Energy Resources: Case Study

1. INTRODUCTION

The provision of adequate water supplies to households in underdeveloped rural areas remains a crucial area of concern in South Africa. In a vast and relatively dry country like South Africa, the satisfaction of basic water needs is for many people, a daily struggle [1]. This leads to poor conditions and, in extreme cases, the migration of the rural population to urban centres [2]. Considering the importance of clean, disease-free water in all fundamental human activities, there can be no doubt that lack of an adequate water supply acts as a major constraint to the development of rural communities. The rural regions of the Northern Cape in South Africa are a good example of an area facing this problem. Therefore, in order to facilitate the collection of potable water, various types of water pumping technologies have been employed in the past.

Of the systems used, photovoltaic (PV) and diesel groundwater pumping systems have been in operation, and in most cases, have been successfully supplying rural communities in the Northern Cape with drinkable water. Although both pumping technologies have their merits, there still exists a need to perform a thorough long-term field study of PV systems in the rural Northern Cape regions.

As an attempt to test and assess the reliability and capabilities of the PV system, a research project was initiated at CPUT in the department of Mechanical Engineering. The project was divided into two phases. Phase 1 involved the development of a PV pilot water pumping system in order to conduct laboratory assessments and preliminary tests for monitoring a PV station prior to implementation in the field. The system consisted of data acquisition devices that collect data and store it. Phase 2 was concerned mainly with establishment and implementation of an actual telemetry link.

2. CASE STUDY

Lepelsfontein is a small village in the Northern Cape, some 500 km north of Cape Town in South Africa. It has a population of roughly 450 people. The physical infrastructure comprises gravel roads, manual telephones and a primary school. The water supply system in the Lepelsfontein area comprises a number of sources. The main source is groundwater from a borehole.

A three-phase PV submersible centrifugal pump is used to pump water. There is also a diesel pump which is used as a back up to the PV pump in the event of PV pump failure or in times of extended cloud cover. The PV system is situated about 2 km to the south west of Lepelsfontein village. The PV pump operates seven days a week. A diesel pump becomes operational only when PV pump is not working (when it is faulty, being maintained or during extended cloud cover). Water is pumped to 2 storage tanks located in the village. Each storage tank has a capacity of 30 kl.

Water from storage tanks is gravitated to a diesel pump located at about 300 m down the hill. Purifying/desalinating chemicals are added before water is pumped to the supply tanks. Water has to be desalinated as it is being claimed that the sea, which is about 10 km to the south east of the settlement, affects the quality of underground water and therefore it is not readily available for consumption. There are four supply tanks of 10 kl each located at about 400 m from the diesel desalinating pump house uphill. Water from the supply tank is gravitated to the village and is accessed through standpipes.

The PV water pumping facility at Lepelsfontein comprises three subsystems namely, a set of PV panels, an inverter and a three-phase submersible centrifugal pump.

2.1. Field results

The results presented in this section are obtained from the Lepelsfontein PV water pumping system. The data logger captured the information from the 03/12/04 to 02/02/05. The results shown below are the results captured only when the pump was in operation.

2.1.1. Array efficiency vs irradiance

Efficiency of an array is the amount of solar energy the module can convert into electrical energy. Figure 1 shows the efficiency of the array at different times of the trial period. The array efficiency is dependant on several factors such as; time of day, weather conditions, wind speed, and irradiance as well as the temperature of the array. The maximum array efficiency obtained was 3.9%. The obtained efficiency of 3.0% is quite low and the discrepancy of the results at high solar intensities is in part attributed to the temperature effects of solar cells at elevated cell temperatures. These high temperatures increase the irradiance power thus having a negative impact on array power generation. If the assumed optimum efficiency point of the pump is considered, the expected array efficiency of 22% can be taken, which will affect the overall system efficiency proportionately. At the operating condition of 2.6 m^3/day, the efficiency is as low as 15%.

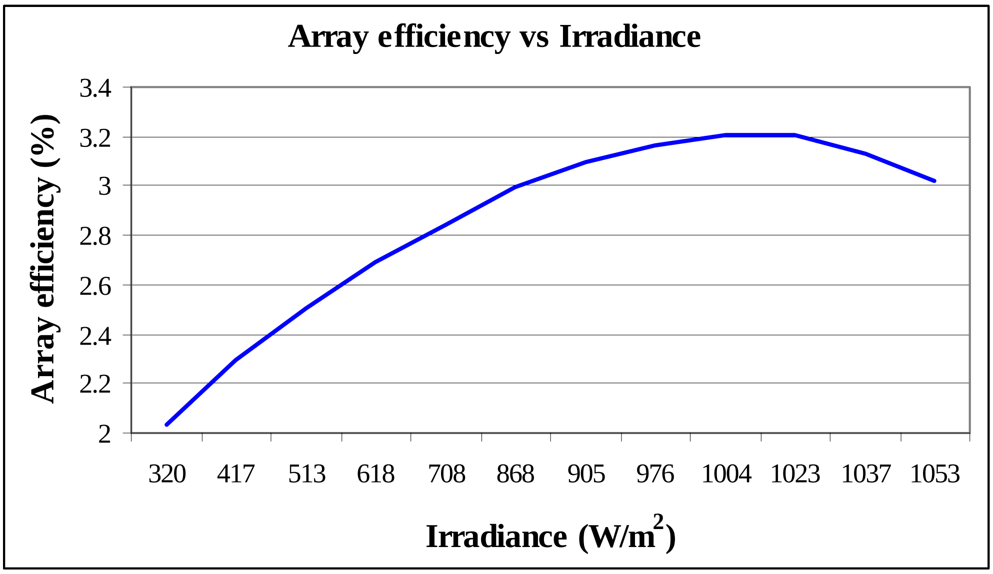

Figure 1: Array efficiency versus irradiance

2.1.2. Overall efficiency vs time

The overall efficiency of the system is determined by the power delivered by the pump and power from the sun (irradiance power). Figure 2 shows the efficiencies ranging to a maximum of 3.2%, which is acceptable when one considers an overall system efficiency of 3% and 4% from the Intermediate Technology Development Group Manual [3] and other literature.

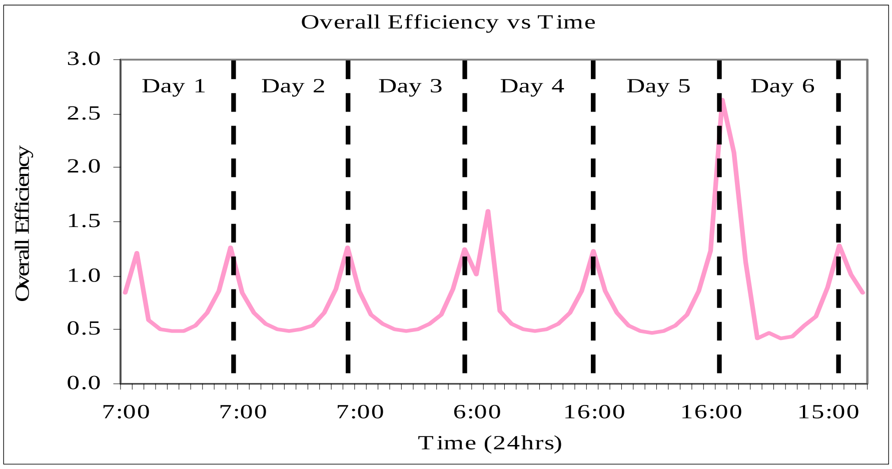

Figure 2: Overall efficiency versus time

A summary of the field results (actual and design) is shown in table 1 below.

Table 1: Summary of field results

Component	**Array**	**System**	**Overall**
Actual efficiency	4.0%	32.0%	1.3%
Design efficiency	20.0%	30-40%	6-8%

2.1.3. Economic results and analysis

In order to establish whether this PV pumping system is economically viable when it is compared with other pumping technologies, the results from this system were used to perform a life cycle costing and a comparison was made with a comparably-sized diesel system. A 15, 20, 25 year life-cycle costing of the field PV and diesel systems was performed and the actual results are presented in table 2. Included in the analysis, is also a prediction of unit (R/m^3) and pumping costs (R/m^4) if design conditions were achieved, i.e. flow of 20m^3/day. Figure 3 below shows the comparison of PV actual and diesel systems cumulative and energy costs.

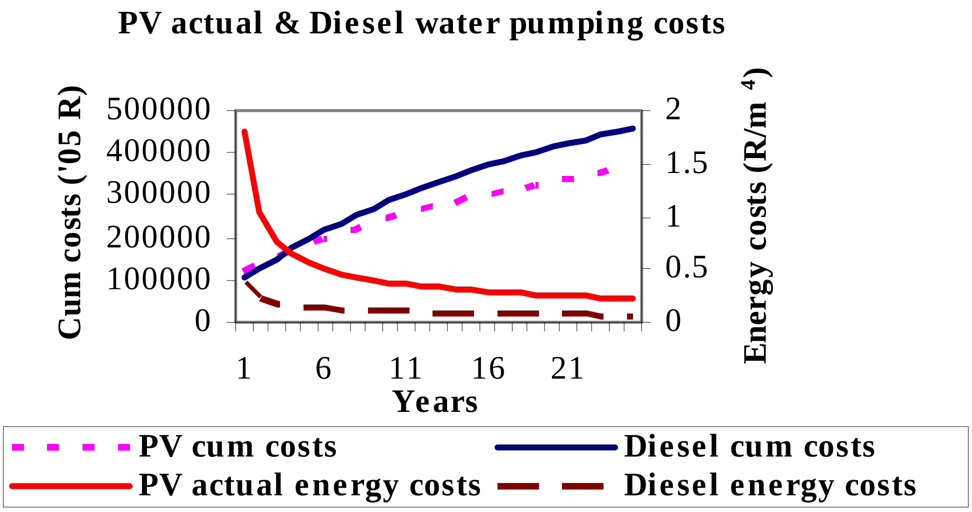

Figure 3: PV actual & diesel systems cumulative & energy costs

The life cycle cost analysis of the PV pumping system indicates that the average pumping costs over 25 years are likely to be below 22 cents/m^4, while pumping costs of diesel are likely to be below 7 cents/m^4 when the pump operates at 3.6m^3/day.

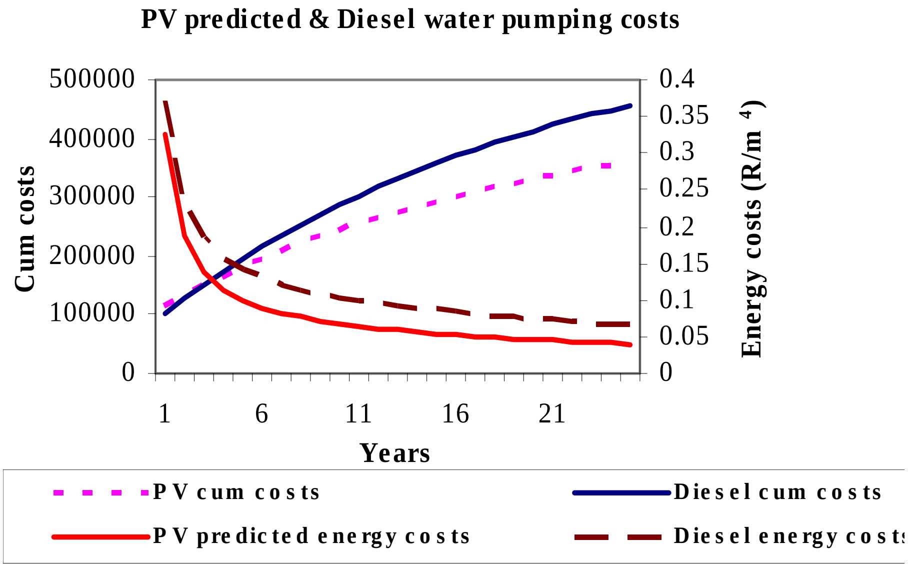

Figure 4: PV predicted & diesel systems cumulative & energy costs

However, if the pump operated at its optimum design conditions (20m^3/day), then the pumping costs of PV would reduce to 4 cents/m^4, 43% less than that of diesel (figure 4).

From the two water-pumping technologies, the unit water cost for Lepelsfontein is about five times the unit cost of Rooifontein. These could be caused by a number of factors, including a high capital cost for Lepelsfontein, very low pump output as well as high operating costs (salary of a pump caretaker). The pumping costs for Lepelsfontein are about three times higher than those of Rooifontein. In contrast, the unit water cost is 90% that of diesel and the pumping cost is about 60% that of diesel when the design conditions for PV are assumed.

Table 2: Summary of PV and diesel life cycle (LCC), unit (UWC) and pumping (EC) costs

	PV					**DIESEL**		
Yrs	**LCC (R)**	**UWC @ 3.6m^3/day**	**UWC @ 20m^3/day**	**EC @ 3.6m^3/day**	**EC @ 20m^3/day**	**LCC (R)**	**UWC @ 21m^3/day**	**EC @ 21m^3/day**
15	293207	R15.08/m^3	R2.72/m^3	R0.302/m^4	R0.054/m^4	358310	R3.12/m^3	R0.087/m^4
20	331390	R12.79/m^3	R2.30/m^3	R0.256/m^4	R0.046/m^4	413656	R2.70/m^3	R0.075/m^4
25	361024	R11.14/m^3	R2.01/m^3	R0.223/m^4	R0.040/m^4	456611	R2.38/m^3	R0.066/m^4

3. CONCLUSIONS

The findings of this study do support the existing body of evidence, which indicates that PV pumping can be competitive with diesel water pumping under specific head and flow conditions. However, the results obtained in this study are short-term results, making it difficult to make valid judgements with regard to how this system behaves in the long run. Yet the socio-institutional implementation strategies are crucial to the techno-economic success of actual pumping schemes. Even if diesel generators or other conventional pumping systems may appear to be cheaper on a life cycle cost comparison, it might be preferable to opt for a PV system because of the operational advantages. Future work will evaluate a larger number of systems and eventually record long-term results which will be used to assess the reliability and functionality of the systems [4].

4. REFERENCES

1. Omar I. & Law S., *Energy Alternatives for the supply of water in Namaqualand,* Energy Research Institute, University of Cape Town, 1991.

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3. Intermediate Technology Development Group. *Solar (Photovoltaic) Water Pumping*, URL: http://www.itdg.org/docs/technical_information_service/solar_pv_waterpumps.pdf

4. Makhomo S R., *Remote Monitoring and Evaluation of a PV groundwater pumping system in Namaqualand*, unpublished MTech dissertation (2005), Department of Mechanical Engineering, CPUT, Bellville, South Africa.