Financial and Economic Analysis of 75 MW Photovoltaic Project for Jordan

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Abstract: Jordan has a good natural potential for solar energy source. To reach at economic practicability of solar energy sources, Jordan needs to accelerate the development of the national photovoltaic projects. The economic and financial analysis of the 75 MW Photovoltaic Project for Jordan is presented in this paper. Comparing analysis considers, seven different scenarios regarding the type of the modules and of the mounting system as well as three different cases to further evaluate the effects of land requirements based on an equivalent installed capacity. Based on the analyzed scenarios, it was found that the project will serve as a “fuel saver”, as the energy generated at the Jordan Photovoltaic Project replaces energy generated at the thermal plant with the highest variable costs in the grid. This replacement has it, which avoids the CO₂ emissions associated with thermal generation, as the further advantage.

Key words: Economic analysis, financial analysis, photovoltaic, CO₂ emissions.

1. Introduction

The economic and financial analysis of the 75 MW Photovoltaic Project for Jordan serves to answer two key questions: Is the project profitable for the investor? And is the project beneficial for the economy of Jordan? Financial and economic analyses use a similar approach to answer these questions. Both analyses have in common that they compare the benefits of the project to its costs and assess the project over its entire lifecycle based on the discounting technique. However, financial and economic analyses differ in their concepts of determining project costs and benefits. While the financial analysis deals only with the costs and benefits incurred by the investor, the economic analysis also includes indirect costs and benefits which are caused by the project but incurred, or enjoyed, by three parties. The direct benefit of the 75 MW Photovoltaic Project in Jordan is the energy provided by the project. From the investor's point of view, as reflected in the financial analysis, the value of this

benefit is equal to the revenues of that from the sales of energy. From the economy's point of view, as reflected in the economic analysis, this benefit is equal to the cost alternative project which would be avoided (producing the same output), if the photovoltaic power plant is implemented. Therefore, the standard approach to the economic analysis of photovoltaic projects is to assume that the value of solar generation is equivalent to the avoided cost of alternative thermal generation. The economic analysis should consider the true costs and benefits of the project to the economy. Market prices, as used in the financial analysis, do not always reflect the true economic costs.

Jordan is a net importer of energy, importing 96% of its total energy consumption according to government statistics. Over 80% of energy is imported via the AGP (Arab Gas Pipeline), which transports natural gas from Egypt to Jordan, also Jordan is subject to market and political factors, making solar energy an attractive option [1]. Like most countries in the world, Jordan has seen a steady increase in its energy demand (6%-8%) since 1998, in addition to keeping up with the increased energy demand, Jordan faced the challenge of reducing

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its dependence on foreign energy supply [2-4]. Solar energy as one of the most important sources of renewable energy, obtains increasing attention in Jordan. Jordan is considered one of the sun-belt countries where the average annual solar radiation per day is 3.8 kWh/m² in winter and more than 8 kWh/m² in summer. In addition, the average sunshine duration is more than 300 days per year, and the yearly global solar radiation ranges from 1,700 kWh/m² in Jordan valley and over 2,250 kWh/m² for hill area [5-7]. Researchers in renewable energies have developed many ways for the financial and economic analysis in many electrical power systems worldwide like Korea, Germany and USA, Ref. [8] presents performance of a photovoltaic power generation project and an economic analysis of the project in Korea with 20 MW, validated the suggested Korea model methodology of economic analysis of a project by analyzing the performance and economic efficiency of this power generation project. The economic analysis by suggested methodology is considered to have sufficient validity, and is expected to be used in model development of photovoltaic power generation project site selection and methodology development. Ref. [9] has studied a large scale PV (photovoltaic) system installed in the Main Stadium in Taiwan, the financial analysis according to the hourly solar irradiation and temperature provided by the weather bureau. The cash flow of annual power generation, the O & M (operating and maintenance) cost and the capital investment cost of the PV system is then used to derive the payback years and the internal rate of return for the PV system under different selling price of PV power generation. Ref. [10] compares PV power stations economic analysis between Germany and the United States to examine which country more efficiently provides renewable energy in their usages. For the comparative analysis, this study utilizes DEA (data envelopment analysis) as a methodology to evaluate the performance of PV power stations from the perspective of both solar and land usages. Ref. [11] presents economic analysis

of a 1.2 MW capacity grid-connected PV power plant installed at the Colorado State University-Pueblo. Array efficiency is used to measure the performance of the PV system and predict the amount of energy generation and resulting cash flows. It is identified that the cost of the PV system, financial assistance program, and energy pricing are crucial for the economic viability of PV project in addition to a favorable climatic condition. Ref. [12] represents economic analysis of large scale photovoltaic power plant in Thailand based on CO₂ emission reduction. Also there are many researchers present methods the financial and economic analysis by sizing photovoltaic systems indicates that they fall into mainly two categories, analytical methods and simulation-based schemes. In one of the study, a generalized methodology based on a time series simulation approach for generating a “sizing curve” relating the generator rating and storage capacity is presented [13]. The authors in Ref. [14] quantified energy losses and the most relevant performance parameters of a 2 kW, grid connected photovoltaic system in Spain. The different economic and financial aspects have also been calculated for different financial scenarios and concluded that the use of solar-energy supply systems implies no compromise for the tourists in terms of comfort, reliability of operation and facilities compared with conventional lodging and renewable systems are mature technologies and provide alternative solutions to the increasing global energy demand problem [15]. Also many studies paper financial and economic analysis made based on the type of PV modules. The authors in Ref. [16] present a cost comparison between a-Si (amorphous silicon) and CdTe (cadmium telluride) technology for a stand-alone photovoltaic system by applying LCC (life-cycle costing) method of analysis in Malaysia.

2. Project Costs and Benefits

2.1 Technical Assumptions

The following analysis of the 75 MW Jordan Photovoltaic Project considers seven different

scenarios as shown in Table 1 regarding the type of the modules and of the mounting system as well as three different cases to further evaluate the effects of land requirements based on an equivalent installed capacity:

- For the first case, the same ground area of approximately 1,100 km² was used as the available area for each mounting alternative. From this area, the maximum PV nominal power allowed for each technology and mounting system was determined. Furthermore, no land costs were taken into consideration;
- The second case considers a constant installed capacity in MWp for all seven mounting alternatives, which in turn results in different ground area requirements. This has been evaluated without the effect of land related costs;
- The third case also takes into account a constant installed capacity in MWp for all seven mounting alternatives, which in turn results in different ground area requirements. However, in this case, the effect of land related costs has been included. The construction period of the photovoltaic power plant will be 8 months and afterwards it will be operated for 20 years. Due to daily and seasonal fluctuations of the solar energy

availability, the photovoltaic power plant cannot provide capacity with a certain degree of reliability (“firm capacity”).

2.2 Project Benefit-Energy Output

The analyzed Photovoltaic Project in Jordan is capable of generating energy up to 187.2 GWh per year. The annual energy production of the Jordan Photovoltaic Project in a P50 (Peak power 50 MW) case is estimated as shown in Table 2. The P50 values will form the basis for the calculation in the base scenario. With uncertainties of 10%, the annual energy production for the probability cases P75, P90 and P95 has been calculated as shown in Table 3.

2.3 Financial Project Costs

The construction costs of the Jordan Photovoltaic Project include project development costs, EPC (engineering, procurement and construction) (energy performance certificate) costs, i.e., PV modules, inverters, mounting structures, electrical equipment, as well as physical contingencies and price contingencies. Furthermore, costs related to the substation and to the grid connection which are in the scope of NEPCO

Table 1 Plant data of the Jordan Photovoltaic Project.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Technology selection	Mono-Si	Poly-Si	a-Si	CIGS (copper indium gallium selenide)	CdTe	Mono-Si	Mono-Si
Mounting system	Fixed	Fixed	Fixed	Fixed	Fixed	1-axis	2-axis
Constant ground area							
Installed capacity (MWp)	82.080	80.154	39.874	74.637	72.900	82.080	24.076
Area requirement (m ²)	1,092,200	1,092,200	1,092,200	1,092,200	1,092,200	1,092,200	1,092,200
Constant installed capacity							
Installed capacity (MWp)	82.080	82.080	82.080	82.080	82.080	82.080	82.080
Area requirement (m ²)	1,092,200	1,116,288	2,248,992	1,198,368	1,231,200	1,092,200	3,726,432

Table 2 Annual energy production.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Constant ground area							
Annual energy production (MWh/year)	162,031	153,829	84,358	148,358	150,356	187,190	55,148
Constant installed capacity							
Annual energy production (MWh/year)	162,031	157,173	174,522	162,738	169,536	187,190	41,450

Table 3 Probability scenario.

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Uncertainties	(%)	10	10	10	10	10	10	10
Constant ground area								
Annual energy production P75	(MWh/year)	151,102	143,453	79,010	138,351	140,215	174,564	51,428
Annual energy production P90	(MWh/year)	141,266	134,115	73,867	129,345	131,087	163,201	48,080
Annual energy production P95	(MWh/year)	135,379	128,526	70,789	123,955	125,625	156,400	46,077
Constant installed capacity								
Annual energy production P75	(MWh/year)	151,102	146,572	162,751	151,761	158,101	174,564	38,654
Annual energy production P90	(MWh/year)	141,266	137,030	152,156	141,882	147,809	163,201	36,138
Annual energy production P95	(MWh/year)	135,379	131,320	145,816	135,970	141,650	156,400	34,632

(National Electrical Power Company) have been taken into account. The total project costs in case of constant ground area are illustrated in Table 4. In case of constant installed capacity, the total project costs are shown in Table 5.

2.4 Operation and Maintenance Costs

Annual O & M costs are estimated between US\$0.42 million and US\$1.42 million for the different cases and scenarios, equivalent to between 0.2% and 0.8% of the construction costs. Between 83% and 88% of them are local costs, mainly costs of O & M services for the modules and the plant as well as for inverter maintenance. About 12% to 17% of the O & M costs are foreign costs. Table 6 shows the O & M costs in the case of constant ground area and in the case of constant installed capacity. In addition, the third case considers land costs of 0.1 JOD/m² which have to be added to the O & M costs outlined in Tables 7 and 8.

3. Financial Analysis

3.1 Methodology

The financial analysis of the 75 MW Jordan Photovoltaic Project serves to assess the financial performance of the project over the lifetime period. Project profitability is usually measured by the FIRR (financial internal rate of return) and the NPV (net present value). For the calculation of FIRR and NPV, it is sufficient to compare the project costs with the

revenues in a simple cash flow analysis without consideration of a financing plan. The FIRR provides a first approximation of the maximum weighted average cost of capital (i.e., cost of equity and loan interest) at which the project is still financially feasible. In the particular case of financing of this project, which is 100% grant financed, it is obvious that the weighted cost of capital is zero and the project is financially viable. To this end, no further analysis would be required. However, it is yet interesting to know, whether the project would also be financially viable, if it had to be implemented without the grant. This is investigated in the following analysis.

3.2 Parameters and Assumptions

Further to the project output and project cost described previously, the financial analysis is based on the following parameters and assumptions:

- Time schedule: construction is assumed to start on March 1, 2014. Commercial operation date is assumed to be after 8 months of construction, on November 1, 2014. The operation period of 20 years ends of October 31, 2034;
- Prices: the price base for the cost estimation (reference date) is May, 2013 and the exchange rate at the reference date is 1.41 US\$/JOD. The discount rate for calculation of the levelized cost is 7%;
- Tariff: the tariff paid for the annual energy production of photovoltaic projects in Jordan is set by the Jordanian government at 120.00 JOD/MWh. With

Table 4 Total project costs (in 1,000 US\$) at constant ground area.

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Project development expenses up to contract award	800	800	800	800	800	800	800
Project development expenses up to commissioning	3,200	3,200	3,200	3,200	3,200	3,200	3,200
Project development costs	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Site preparation	3,577	3,577	3,577	3,577	3,577	3,577	3,577
PV modules	64,515	56,701	17,760	53,776	47,750	64,515	18,924
Inverters	21,505	21,000	10,447	19,555	19,100	21,505	6,308
Mounting structure	35,770	35,770	35,770	35,770	35,770	71,539	171,694
Wiring and cabling	7,527	7,350	3,656	6,844	6,685	8,602	2,839
Electrical equipment/site security/monitoring	10,752	10,500	5,223	9,777	9,550	10,752	3,154
Development/installation/administration	12,903	12,600	6,268	11,733	11,460	12,903	3,785
Physical contingencies (5%)	7,827	7,375	4,135	7,052	6,695	9,670	10,514
Price contingencies (5%)	8,219	7,744	4,342	7,404	7,029	10,153	11,040
EPC scope	172,595	162,617	91,178	155,488	147,614	213,216	231,833
132 kV OHL (overhead transmission line)	1,128	1,128	1,128	1,128	1,128	1,128	1,128
132 kV bays (6)	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Transformers	2,538	2,538	2,538	2,538	2,538	2,538	2,538
33 kV feeders (9)	846	846	846	846	846	846	846
Civil works	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Telecommunication & control	353	353	353	353	353	353	353
Commissioning, supervision, engineering and consulting	494	494	494	494	494	494	494
Physical contingencies (10%)	818	818	818	818	818	818	818
Price contingencies (6%)	540	540	540	540	540	540	540
NEPCO scope	9,536	9,536	9,536	9,536	9,536	9,536	9,536
Total project costs	186,130	176,152	104,714	169,023	161,150	226,752	245,369

Table 5 Total project costs (in 1,000 US\$) at constant installed capacity.

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Project development expenses up to contract award	800	800	800	800	800	800	800
Project development expenses up to commissioning	3,200	3,200	3,200	3,200	3,200	3,200	3,200
Project development costs	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Site preparation	3,577	3,656	7,365	3,925	4,032	3,577	12,204
PV modules	64,515	58,063	36,558	59,139	53,762	64,515	64,515
Inverters	21,505	21,505	21,505	21,505	21,505	21,505	21,505
Mounting structure	35,770	36,558	73,654	39,247	40,322	71,539	585,795
Wiring and cabling	7,527	7,527	7,527	7,527	7,527	8,602	9,677
Electrical equipment/site security/monitoring	10,752	10,752	10,752	10,752	10,752	10,752	10,752
Development/installation/administration	12,903	12,903	12,903	12,903	12,903	12,903	12,903
Physical contingencies (5%)	7,827	7,548	8,513	7,750	7,540	9,670	35,868
Price contingencies (5%)	8,219	7,926	8,939	8,137	7,917	10,153	37,661
EPC scope	172,595	166,439	187,718	170,884	166,261	213,216	790,880
132 kV OHL	1,128	1,128	1,128	1,128	1,128	1,128	1,128
132 kV bays (6)	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Transformers	2,538	2,538	2,538	2,538	2,538	2,538	2,538
33 kV feeders (9)	846	846	846	846	846	846	846

Table 5 continued

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Civil works	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Telecommunication & control	353	353	353	353	353	353	353
Commissioning, supervision, engineering and consulting	494	494	494	494	494	494	494
Physical contingencies (10%)	818	818	818	818	818	818	818
Price contingencies (6%)	540	540	540	540	540	540	540
NEPCO scope	9,536	9,536	9,536	9,536	9,536	9,536	9,536
Total project costs	186,130	179,974	201,253	184,420	179,796	226,752	804,416

Table 6 O & M costs (in 1,000 US\$) at constant ground area.

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
O & M services modules and plant	323	315	157	293	286	430	126
Insurance	108	105	52	98	95	108	32
Administrative services	215	210	104	196	191	215	63
Security services	108	105	52	98	95	108	32
Spare parts without inverter	215	210	104	196	191	215	63
Inverter maintenance	323	315	157	293	286	323	95
Water and module cleaning	7	7	7	7	7	7	7
Total operation and maintenance costs	1,297	1,267	634	1,180	1,153	1,405	417

Table 7 O & M costs (in 1,000 US\$) at constant installed capacity.

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
O & M services modules and plant	323	323	323	323	323	430	430
Insurance	108	108	108	108	108	108	108
Administrative services	215	215	215	215	215	215	215
Security services	108	108	108	108	108	108	108
Spare parts without inverter	215	215	215	215	215	215	215
Inverter maintenance	323	323	323	323	323	323	323
Water and module cleaning	7	7	14	8	8	7	23
Total operation and maintenance costs	1,297	1,297	1,304	1,298	1,298	1,405	1,421

Table 8 Land costs (in 1,000 US\$) at constant installed capacity.

(000 US\$)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Land costs	154	157	317	169	174	154	525

an exchange rate of 1.41 US\$/JOD, the tariff amounts to 16.92 US cent/kWh;

- Residual value: at the end of the operation period of the PV modules and mounting structures, i.e., after 20 years, the civil works will still have a residual technical lifetime. However, since all other project assets will have been worn out at the end of the operation period and will not be operating further, the civil works cannot be used anymore. The FIRR calculation for the project company does therefore not

reflect any residual value of the civil works;

- Taxation: the project company will be completely exempted from the payment of income tax. The parameters and assumptions are summarized in Table 9.

3.3 Results and Discussions

The 75 MW Jordan Photovoltaic Project has a tariff of 16.92 UScent/kWh. Regarding Scenario 7, the tariff is not sufficient to cover the project costs and the operation and maintenance costs over the project

Table 9 Parameters and assumptions for the financial analysis.

Item	Parameter
Time schedule	
Construction period	(months) 8
Start of construction	(date) March 1, 2014
COD (commercial operation date)	(date) November 1, 2014
Operation period	(years) 20
Last commercial operation date	(date) October 31, 2034
Prices and tariff	
Price base	(date) May 2013
Exchange rate	(US\$/JOD) 1.41
Discount rate for levelized cost calculation (in real terms)	(%) 7
Base tariff	(JOD/MWh) 120.00
Technical lifetime	
Project development cost	(years) 20
EPC cost	(years) 20
NEPCO cost	(years) 20

lifetime, as the levelized costs are higher than the feed-in tariff. In Scenario 7, the FIRR and the NPV are negative. Scenario 7 is therefore not financially viable and should be disregarded when pursuing this project further. For the other cases and scenarios, the FIRRs are between 11.1% and 13.6% and thus exceed the discount rate that reflects the costs of financing. The NPVs, at a discount rate of 7%, are between US\$28.6 million and US\$81.2 million for the remaining scenarios. They are therefore financially viable as shown in following Figs. 1-3.

4. Economic Analysis

4.1 Methodology

The economic analysis of the 75 MW Jordan Photovoltaic Project is carried out as a conventional cost-benefit analysis, where the costs of the photovoltaic project are compared with its benefits. The costs of the project comprise all costs incurred during implementation and subsequent operation of the project, i.e., investment costs, operation and maintenance costs and dismantling costs. The benefits of the project are equivalent to the avoided cost of thermal generation, because without the project, the equivalent energy would have to be provided by thermal power plants within the grid. In principle, the

implementation of a photovoltaic project avoids the energy cost of the thermal alternative (fuel costs and variable O & M costs). For the capacity which cannot be guaranteed on a reliable basis, a backup has to be provided in the grid, thus, there is no avoided cost associated with the non-firm capacity. The Jordan Photovoltaic Project does not provide firm capacity, and as a result, there is no capacity benefit to be considered.

Nevertheless, the Jordan Photovoltaic Project will save the cost of energy generation elsewhere in the grid. Most of the thermal power plants are run on imported natural gas or diesel oil. With increasing shortage of gas, diesel oil is the most widely used fuel. It is therefore assumed that energy from the Jordan Photovoltaic Project is used to substitute diesel oil [17].

Furthermore, solar generation prevents greenhouse gas emissions which would otherwise result from thermal generation. While NO_x and SO_x emissions from thermal plants can be reduced with appropriate equipment, present thermal technology does not allow recovery of CO₂ from the flue gases. Therefore, the avoided cost of CO₂ emissions has to be considered explicitly in the economic analysis of the Jordan Photovoltaic Project. Since emission trading has been established, this cost used to be derived from the price

Fig. 1 Financial indicators at constant ground area: (a) FIRR; (b) the NPV; (c) levelized costs; (d) *B/C* (benefit/cost) ratio.

Fig. 2 Financial indicators at constant installed capacity: (a) FIRR; (b) the NPV; (c) levelized costs; (d) *B/C* ratio.

Fig. 3 Financial indicators at constant installed capacity including land costs: (a) FIRR; (b) the NPV; (c) levelized costs; (d) *B/C* ratio.

of carbon credits (emission reduction certificates), which was seen as a value that approximates the costs of CO₂ for the economy and society. However, given the current state of the carbon credit system, no meaningful values can be obtained from there. Thus, the avoided cost of CO₂ emissions will be derived from damage or mitigation costs which have been investigated by technical experts in numerous studies [18-20].

The costs of the 75 MW Jordan Photovoltaic Project as well as its benefits are set up as cash flows over the entire operation period of 20 years. The net cash flows are then discounted to obtain the NPV of the project. The present values of costs and benefits serve to derive the benefit/cost ratio. In addition, the EIRR (economic internal rate of return) is calculated.

4.2 Parameters and Assumptions

The economic analysis is based on the following parameters and assumptions:

- General evaluation period: the evaluation period is 20 years, equivalent to the operation period;
- Discount rate: the evaluation of photovoltaic

projects is based on a discount rate of 8%, which is to reflect the opportunity costs of capital for the country;

- SCF (standard conversion factor): a SCF of 0.9 is used to convert the market prices for local goods and services to economic shadow prices. This value is widely used in economic analyses for countries with a similar economic environment to Jordan and thus expresses an appropriate order of magnitude for this parameter.

4.2.1 Jordan Photovoltaic Project

- Firm capacity: due to the intermittent solar generation availability, the Jordan Photovoltaic Project does not provide firm capacity. This means that there will be no economic benefits from a reduction of capacity costs in the economic analysis, but only benefits from the avoidance of variable costs;

- Annual energy production: the annual energy production of the different scenarios is between 55.1 GWh and 187.2 GWh in case of constant ground area and between 41.5 GWh and 187.2 GWh in case of constant installed capacity as described in Section 2.2;

- Investment costs: the financial project costs are

converted into economic costs by applying the standard conversion factor of 0.9 to the local cost components;

- Economic lifetime: all equipment is assumed to have an economic lifetime of 20 years;
- Operation and maintenance costs: the economic O & M costs and the economic land costs are determined by applying the SCF of 0.9 to the local part of the financial O & M costs and to the land costs.

4.2.2 Thermal Alternative

• Alternative plant: considering Jordan's plant mix, the thermal alternative is assumed to be a GT (gas turbine) plant capable of dual-firing with natural gas and diesel oil. As a consequence of the limited supply of gas, it must be assumed that the alternative thermal plant will be fueled with diesel oil. This would be the case no matter whether the alternative plant is assumed to be a plant that would need to be built in place of the photovoltaic project in the course of expansion of the power generation system or a plant within the existing generation park that can remain undispatched during the times that the photovoltaic project generates electricity. Regarding the interconnection of the Jordan Photovoltaic Project to the network, it is assumed that there are no incremental advantages or disadvantages in relation to the assumed thermal alternative, i.e., transmission savings related to costs and losses are equal to zero, as it cannot be predicted at this point of time, where the alternative thermal plant would be located;

• Operation and maintenance costs: fixed O & M costs are part of the capacity costs of the thermal alternative which are not considered in this analysis due to the lack of firm capacity of the Jordan Photovoltaic Project. Variable O & M costs of a GT plant are assumed to be 0.07 US cent/kWh;

• Fuel costs: according to the study "Analyses of Energy and Electricity Supply Options in Jordan" the price of diesel oil is 953 US\$/toe. Table 10 summarizes the fuel costs in US cent/kWh for diesel oil based on a heat rate of the GT plant of 12,000 kJ/kWh;

- CO₂ costs: the cost of avoided CO₂ emissions

depends on the type of fuel used for thermal generation. The CO₂ output of diesel oil is 74.8 kg/GJ. At the assumed heat rate of the GT plant, this results in emissions of 0.898 kg CO₂ per kWh. For this economic analysis, the avoided cost of CO₂ emissions have been taken from the study "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis". With a cost of US\$21.4 per ton of CO₂, the CO₂ costs are 1.92 UScent/kWh for diesel oil, as shown in Table 11.

4.3 Results and Discussions

Based on the assumptions outlined above, the Jordan Photovoltaic Project has an EIRR of between 22.7% and 26.6% for all six scenarios as Scenario 7 is also not economically viable. The EIRR indicates the actual profit rate of the total investment outlay. A project is considered feasible when the EIRR is greater than the agreed economic discount rate. Thus, the economic analysis confirms that the Jordan Photovoltaic Project is economically feasible except for Scenario 7. At a discount rate of 8%, the project has EIRRs, NPV and benefit/cost ratios for the different cases and scenarios as summarized in Figs. 4-6.

5. Conclusions

The 75 MW Jordan Photovoltaic Project has (for the discussed options) total costs between US\$104.7 million and US\$245.4 million for case 1 as well as

Table 10 Fuel cost of thermal alternative.

Item		Diesel oil
Fuel price	(US\$/toe)	953.00
Fuel price	(US\$/MJ)	0.0228
Fuel price	(US\$/MMBTU)	21.57
Heat rate	(kJ/kWh)	12,000
Fuel cost	(UScent/kWh)	27.31

Table 11 CO₂ cost of thermal alternative.

Item		Diesel oil
CO ₂ emission factor	(kg CO ₂ /GJ)	74.80
CO ₂ emission factor	(kg/kWh)	0.898
CO ₂ cost	(US\$/ton)	21.40
Specific CO ₂ cost	(UScent/kWh)	1.92

Fig. 4 Results of the economic analysis at constant ground area: (a) EIRR; (b) the NPV; (c) B/C ratio.

Fig. 5 Results of the economic analysis at constant installed capacity: (a) EIRR; (b) the NPV; (c) B/C ratio.

Fig. 6 Results of the economic analysis at constant installed capacity including land cost: (a) EIRR; (b) the NPV; (c) B/C ratio.

total project costs between US\$179.8 million and US\$804.4 million for the cases 2 and 3, all in prices at the reference date May, 2013. The financial internal rate of return of the Jordan Photovoltaic Project in Scenario 7 is negative. It is the scenario with the lowest performance. Therefore, Scenario 7 should be excluded from the further process. All other scenarios in all three cases have FIRR above 7% and are therefore financially viable and can be pursued further. The project will serve as a “fuel saver”, as the energy generated at the Jordan Photovoltaic Project replaces energy generated at the thermal plant with the highest variable costs in the grid, which is a diesel-fired gas

turbine. This replacement has as the further advantage that it avoids the CO₂ emissions associated with thermal generation. With a gas turbine plant using diesel oil as the alternative thermal plant, the project has discounted economic net benefits (NPV) between US\$103.6 million and US\$231.5 million as well as benefit/cost ratios between 2.20 and 2.53 at a discount rate of 8% for the remaining six scenarios in the different cases, the economic internal rate of return is between 23.0% and 26.6%, respectively. The economic net benefits of the project except for Scenario 7 are robust and remain significant even under a variety of different sensitivities.

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