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Priority option of photovoltaic systems for water pumping in rural areas in ESCWA member countries*

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Abstract

Many rural areas in ESCWA member countries are still suffering from a lack of access to energy services, especially electricity supply. Photovoltaic (PV) applications could supply electrical energy needed in rural, remote, and deserted areas for water pumping to supply the Bedouins and their herds as well as the villagers and their livestock with their needs of potable water. In this paper three options for electric supply to the water pumping system are evaluated: 1) Extension of national electric grid (to 5 and10 kms), 2) Diesel generation sets, 3) PV systems (with system cost 5, 7, 10, and 15 $US /Wp). The cost analysis has been done for determining the cost of the kilowatt hour produced from the three options during the life of the PV systems (assumed to be 20 years), and for two scenarios the first considers the diesel fuel price is equal 250 US$/ton, and a simple interest rate is 6% and the second scenario considers the diesel fuel price is equal 350 US$/ton, and a simple interest rate is 10%. The paper concluded with listing, of priority order of technical alternatives based on comparing the balance costs for each kwh produced during the life of PV system. The opportunity for competition between photovoltaic systems and other alternative systems depends on the price level that photovoltaic systems can achieve. The PV systems are competent with other options when the total cost of the PV system less or equal to 7$US / Wp. On the Other side, most of the Arab countries have remote and deserted areas The paper will come out with estimation of PV systems needed for water pumping during the 10 coming years in ESCWA member countries, which could be a very good opportunity for the application of the PV Systems market.

Keywords: Photovoltaic systems; Water pumping; ESCWA

*ESCWA member countries are: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, and Yeman.

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1. Introduction

Many rural areas in ESCWA member countries are still suffering from a lack of access to energy services, especially electricity supply. Electrical energy supply by extension of the national electric grid to villages and small communities in rural and remote areas, in several ESCWA countries, is very difficult. Photovoltaic (PV) applications could play that role and supply electrical energy needed in rural, remote, and deserted areas for rural electrification, especially for water pumping, to supply the Bedouins and their herds as well as the villagers and their livestock with their needs of potable water.

2. Energy and power capacity needed for water pumping

The evaluation of PV water pumping is related to several factors such as: (1) areas where underground water is available and needed, (2) daily volume of water to be pumped, (3) the pumping depth, (4) site features and climatic conditions, (5) infrastructure and local technical skills, and (6) technical alternatives available for water pumping. The daily electrical energy needed and the nominal power required for different values of the pumping depth H multiplied by the daily volume of water needed V (m * m^3/day) is calculated based on the relation:

$$(W = pgVH/3600 = 0.002725VH \text{ (Wh/day)} \quad (1)$$

p is the water specific weigh, g is the gravity acceleration.

3. Technical alternatives and cost analysis for water pumping

The technical alternative options which could be available to provide electric power for water pumping in the site are:

- Extension of national electric grid (extension to 5 and 10 Km),
- Diesel generation set,
- Photovoltaic systems.

The total costs of a water pumping system include: investment costs (capital costs), and recurrent costs (running and maintenance costs). The cost analysis has been done for determining the cost of different daily pumped water (in m^3) for different pumping depth (in m) given in (m^3 * m) produced from the three technical alternative options during the life of the system which assumed to be 20 years, and for two scenarios; Scenario (A) considers fuel price equal 250 US$/ton and a simple interest rate equal 6%, and

Table 1
Cost of different daily pumped water for different pumping depth produced through extension of national electric grid during 20 years 1 (1 US$/1 m^3 * 1 m/day)

Daily pumped water* pumping depth (m^3 * m/day)	1500		2000		2500		3500		4500	
Scenarios (A) or (B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Distance from the electric grid 5 Kms	1.83	2.39	1.44	1.88	1.31	1.71	1.08	1.41	0.94	1.22
Distance from the electric grid 7 Kms	2.66	3.76	2.20	2.91	1.91	2.53	1.36	2.00	1.27	1.68

Table 2
Cost of different daily pumped water for different pumping depth produced by diesel generation set during 20 years 2 (1US$/1 m^3 * 1 m/day)

Daily pumped water multiplied by pumping depth (m * m^3/day)	1500	2000	2500	3500	4500
The cost according to Scenario (A)	1.65	1.45	1.32	1.24	1.16
The cost according to Scenario (B)	2.05	1.81	1.68	1.58	1.58

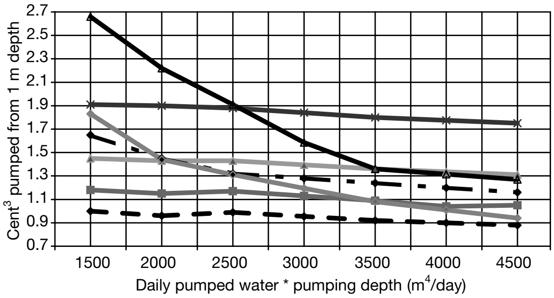

Fig. 1. A comparison of cost of a cubic meter of water pumped by different pumping options (cent/m^3) for Scenario A.

Scenario (B) considers fuel price equal 350 US$/ton and a simple interest rate equal 10%. Tables 1–3 show the results of these analysis.

Figs. 1 and 2 show the comparison of the results of these cost analysis of the three technical options: for scenario (A) and scenario (B) respectively. Table 4 presents the sequence of priority of these three technical options for water pumping.

4. Lessons learned from developing countries experience

Many lessons could be learned from ESCWA member countries and developing countries experience in using water pumping.

In the Badiat of Jordan: PV water pumping systems have an excellent technical, economical and social acceptance from Bedouins when those were used instead of diesel water pumping sets. The reliability of PV water pumping systems leads to the availability of drinkable water all round the year with no need for operator, while for the diesel pumping system operator should be all the time available in the station.

In Brazil: 2867 PV pumping systems were installed, the experience reveals many problems (4). It is not enough to make the financial resource available. It is important to reduce failure in this kind of projects by, adequate information on the local characteristics of the well, quality control of equipment on delivery and in the field with the adaptation of the technology, necessary maintenance for the smooth running of the system and the participation of the user in the process and monitoring of the equipment.

Table 3
Cost of different daily pumped water for different pumping depth produced by photovoltaic system during 20 years (1 US$/1 m^3 * 1 m/day)

Daily pumped water multiplied by pumping depth (m * m^3/day)	1500		2000		2500		3500		4500	
Scenario	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Cost of Wp (5 US$/Wp)	1.0	1.24	0.96	1.22	0.99	1.26	0.92	1.18	0.88	1.13
Cost of Wp (7 US$/Wp)	1.18	1.48	1.15	1.46	1.17	1.50	1.09	1.41	1.05	1.36
Cost of Wp (10 US$/Wp)	1.45	1.85	1.43	1.84	1.43	1.85	1.36	1.76	1.31	1.71
Cost of Wp (15 US$/Wp)	1.91	2.45	1.90	2.46	1.88	2.44	1.80	2.34	1.75	2.29

5. Prospects for PV application in water pumping

Utilization of PV systems in water pumping has increased in the last decade in remote and deserted areas, where no reliable electricity supply is available, due to its importance for health and food production, the natural relation between solar energy and water requirement, no energy bill and minimal operating and maintenance cost. It is estimated that PV water pumping system will be used increasingly in ESCWA MCs till the year 2010 according to the Table 6. The total PV potential estimated for water pumping application in these countries ranges between 10.4 and 15 MWp. This depends on the facilities available for the spread of these technologies and on the extent of socio-economic benefits that can be achieved, when applied. It is expected that these PV systems will power a number of water pumps ranging between 1970 and 2780 pumps.

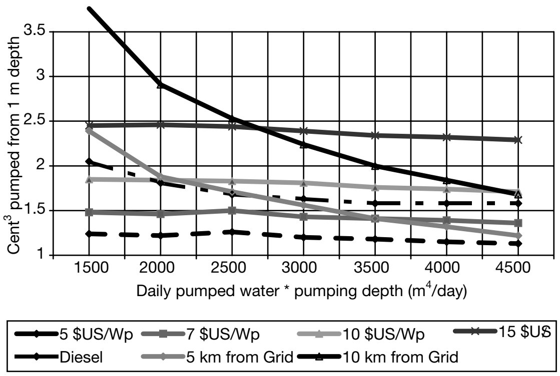

Fig. 2. A comparison of cost of a cubic meter of water pumped by different pumping options (cent/m^3) for Scenario B.

Table 4
Sequence of priority options for water pumping

Scenario (A)*		Scenario (B)*	
Volume × depth	Sequence of priorities	Volume × depth	Sequence of priorities
1500 m^3 * m	– PV systems with 5, 7, and 10 US$/Wp – Diesel generator – Extension of N.E. grid to 5 Km	Up 2000 m^3 * m	– PV systems with 5 and 7 US$/Wp – Diesel generator – PV system with 10 US$/Wp – Extension of N.E. grid to 5 Km

2000 m^3 * m	– PV systems with 5 and 7 US$/Wp
	– Equity of three options:
	  – Extension of N.E. grid to 5 Km
	  – PV system with 10 US$/Wp
	  – Diesel generator (scenario (A))
	– Diesel generator (scenario (B))
	– PV system with 15 US$/Wp
		2000 to 3500 m^3 * m	– PV systems with 5 US$/Wp
			– Diesel generator
			– PV system with 7 US$/Wp
			– Extension of N.E. grid to 5 Km

3000 m^3 * m	– PV systems with 5 and 7 US$/Wp – Diesel generator – PV system with 10 US$/Wp – Extension of N.E. grid to 5 Km		
More than 3500 m^3 * m	– PV systems with 5 US$/Wp – Extension of N.E. grid to 5 Km – Diesel generator – PV system with 7 US$/Wp – Extension of N.E. grid to 10 Km	More than 3500 m^3 * m	– PV systems with 5 US$/Wp – Diesel generator – Extension of N.E. grid to 5 Km – PV system with 7 US$/Wp

Table 5
Status in 1999 and prospects for the PV applications for water pumping in ESCWA member countries till 2010

Country	Status in 1999		Forecasted till 2010	
	No. of Applications	Capacity (KWp)	No. of Applications	Capacity (KWp)
Bahrain	1	3.00	10–20	50–100
Egypt	8	22.00	1500–2000	7500–10000
Iraq	1	7.50	50–100	300–600
Jordan	24	103.28	70–100	350–500
Kuwait	–	–	–	–
Lebanon	–	–	10–20	50–100
Oman	2	9.55	30–50	180–300
Palestinian Authority	1	0.53	20–40	100–200
Qatar	–	–	–	–
Saudi Arabia	n.a.	n.a.	150–200	750–1000
Syrian Arab Republic	2	5.75	50–100	500–1000
United Arab Emirates	–	–	30–50	150–250
Yemen	n.a.	n.a.	50–100	500–1000
Total	39	151.61	1970–2780	10430–15050

Source: Estimated values, n.a., information not available; –, Application does not exist. It is estimated that PV capacity needed for a water pump is 5–6 kWp.

6. Conclusion

The opportunity for competition between photovoltaic systems and other alternative systems depends on the price level that photovoltaic systems can achieve. The PV systems are competent with other options when the total cost of the PV system less or equal to 5$US / Wp. This applies for all volumes multiplied by the depth and for both scenarios (A&B). However, when the volume * depth is up to 2000 m^4 PV system with 7$US/ Wp is suitable. On the other hand, it is estimated that PV applications for water pumping in ESCWA MCs could increase till the year 2010 to become10.4 to 15.0 MWp, that depends on the facilities available for the spread of these technologies and on the extent of socio-economic benefits that can be achieved, when applied.

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