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Techno-Economic Feasibility of Energy Supply of Remote Dump Site in Jordan Badia by Photovoltaic Systems, Diesel Generators and Electrical Grid

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Abstract: In the development of energy sources in remote regions in Jordan at the brink of the 21st century, it is necessary to view the use of solar energy in all applications as one of the most promising new and renewable energy sources. As a contribution to the development program of remote areas in Jordan Badia, this paper presents three energy supply alternatives (photovoltaic system, diesel generator and electric grid) for a dump site for providing the electrical loads to the dump site according to their energy requirements. The result of this study shows that remote dump site in Jordan Badia will require about 5.32 kWh/day or 1940 kWh/yr to meet their basic power requirements for such loads as lighting and electronic appliances-radios and fans. Four dynamic indicators were used to compare the economic-effectiveness of these energy systems. It is found that providing electricity to a dump site in a remote zone using photovoltaic systems is very beneficial and competitive with the other types of conventional energy sources, especially considering the decreasing prices of these systems and their increasing efficiencies and reliability. They have also the advantage of maintaining a clean environment. It is recommended that solar photovoltaic-based dump site electrification application should be encouraged by the government, especially for those rural sites without access to a grid supply.

Key words: Dynamic indicators, Jordan badia, photovoltaic, techno-economic feasibility

INTRODUCTION

Energy is a basic pre-requisite for economic development. The rapid depletion of fossil-fuel resources, the limited reserves and their unstable prices on a worldwide basis have necessitated an urgent search for alternative energy and significantly increased the interest in renewable energy sources. Of the many alternatives, photovoltaic energy has been considered as promising toward meeting the continually increasing demand for energy (Borowy Bogdan and Salameh Ziyad, 1996; Chedid *et al*., 1997). Since the oil crises of the early 1970s, utilization of solar power has been increasingly significant, attractive and cost effective (Elhadidy and Shaahid, 2000; Elhadidy, 2002). In numerous remote and rural areas in the world, a noteworthy number of domestic consumers, farms and small business are not connected to main electrical grid system. This is especially in the developing countries, where large distances and the lack of capital are some of the obstacles to the development of a grid system (Elhadidy and Shaahid, 2000; Elhadidy, 2002; Tay *et al*., 2011; Nakata *et al*., 2011).

Solar energy is one of the potential renewable energy sources, which is being harnessed in a commercial scale today. Solar energy is non-depletable source, non-polluting, low operating cost, high reliability and cost free in it original radiation form. Therefore, solar energy will represent a suitable solution for energy requirements especially in rural areas.

Rapid developments in the solar photovoltaic technologies in recent years have made these technologies competitive alternatives to conventional energy systems. Parallel to this development, photovoltaic systems have made a significance contribution to daily life in developing countries where one third of the world's people live without electricity.

The first problem in remote areas, there are fewer users per kilometer of high, medium and low voltage line than in urban zones. Also, average consumption is generally much lower than for urban or industrial customers. The second problem is the feasibility of rural electrification via a distribution grid is much lower than that of urban or industrial electrification; since the investment is higher, the costs are greater and the revenue received by utilities is lower (Celik, 1998; Vallve and Serrasolses, 1997). Therefore, even though they generate little power in comparison to central power plants, photovoltaic energy systems could meet the modest needs of remote areas in the Third World villages and remote sites. Low per capita consumption magnifies the

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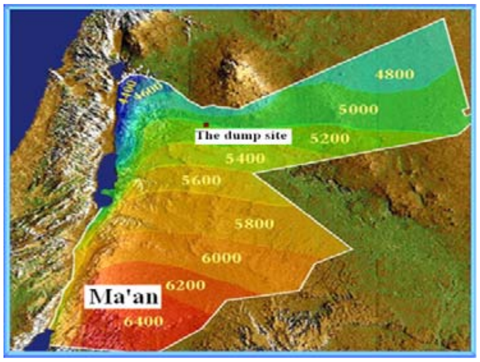

Fig. 1: Solar irradiance map of Jordan (Source: Meteorological department/Jordan)

renewable systems benefits because so little electricity is needed to raise the quality of life (Celik, 1998).

Jordan is a small country located in the Middle East which lacks oil reserves. It is highly dependent on the import of crude oil and petroleum products to satisfy its needs. The increase in oil prices has put extreme pressure on the Jordanian economy resulting in challenges and disturbance affecting the country policy makers' plans toward development. The government has reacted actively to overcome the negative effect and deterioration on its economy by gradually reducing its support to oil product prices.

Therefore, new sources of energy are needed. Governments all over the world, including the Jordanian government, have been searching for new sources and ways to overcome these circumstances, together with other factors such as using environmentally - friendly sources. One possible solution is to utilize renewable energy recourses as solar energy.

The main objective of this paper is to investigate the techno-economic feasibility of three different energy system to supply a remote area in the Jordan Badia and to use the result of this study by Jordanian government as a guide in any project in the same area and to help the decision makers in the energy sector in Jordan.

Figure 1 shows the solar irradiance map of Jordan. It can be seen that the Southern part of Jordan (Ma'an area) receives the highest irradiance compared to the other parts of Jordan, which makes this area the most suitable one for solar energy harvesting.

RESEARCH METHODOLOGY

Investigated site: Al-Manareh dump site was considered to be one of three dump sites in Jordan Badia to be subject to this study to compare by three different electrical energy supply systems using a techno-economic comparison study.

The dump site is located in the Northeast Badia of Jordan (South of Al-Manareh village) by 11 km. Its inhabitants only from the people that keeping the site save and controlled the process. There is a road available to the main road.

The Jordanian Badia climate is mostly arid desert and high in temperature, where winter temperatures average around 8-10ºC and summer temperatures exceeds 38ºC during months June - August and the annual average of ambient temperature amounts to 23ºC. The rainy season is in the period (November to April), where the average annual rainfall varies from less than 50 mm to over 150 mm in some parts of the Badia (Dayu, 2011; JMD, 1998).

Jordan lies in the so-called earth-sun belt area and possesses a high and good potential for solar energy to make use of these energy sources feasible and commercially attractive. the daily average of solar radiation on a horizontal surface is in the selected dump site is 5.2 kWh/m^2.day (Dayu, 2011). The average annual solar radiation per day is 3.8 kWh/m^2 in winter to more than 8 kWh/m^2 in summer and the sunshine duration is about 3300 hours per year (Borowy Bogdan and Salameh Ziyad, 1996; Chedid *et al*., 1997; Elhadidy and Shaahid, 2000; Elhadidy, 2002; Gordon, 1987; Hadj Arab *et al*., 1995; JMD, 1998; Kolhe *et al*., 2002).

While, the wind energy potential are low, where the annual average of wind velocity in the Jordan Badia is about 4.4 m/s which make the utilization of wind energy converters surely unfeasible. Solar energy is in fact considered the main and most reliable renewable energy source in Jordan even during the winter season (Hammad, 1999; Kabariti, 2002). Solar energy is used for water pumping, water desalination, electrification of remote villages, mosques, teachers' residences, police stations, clinics, communication systems and other applications (Al-Mehaidat, 2003; Habali *et al*., 1988; Kabariti, 2002; Odeh, 2001; RSS, 1994).

The daily energy needs in such sites are very low. The people in the site had been used diesel generator for power and light before and now they used photovoltaic energy system. The site is located about 11 km from the nearest national grid. Based on that, this remote dump site has been selected as a model for a solar electrification in Jordan Badia.

The PV-power supply system: The load profile to be met in a renewable system is of the same importance as the weather data. In general, the demand to be met by a power system is time dependent. Therefore, for correct system sizing, the general non-constant load demand pattern must be considered (Protogeropoulos, 1992).

The remote dump site is about 11 km from the national grid, while the electrical load is mainly concentrated on the night period.

The appliances considered were those having the highest identified probability of use, and consequently satisfying the basic energy needs. These appliances are (lighting, TV, small refrigerator, radio and fan). It is

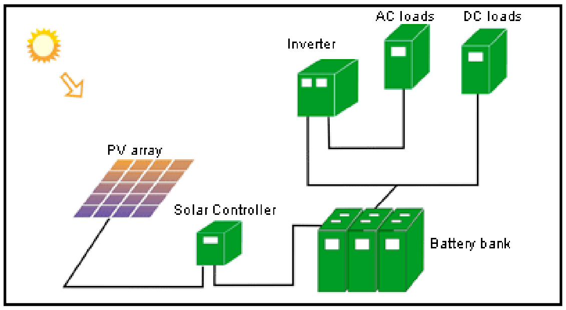

Fig.2 : PV power system of the remote dump site (Al-Manareh site).

noticed that the largest amount of energy consumption is concentrated in the evening, when the lighting, TV and refrigerator are working.

It is expected that most of these sites will have electrical loads as shown in Table 1. Using Table 1, it is found that the average daily load energy for the dump site (E_L) is about 5.32 kWh/ day. For this study the total energy consumption is 1942 kWh/year.

In sunny parts of the world, stand-alone photovoltaic systems are becoming cost-effective for the remote and rural electrification of widely scattered homes and villages. For the majority of the population living in remote, rural and isolated locations, stand-alone photovoltaic systems can be considered a promising option and a very reliable power source, with the minimum attention and maintenance (Gordon, 1987; Markvart, 1997). Electrical load supply with a minimum cost by a photovoltaic installation is a complex problem in which many parameters must be taken into account, such as climatic data, components cost, and the distribution of the electrical load. In order to size a system acknowledgement of the solar radiation data for the site, the load demand profile, and the importance of supply continuity are required. The solar photovoltaic array is sized to replace the load on a daily basis for average weather conditions (Vallve and Serrasolses, 1997; Hadj Arab *et al*., 1995; Markvart, 1997). Photovoltaic stand-alone system sizing involves finding the cheapest combination of array size and storage capacity that will meet the anticipated load requirements with the minimum acceptable level of security (Bhuiyan and Asgar, 2003). The required photovoltaic energy system to cover the dump site load is illustrated in Fig. 2.

The area size of the photovoltaic array is obtained as follow (Ahmed, 2002; Mahmoud and Ibrik, 2006; Mahmoud *et al*., 1991):

$$\text{PV (Area)} = E_L/H \times \eta_{pv} \times \eta_{out} \quad (1)$$

where, E_l (daily energy consumption) = 5.32 kWh
H (the annual average solar radiation) = 5.2 kWh/m^2.day (MEMR, 2011)
η_{pv} (module efficiency) = 12%
η_{out} (the efficiencies of the system components) = $\eta_v \times \eta_r$ ($\eta_v = 0.9$, $\eta_r = 0.92$)

By using Eq. (1) and the above collected and assumed data, we obtain the area of the PV generator:

$$\text{PV (Area)} = \frac{5.32}{0.9 \times 0.92 \times 5.2 \times 0.12} = 10.3 m^2$$

Under standard conditions (average solar radiation of 1000W/m^2 and module temperature 25ºC), the peak power of the solar generator has been calculated by the following equation (Ahmed, 2002; Mahmoud *et al*., 1991):

$$P_{pv} = 1000\text{W/m}^2 \times A_{pv} \times \eta_{pv} (2)$$

where, A_{pv}: Array area (m^2); h_{pv}: Efficiency of PV module.

$$P_{pv} = 1000\text{W/m}^2 \times 10.3 \times 0.12 = 1236 \text{ W}$$

Assume a safety factor 1.2 for compensation of resistive losses and photovoltaic cell temperature losses, then the peak power of the photovoltaic generator will be:

$$P_{pv} = 1236 \times 1.2 = 1.483 \text{ kWp}$$

This figure was rounded up to 1.5 kWp. A 170 W mono-crystalline PV module type was selected. According to (Al-Mehaidat, 2003; Mahmoud and Ibrik, 2006), the number of modules needed (N_{pv}); is equal to the peak power of solar generator (P_{pv}) divided by the power of one module (P_m), as shown in the following equation:

$$N_{PV} = \frac{P_{PV}}{P_m} \quad (3)$$

where P_{pv}: The peak power of solar generator; P_m: The power of one module.

$$N_{pv} = \frac{1500}{170} = 9 \text{ modules}$$

This figure was rounded up to 10 modules. Thus, 10 modules are used to supply the dump site with the required energy. The modules can be connected to give the desired voltage according to the design of the other parts of the PV system and the load specifications.

Stand-alone power systems often store energy generated during the day in a battery bank for use at night. Therefore, the photovoltaic system is equipped with a

Table 1: The daily load energy requirements for a dump site in remote zones

Appliances	No. of units	Appliance power (W)	Expected daily use (h)	Electrical energy requirements (kWh/day)
Fluorescent tube 20W each	16	320	5	1.6
Small refrigerator	1	200	12	2.4
TV	1	100	6	0.6
Cassette player	1	60	4	0.24
Cooling fan	1	60	8	0.48
Total energy (kWh/m^2/day)		5.32		

storage battery, in order to meet the demand requirements during the cloudy days in the application period. The optimized storage capacity in general should be of the minimum size which meets the demand requirements during the application period (Samimi *et al*., 1997). There are many factors that influence the choice and performance of a battery in a photovoltaic system. The battery bank is sized to operate the loads during a sequence of below average insulation days, called the days of autonomy. In battery sizing some other factor like maximum depth of discharge, temperature correction, rated battery capacity and battery life are considered (Bhuiyan and Asgar, 2003).

The storage capacity of battery block for such systems is considerably small. Therefore, lead-acid batteries type should be selected. Such battery types are available but at much higher price than regular batteries. According to (Ahmed, 2002; Mahmoud and Ibrik, 2006; Mahmoud *et al*., 1991), the storage capacity required for the photovoltaic energy system can be calculated by the following equation:

$$\text{Battery storage} = \frac{N_c \times E_L}{DOD \times \eta_{out}} \quad (4)$$

where,
N_C: period of storage required (days)
E_L: daily demand of energy (kWh)
DOD: deep of discharge
η_{out} (the efficiencies of the system components) = $\eta_V \times \eta_r (\eta_V = 0.9, \eta_r = 0.92)$

Assuming that DOD = 0.75, the largest number of continuous cloudy days in the selected area is 3 days and E_L = 5320 Wh, we obtain:

$$\text{Battery storage} = \frac{3 \times 5320}{0.75 \times 0.828} = 26\ kWh$$

The required amp. hours of batteries, if 24 V system is chosen = 26000/24 = 1100 Ah. So, 12 battery cells (2 V, 1100 Ah) connected in series are needed for this system. This battery bank can drive the loads for 3 days without any sunshine.

Charge controllers are required in renewable systems to regulate the battery charge and to control the operation of the load. This is the function of the charge controller. Excessive discharge is avoided by monitoring the battery voltage and disconnecting the load from the battery if the voltage falls below a pre-set minimum value (Markvart, 1997). The battery charge controller is chosen to maintain a longer lifetime for the batteries (Ahmed, 2002; Mahmoud and Ibrik, 2006). For this system the required rated power of charge controller is 1700 W. The rated power of the charge controller is as follow:

$$1500\ W \le P_{CR} \le 1800\ W$$

An inverter is a standard item of electronic equipment, which is used in many different applications. Inverters convert Direct Current (DC) voltage to Alternating Current (AC). Therefore, the input power is the DC power from the renewable energy system or battery, and the output is AC power used to run AC appliances or fed into the utility grid (Markvart, 1997). The input of inverter has to be matched with the battery block voltage while its output should fulfill the specifications of the electric appliances. The rated power of the inverter is as follow:

$$1500\ W \le P_{INV} \le 1800\ W$$

The diesel electric generator: In Jordan, diesel generators are not widely used to provide remote villages and sites with electric power. These have the advantage of being able to deliver the required power on demand. However, they also suffer from a number of drawbacks. Diesel generator engines are inherently noisy and expensive to run, especially for consumers in rural areas where fuel delivery costs may be high. Also, installing diesel generators in these villages and remote sites is very restricted for many reasons. Fuel buying around the year, and operation and maintenance of these generators are the most significant factors against the economic deployment of diesel generators. In addition, small consumers always have a low load factor; this in turn reduces the overall efficiency and increases percentage maintenance costs and they pollute the environment (Mahmoud and Ibrik, 2006; Mousa *et al*., 1998).

In this remote dump site, the people was used a 7.5 kW diesel generator type (lister petter) with single phase output AC voltage (220 V, 50Hz).

Electric grid extension: Jordan has an excellent national electrical grid which covers about 99% of the population of Jordan, that's account about 6 million people. I addition, Jordan one of the Arab countries that have connect their electrical national grid with each other, such as: Jordan, Egypt, Syria and Lebanon. In spite of this, there is in Jordan some remote sites that does not afford electricity from the national grid, such as Al-Manareh dump site. As we know, transmission lines are designed to transport large amounts of electric power, usually expressed in watts or kilowatts, over long distances (Mahmoud and Ibrik, 2006).

According to (Mahmoud and Ibrik, 2006), the transmission line voltage (V_t) is given by the following Equation:

$$Vt = 5.5\sqrt{0.62L + \frac{S}{150}} \text{ (kV)} \quad (5)$$

where L the length of the transmission line = 11 km, and S is the three phase apparent power of the load = 11 kVA. By applying the above equation we obtain:

$$Vt = 5.5\sqrt{0.62 \times 11 + \frac{11}{150}} = 14.3 \text{ kV}$$

In Jordan, the next standard transmission line voltage value, is 33 kV.

Economic estimation: For many remote applications, stand-alone photovoltaic energy systems are presently economical, where the cost of other energy resources, such as extending utility power lines or transporting fuel, is very high (Kolhe *et al*., 2002). At present, photovoltaic energy systems is most competitive where small amounts of energy are required far from the grid (Markvart, 1997). The price of the PV system and its installation are important factors in the economics of PV systems. These include the prices of PV modules, storage batteries, the control unit, the inverter, and all other auxiliaries. From the economical viewpoint, photovoltaic energy systems differ from conventional energy systems in that they have high initial cost, low operating costs, there is no fuel cost, and reliability is high so replacement costs are low (Ahmed, 2002; Markvart, 1997).

The total hardware cost of a stand-alone photovoltaic energy system with battery storage depends on the surface area (or peak power of the photovoltaic modules), the storage capacity (in kWh or Ah of the battery), the peak power of the DC/AC inverter, the area (or peak power) of power conditioning and the area (or peak power) of supports (Notton *et al*., 1998).

Life-cycle costing is the most complete analysis and is the usual method for determining whether an application is economic. In this method, not just the capital costs (the total initial cost of buying and installing the system), but all future costs (operation and maintenance, replacement) for the entire operational life of the photovoltaic system, the discount rate (the rate at which money would increase in value if invested) and inflation rate (the rate of price increase of a component above or below general inflation) are considered. The period for the analysis must be the lifetime of the longest-lived system being compared. The inflation rate is usually assumed to be zero.

The life-cycle cost of a solar photovoltaic system consists of the initial capital investment (C_0), the present value of operation and maintenance costs ($O\&M_{pv}$) and the present value of the total replacement cost (R_{pv}) [16, 20].

$$LCC = C_0 + O\&M_{pv} + R_{pv} \quad (6)$$

The initial capital investment C_0 is the sum of the investments of each part of the photovoltaic system, i.e. photovoltaic array, DC/AC converter (maximum power-point trackers), storage batteries, electric control and battery charger, miscellaneous (electric cables, outhouse, etc.), packaging, transportation and installation, etc. Operation and maintenance costs include taxes, insurance, maintenance, recurring costs, etc. (Kolhe *et al*., 2002). The life-cycle maintenance for a lifetime of N years is:

$$O\&M_{pv} = O\&M_0 \, N \quad (7)$$

where $O\&M_0$ is taken as:

$$O\&M_0 = m\,(C_0) \quad (8)$$

where m is a percentage of the initial capital cost

The battery replacement cost (R_{pv}) is mainly a function of the number of battery replacements over the system lifetime, without taking the salvage value of replaced batteries (Kolhe *et al*., 2002).

Total life-cycle cost (LCC) = Total installed cost +Life cycle O&M cost + Total replacement cost (9)

The Annualized Life-Cycle Cost (ALCC) is the total LCC expressed in terms of a cost per year. However, the LCC cannot simply be divided by the number of years in the analysis, as this takes no account of the change in value of money due to inflation and interest rates. The LCC must instead be divided by the present worth factor found using the chosen discount rate, inflation rate of zero and a number of years equal to the analysis period (Markvart, 1997).

Annualized life-cycle cost (ALCC) =
Total life-cycle cost / Present worth factor (10)

The unit electricity cost probably is the most valuable figure in comparing electricity-generating systems and is the net cost of generating each kilowatt-hour during the lifetime of each system (Markvart, 1997).

A common and simple way to evaluate the economic merit of an investment is to calculate its payback period, or break-even time. The payback period is the number of years of energy-cost saving it takes to recover an investment's initial cost. In this way, the payback period in years is given by (Dayu, 2011; Manwell *et al*., 2002; Protogeropoulos, 1992).

$$PBP = \frac{C_{tot}}{(Q_D \times e)} \tag{11}$$

where, C_{tot}: total system costs; Q_D: the annual energy production (kWh/year); e: the cost of the conventional electricity per energy unit ($/kWh).

In an economic evaluation of the photovoltaic energy system, the following parameters are usually considered:

- **The total life-cycle costs:** The sum of all costs of the system over its lifetime, expressed in today's money.
- **Annualized life cycle cost:** The total LCC expressed in terms of a cost per year.
- **The unit electricity cost:** Is the net cost of generating each kilowatt-hour during the lifetime of each system.
- **Payback period:** The time it takes for the total costs to be paid for by the monetary profits and other benefits of the system.

For the present PV system, the life cycle cost will be estimated as follows. The lifecycle of the system components will be considered as 25 years except for the batteries, which will be considered to have a lifetime of 8 years. Also, the annual inflation rate in batteries prices is considered to be 0% and the market discount rate as 10%.

The cost of the first group of batteries (A) (Ahmed, 2002) = No. of batteries × cost of battery = 12 × 200$ = 2400 $ (12)

The present worth (Ahmed, 2002), of the second group of batteries (after 8 years):

$$= \frac{A \quad (1+i)^{N-1}}{(1+d)^{N}} \tag{13}$$

$$= \frac{2400(1+0)^7}{(1+0.1)^8} = 1120\$$$

The present worth of the third group of batteries (after 16 years) = $\frac{2400 \quad (1+0)^{15}}{(1+0.1)^{16}} = 522\ \$$

The initial cost of the PV system (Ahmed, 2002) = PV array cost + first group of batteries cost + battery charge cost + inverter cost + auxiliaries cost = 22850 US$ (14)

where the auxiliaries cost = 5% of the PV array cost (Ahmed, 2002). The PV system installation cost can be estimated as 10% of the initial cost. Also, the annual maintenance and operation cost is about 2% of the initial cost (Ahmed, 2002; Markvart, 1997).

Using Eq. (9), the total life cycle cost = 22850 + (1120 + 522) + (0.02 × 25 × 22850) = 35917 US$

The life cycle output energy (Ahmed, 2002; Markvart, 1997) = E_L × 365 × 25 = 5.32 × 365 × 25 = 48545 kWh (15)

By using Eq. (10), the annualized life cycle cost =

$\frac{35917}{9.077} = 3956.92$ $/year

The present worth factor was taken from tables at 25 life time, 10% discount rate and 0 inflation rate for this project.

The cost of 1 kWh from the PV generator [1] $= \frac{35917}{48545} = 0.74\ \$/kWh$

PBP = $\frac{35917}{48545 \times 0.0436} = 17$ year

The diesel generator was used to feed the dump site in question with its energy requirements before and after that and because of many problems the photovoltaic power system was used. For techno-economic evaluation, it's important to estimate its life cycle cost and the other parameters for comparison. This will give an indication of the difference in energy cost between the three energy supply systems (Ahmed, 2002).

There are some assumptions in order t estimate the diesel generator life cycle cost o:

- Single diesel generator will be used, with a power capacity of 7.5 kW.
- For every 4 years, the diesel generator needs reviving. The cost of reviving is about 20% of their initial price (Ahmed, 2002).
- The operation, maintenance and oil changing cost is about 5% of the initial price (Ahmed, 2002).
- Fuel consumption is about 20 l/day (MMA, 2011).
- For renewable energy projects in Jordan, the inflation rate in prices is about 0%, while the market discount rate is about 10%.

According to Ahmed (2002), the life cycle cost of diesel generator system = Initial cost + (present worth of 20% from the initial cost × 6 times reviving) + (present worth of 5% from the initial cost for maintenance, operation and oil changing) + (present worth of fuel consumption for 25 years) (16)

The cost of commercially available diesel generator may vary from $250 to $1000/kW (Ahmed, 2002; Tay *et al*., 2011). For larger units per kW cost is lower and smaller units cost more. Since the peak power demand is less than 5 kW, in this analysis diesel generator cost was 2215 US$ (MMA, 2011). At present, in Jordan, diesel price is around $ 0.78/l. Initial cost = 1× 2215 $/unit = 2215 US$

Present worth of reviving = $\frac{A\,(1+i)^{N-1}}{(1+d)^{N}}$

for N = 4, 8, 12, 16, 20, 24

where in this equation, A = 20% from the initial cost:

Present worth of reviving:
= (0.2×2215) ×

$$\left\{\frac{(1+0)^3}{(1+0.1)^4}+\frac{(1+0)^7}{(1+0.1)^8}+\frac{(1+0)^{11}}{(1+0.1)^{12}}+\frac{(1+0)^{15}}{(1+0.1)^{16}}+\frac{(1+0)^{19}}{(1+0.1)^{20}}+\frac{(1+0)^{23}}{(1+0.1)^{24}}\right\}$$

= 870 US$

Present worth of maintenance, operation and oil changing

$$[1] = \sum_{N=1}^{N=25}\frac{A\,(1+i)^{N-1}}{(1+d)^{N}} \quad (17)$$

where in this equation, A = 5% from the initial cost Present worth of maintenance, operation and oil changing:

$$= \sum_{N=1}^{N=25}\frac{(0.05*2215)(1+0)^{N-1}}{(1+0.1)^{N}} \quad 1008\ \$$$

Present worth of fuel consumption (Ahmed, 2002) for 25

$$\text{years} = \sum_{n=1}^{N=25}\frac{A\,(1+i)^{N-1}}{(1+d)^{N}} \quad (18)$$

where in this equation, A = first year fuel cost = 20 l/day × 365 × 0.78$/l = 5694 US$

Present worth of fuel consumption for 25 years =

$$\sum_{N=1}^{N=25}\frac{5694\,(1+0)^{N-1}}{(1+0.1)^{N}} = 51685\ \text{US\$}$$

The life cycle cost of diesel generator system =
2215 + 870 + 1008 + 51685 = 55778 US$

The annualized life cycle cost = $\frac{55778}{9.077} = 6145$ $/year

The life cycle output energy = 5.32×365×25
= 48545 kWh

The cost of 1 kWh from the diesel generator =

$$\frac{55778}{48545} = 1.15\ \$/kWh$$

$$\text{PBP} = \frac{55778}{48545\times 0.0436} = 26.34 \ \text{year}$$

Most of the Transmission Line System (TLS) consists mainly of towers, trusses, conductors, insulators, earthing electrodes, isolator switch distribution transformer, distribution board and other installation accessories (Mahmoud and Ibrik, 2006). The total local initial cost of main system components and accessories and works is about 18570 US$ for every kilometer distance (MEMR, 2011).

For the 11 km distance, the total initial costs = 11× 18570 = 204270 US$

The needed maintenance cost for the TLS and distribution trans former during the lifetime of the system, which is assumed to be 25 years, amounts to 2% of the total initial TLS cost (Mahmoud and Ibrik, 2006).

This means that the yearly maintenance cost (C_m) is: C_m = 0.02× 204270 / 25 = 163.4 US$/year

The total maintenance cost over the 25 year lifetime = 163.4 $/year × 25 year = 4085 US$

Total life cycle cost = total initial cost + total maintenance cost = 204270 + 4085 = 208355 US$

The life cycle output energy = 5.32×365 × 25
= 48545 kWh

The annualized life cycle cost =

$$\frac{208355}{9.077} = 22954.17\ \$/\text{year}$$

The cost of 1 kWh from the electric grid

$$= \frac{208355}{48545} = 4.29$$

$$\text{PBP} = \frac{208355}{48545\times 0.0436} = 98.4\ \text{Years}$$

Table 2: Evaluation results of the dynamic economic methods applied on the three energy supply systems

Dynamic method (indicator)	PV-system	Diesel generator system	Electric grid extension
Life cycle cost ($)	35917	55778	208355
Annualized life cycle cost ($/year)	3956.92	6145	22954.17
Cost of kWh production ($)	0.74	1.15	4.29
Pay-back period (year)	17	26.35	98.4

This indicates that the life cycle cost of the PV system is less than that of the diesel generator system and electric grid for providing a remote zone dump site with energy. Another economic study carried out by (Ahmed, 2002) to compare PV systems and diesel generator systems showed that the life cycle cost of PV systems is slightly higher than that of diesel generator systems, especially in rural regions.

In any case, PV systems are clean and renewable sources of energy; they do not cause pollution of any type during their use. On the other hand, diesel generators cause noise and produce gases and smoke.

RESULTS EVALUATION, CONCLUSION AND RECOMMENDATIONS

Table 2 illustrates the above four dynamic economic methods on the three energy supply systems of the remote dump site, and the obtained evaluation results for the four dynamic methods. The availability of energy is an important pre-condition for developing the national economy and improving people's living standards. From an economical point of view using PV systems in feeding remote and rural zones is very important, especially when their life cycle costs are competitive with the other types of conventional energy sources.

This study has shown that, for a remote dump site, the domestic load demand for light-duty applications represents 5.32 kWh/ day.

Also, it was shown that a photovoltaic energy system provides a less costly option than the other two energy systems for the required system autonomy level in terms of the four dynamic methods.

Therefore, utilizing of photovoltaic power systems in Jordan Badia is more economic feasible for electrification of remote dump sites of geographic, climate and load conditions similar to Al-Manareh dump site in Jordan. In addition, the photovoltaic power systems do not pollute the environment as the case of using diesel generator. This study could serve as a guide to building an appropriate PV-based remote site electrification project in Jordan and also assist government in its Rural Electrification Project.

Based on that, it is recommended that rural PV-based remote sites electrification application should be encouraged by government, by committing additional political and financial support, and establishing pilot projects in each of the remote areas of Jordan to assist in household adoption and diffusion. It is a known fact that the application of PV-systems will offer a quick, economic and reliable answer to the remote sites need for power, especially for those of light-duty appliances. Also, the application and diffusion of PV-systems in rural and remote areas will enhance the quality of life in those areas, which will in turn, help to reduce the pressure caused by the unsustainable use of rural and remote-based natural resources and also reduce rural and remote-urban migration.

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