# Turning sunshine into water: PV water pumping in South Africa

**by Richard Gosnell**

**South Africa has abundant sunshine, but little water. Could photovoltaic (solar-electric) water pumping transform this sunshine into much needed water supplies? The performance of a photovoltaic (PV) pump installed at Sondela Community Garden — a vegetable garden run by 46 Zulu women in a semi-rural area — is assessed.**

THE APPROPRIATENESS of PV pumping depends largely on the circumstances of the community under consideration: their level of technical expertise, access to finance, and remoteness from the national electricity grid. This means that there are a good number of situations in which PV water pumping is the best solution.

At Sondela, the introduction of the pump almost doubled the productivity of the gardeners, largely because of the time saved. Because the gardeners have time to farm more intensively, and because there is sufficient demand for their produce, the introduction of pumps in other similar community gardens should be considered a high priority. The gardeners interviewed indicated that they would prefer a PV pump to a diesel pump, even if it was more expensive. Unfortunately few, if any, community gardens would be able to raise the initial capital to buy a PV pump. Thus the successful dissemination of PV pumps will depend on a financing and maintenance scheme backed by a large organization. The South African Electricity Supply Commission has recently proposed a scheme that may meet these needs.

## Effect on productivity

The annual amortized cost of the pump at Sondela was small in comparison to the extra income the garden generated, and thus introducing the pump reduced the profit of the gardeners only marginally (by three per cent on the conservative assumption that the volume of produce would remain the same). While the profit from the garden was reduced marginally, however, the time spent in the garden was halved. This resulted in the gardeners' productivity almost doubling, from US70 cents/hour to $1.30/hour.

Because work in the garden is far more financially rewarding for the plot holders than either formal employment locally or most types of craft work, pumps should be introduced to allow the women either to farm their existing plots more intensively (for which there is scope), or to farm a larger area.

Gardening is a crucial survival strategy for these women because of their extremely low incomes. Each household's plot represents an effective income of $285 per year, which increases their earnings by 30 per cent (the average annual income is $930). Doubling the productivity of the gardens would thus have a large effect on the prosperity of the gardeners.

## PV versus diesel

From the above it would seem to make economic sense to introduce pumps to gardens similar to Sondela. But what type of pump should be used?

Pumps connected to the national electricity grid have many advantages: they are low risk (as the tariffs are known), low maintenance, and low capital. The costs of this option increase rapidly, however, with the distance of the site from the grid; and this option is not economic for remote sites which have low energy requirements.

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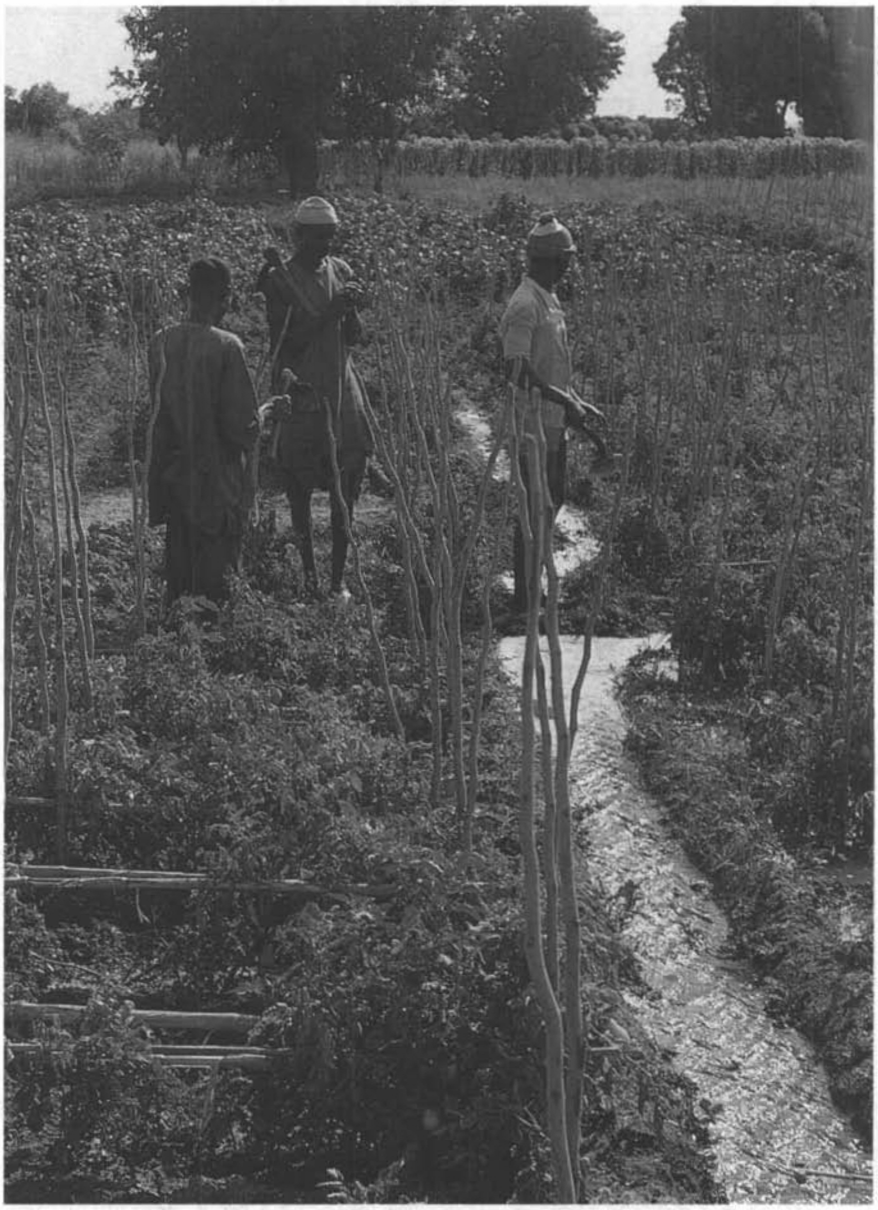
*In some circumstances PV pumping can be the most appropriate way to improve people's access to water.*

So unless this type of site is particularly well suited to a gravity-fed system from a spring, a hydraulic ram, a wind pump, rainwater harvesting, or a hydro-powered pump, one is left with the choice between PV and diesel/ petrol.

After more than four years of using the PV pump in their garden, the gardeners were interviewed in depth to assess their feelings about PV pumps and to determine whether they would prefer a diesel pump. The practical implications of each pump were discussed in depth, and then the gardeners were given three scenarios of the amortized costs of PV versus diesel pumps for their garden. All of the interviewees said they would prefer a PV pump to a diesel pump, even if its amortized costs were up to twice those of the diesel pump. The main reasons cited were the reduced trouble and expense of maintaining the PV pump, and the trouble of collecting diesel (which could take a morning's travel, including 1.5 hours of walking).

This preference expressed by the gardeners is given more weight by the fact that the interviewees had experienced most of the problems that a PV pump is vulnerable to. Early in the project, the PV pump was washed away when the river it drew water from experienced the worst flood in living memory. A new pump was then installed well above the 100-year flood mark. Within a few months, two of the sixteen panels had been stoned, and soon after that eight panels were stolen. In order to guard against theft a simple, robust alarm system was installed and the panels were locked into their frame. After testing the amount by which a fence over the top of the array reduced the array efficiency, it was recommended that a fence be installed to act as a deterrent against vandalism. All the precautions taken (including the increased costs of using a safer site) did not increase the total cost of the pump by more than 10 per cent.



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*A community garden is unlikely to be able to afford PV equipment, but a financing system that will enable the gardeners to do so will have a dramatic effect on their productivity.*

## Economic competitiveness

If the life-cycle costs of each method of pumping are calculated for a project length of 20 years (with capital, maintenance, running, and replacement costs included) it is found that PV pumps are at the moment twice as expensive as diesel pumps at low hydraulic heads (around 40m$^4$/day).[1] (As noted above, however, PV pumps may well be preferred to diesel pumps in remote areas up to twice the amortized cost.) But none of the low-cost PV pumps presently available in South Africa are efficient at low heads (around 12 metres) because they all use positive displacement pumps. Thus the competitiveness of PV pumps could fairly easily be improved by using a well-matched centrifugal pump for these heads instead; and perhaps by the use of passive solar tracking, which could increase the usable output of the array by 20 per cent. The cost of water from PV pumps which conform to this 'best case' would be less than twice that from diesel pumps for the full range of hydraulic heads considered (40 to 1400m$^4$/day).[1]

## Dissemination barriers

While a community garden may prefer a PV water pump to a diesel pump, few, if any, community gardens would be able to raise the initial capital for it. It would be almost impossible for a community garden to budget fairly for the pump, considering that it has a changing membership and that the lifetime and recurring costs of the pump are not accurately known. (Only 11 per cent of the gardeners at Sondela had more than a primary school education.) PV pumps are also inherently a high-risk option — expensive equipment is necessarily left in the open with little natural protection.

So unless some large organization provides the initial finance and organizes the maintenance and budgeting for the pump, PV pumps are not recommended for low-income gardeners. A recent scheme proposed by the South African Electricity Supply Commission provides a model for how the financing of PV pumps could work. The scheme suggests that if PV power is cheaper than extending the grid, then the commission should offer to supply a PV system to the customer on a similar basis to that which they supply grid electricity: the commission should put up the capital, guarantee the supply of power, and provide maintenance for

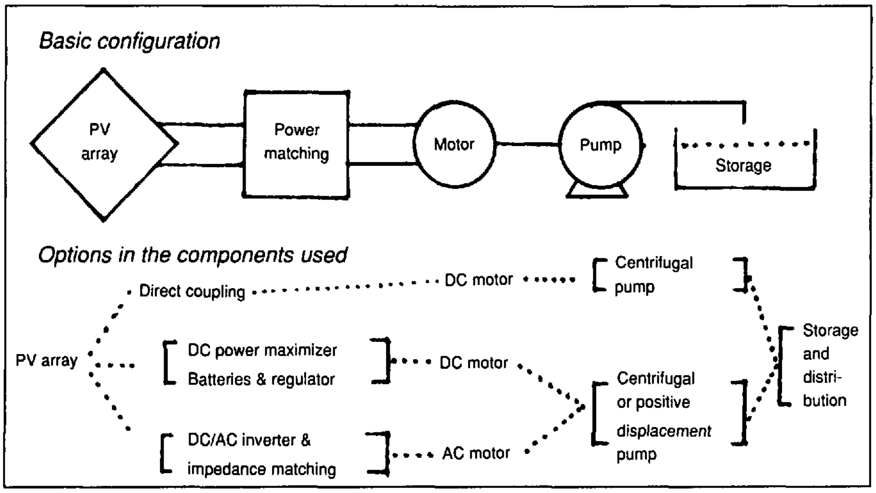


*Figure 1: Possible configuration of a PV pumping system*

the PV system. The commission would then charge the customer monthly tariffs to recover its capital, maintenance, and replacement costs.

The implementation of a policy similar to this would dramatically increase the viability of PV water pumping for low-income groups. It removes the major barriers to buying a PV pump — the high initial capital required, the problems of budgeting and organizing maintenance, and the risk of the loss of an expensive system. The electricity commission requires a high rate of return on its capital, however, and if some other body were able to offer more favourable terms, the outlook for PV pumps would be further improved.

Experience from the case study provided useful guidelines on some of the choices that must be made if a PV pump is to be used.

## Irrigation requirements

Before choosing a pump, the siting and size of the garden should be carefully considered. The cost of pumped water for all pumps drops dramatically as the water demand increases from 3m$^3$/day to 30m$^3$/day. For example, the computed cost for the PV 'normal case' drops by 64 per cent over this range, while that for the diesel 'normal case' drops by 75 per cent. As the water demand increases further (above 30m$^3$/day) the cost of water continues to drop, but more gradually.

One of the most interesting findings of the study was that the gardeners used much less water than is regarded as the optimum by Northern farmers — yet their vegetables grew well, and there was no sign of wilting. It can only be concluded that the women applied the water very efficiently and so required less water. The water usage at Sondela community garden was measured as 5100 litres/ha/day during the winter months after the PV pump was introduced. Conventional estimates of 1in./ha/week would have predicted a requirement of 34 000 litres/ha/day. If this latter figure for water demand had been used, the pump chosen would have been grossly oversized and very expensive.

## Selection of components

A PV pump includes a PV array, possibly a power maximizer or batteries, a motor, a pump, and possibly storage facilities for the pumped water. Some of the possible configurations of these components are shown in Figure 1.

The PV array produces a direct current, so a DC motor is necessary unless a DC-to-AC inverter is used. The array may be directly coupled with the motor or a power maximizer may be used. If the array is directly coupled to the motor a centrifugal pump should be used, otherwise either type of pump is suitable. The choices which need to be made for each component are discussed in turn below.

If the array physically tracks the path of the sun, measurements indicate that about 20 per cent more radiation will be absorbed than if the array were fixed. Passive tracking devices are now available that are likely to be cost effective for many applications.

## Power maximizers

Power maximizers are electronic devices which match the electrical characteristics of the PV array with those of the rest of the system. They are necessary if a positive displacement pump or a badly matched centrifugal pump is used. Batteries can also provide a degree of power matching, but the pumping system is likely to be cheaper and more robust if energy is stored as pumped water rather than in batteries.

Three methods commonly used by power maximizers to track the Peak Power Curve of the array were evaluated.

1. Tracking a fixed array voltage: this method is not recommended because it does not cope well with unforeseen problems like hot spots in the array and shading of the array.
2. The maximizer can set the array voltage to a constant proportion of the open circuit voltage (e.g. $V_a$ = 80% $V_{oc}$). This method has a tracking efficiency near 100 per cent if the correct proportion is used, and it copes well with array hot spots and with shading.
3. 'Intelligent' searching: A maximizer using this method constantly hunts for the Peak Power Curve. If implemented properly this method gives a tracking efficiency of effectively 100 per cent under all conditions. Method 2 may, under some circumstances, be cheaper and as effective.

The power maximizers required for a DC system are simpler than those for an AC system, thus a DC system should be preferred unless the efficiency and reliability of the AC power maximizer has been proved. If it has, an AC system could be preferable as there are no brushes involved and high motor efficiencies can be achieved if both the frequency and voltage to the motor are varied.

Centrifugal pumps tend to be the best suited to low heads (less than 10 metres), while positive displacement pumps (including piston, mono, and diaphragm pumps) are better for higher heads (higher than 20 metres). Between 10 and 20 metres either type of pump may prove to be the best. Any pump used must be submersible or self-priming. Submersible pumps are to be preferred because most self-priming mechanisms reduce the pump's efficiency (venturis can increase the head by eight metres).

PV water pumping has the potential to transform one of South Africa's most abundant resources, sunshine, to one of our most needed, water. It could be the most appropriate method to supply water to a significant number of remote sites, if only there were a satisfactory method of financing. ●

## Notes

1. The hydraulic head is the product of the water requirement (in m$^3$/day) and the height to which the water is lifted (in m).

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