some of these parameters are related to the implemented tariff scheme, while other parameters are related to the PV technology. The main idea was based on the installation of the suitable size of PV generating units for each tariff category at the expense of the government. According to this proposed policy, the consumer shall pay 50–70% of the maximum cumulative charge of his tariff category, see Table 1. This will lead to a win–win situation, where the government wipes out its subsidies to those covered categories, and gets the benefits of charging the consumer as mentioned above. Meanwhile, the consumer will locally generate the majority or all of his own electricity needs, and have the privilege of paying a percentage of incurred bill amount.

Table 16
Computed IRR vs. Bill charge variations for *Base* case and *Best case scenarios*.

Sector	Category	Bill charge incentive (%)—base case scenario					Bill charge incentive (%)—best case scenario				
		40	50	60	70	80	40	50	60	70	80
Residential	**R1**	10.1	10.5	10.9	11.3	11.7	22.9	23.5	24.1	24.7	25.2
	R2	8.8	9.5	10.1	10.7	11.3	21.1	22.0	22.9	23.8	24.7
	R3	6.4	7.5	8.6	9.6	10.6	17.8	19.3	20.7	22.2	23.6
Commercial	**C**	5.6	6.8	8.1	9.24	10.4	16.8	18.4	20.1	21.7	23.3
Street lighting	**S**	13.2	14.2	15.2	16.2	17.1	27.5	29.1	30.6	32.1	33.7

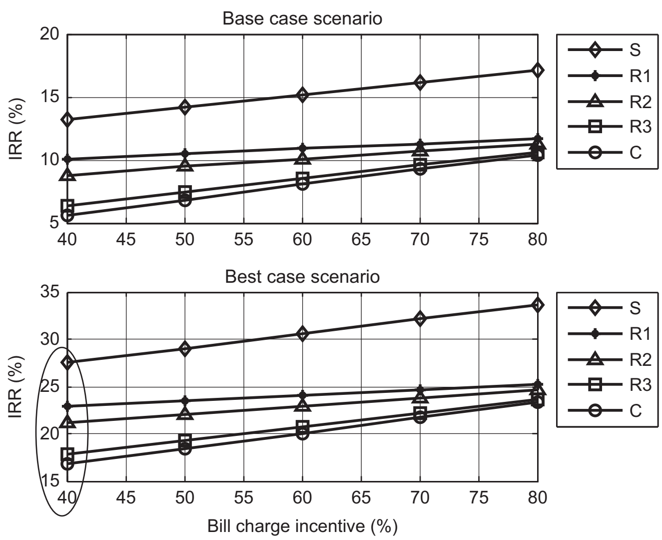

Fig. 5. Effect of bill charge variations on IRR for different categories.

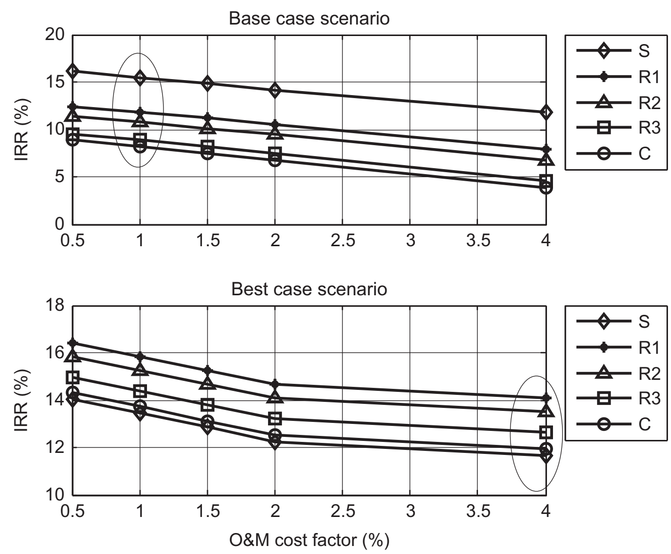

Fig. 6. Effect of O&M cost variations on IRR for different categories.

Table 17
Computed IRR vs. O&M cost factor variations for *Base case* and *Best case* scenarios.

Sector	Category	O&M Cost factor (%)—base case scenario					O&M Cost factor (%)—best case scenario				
		0.5	1	1.5	2	4	0.5	1	1.5	2	4
Residential	**R1**	12.4	11.8	11.2	10.5	7.9	25.2	24.7	24.1	23.5	21.3
	R2	11.4	10.8	10.1	9.5	6.7	24.4	23.8	23.2	22.7	20.4
	R3	9.5	8.9	8.2	7.5	4.6	22.8	22.2	21.6	21.1	18.8
Commercial	**C**	8.9	8.2	7.5	6.8	3.9	22.2	21.7	21.1	20.5	18.3
Street lighting	**S**	16.1	15.4	14.8	14.2	11.8	32.7	32.1	31.5	31.0	28.6

In general, the following conclusions and recommendations can be reached:

a. Both electricity consumers and the government of Jordan will benefit from adopting an incentive policy that was proposed in this paper.
b. The incentives policy can be applied on some of the categories and not all of them. However, further studies including the penetration rate studies, are important.
c. As the prices of the technology of PV generating units go down, they become more economically attractive, and the motive for promoting them increases. This also applies to other RE sources.
d. The effect of lifespan variations of the PV generating unit is negligible on the IRR, and hence on the promotion policy.
   Street lighting is presently the most economically attractive option. Hence, the government may set a PV promotion program to starts with this category.

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Appendix-A

A.1. NPV computation

This will represent the value of money in $ projected at current time, i.e. year 0. The NPV of the income and the cost components computation is done as follows.

A.2. Income assessment

The following steps are implemented:

i. Compute the monthly PV generating unit installation percentage incentives, called (A1).
ii. Compute the monthly subsidy savings, called (A2).
iii. Find the total monthly income, called (MI=A1+A2). These will occur every month over the life time of the PV generating unit and find the monthly based present worth of the annuity factor (F1) (see Appendix-B) using

$$\mathrm{F1} = \left[\frac{(1+i/12)^{12n} - 1}{(i/12)(1+i/12)^{12n}} \right] \tag{1}$$

where, *I* is the annual discount rate, typically 10% in Jordan; *n* is the life time of PV generating unit in years

iv. Find estimated annual income, called (AI=MI × F1).
v. Find the yearly based present worth of the annuity factor (F2) using

$$F2=\left[\frac{(1+i)^n-1}{i(1+i)^n}\right] \quad (2)$$

vi. Compute the NPV of the total income over the whole life time, called (TI=AI × F2).

Selected values for F1 and F2 at different annual discount rates and different life times of the PV project are shown in Appendix A1.

A.3. Expenses assessment

The steps for computing different types of expenses are done according to the following steps:

i. The installation cost in $, called (IC), is found based on the assumed value of the installed capacity.
ii. Compute the total equivalent O&M costs, called (B2=O&M cost × F1/F2).
iii. Find total costs over the life time of the PV generating unit, called (TC=IC+B2).
iv. Find the monthly cost, called (MC=TC/F1).
v. Find annual cost, called (AC=MC × F2).

A.4. Savings assessment

These are found for

i. monthly savings: MS=MI−MC,
ii. annual savings: AS=AI−AC,
iii. NPV-total savings: TS=TI−TC.

Appendix-B

Selected values for the factors F1 and F2 computed based on Eqs. (1) and (2) at different discount rates and for different life times of the PV project. See Appendix Table B1.

Table B1

Discount rate (%)	F1	Life time is 20 years F2	Life time is 25 years F2
1	11.935	217.441	265.342
2	11.871	197.674	235.93
3	11.807	180.311	210.877
4	11.744	165.022	189.453
5	11.681	151.525	171.06
6	11.619	139.581	155.207
7	11.557	128.983	141.487
8	11.496	119.554	129.655
9	11.435	111.145	119.162
10	11.375	103.625	110.047
11	11.315	96.882	102.029
12	11.255	90.819	94.945
13	11.196	85.355	88.665
14	11.137	80.42	83.073

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