Aquarius
Technical Issue Paper 1

Solar Powered Water Pumping Systems

The purpose of *Technical issue papers* is to provide an easy and up-to-date point of reference on technical issues relevant for humanitarian interventions through the consolidation of field experience and current research.

They aim at providing information to assist in funding decisions and monitoring of humanitarian projects and not at providing definitive answers.

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This *Aquarius technical issue paper* has been prepared by the Aquarius group of Watsan Technical Advisors of DG ECHO and has been compiled by Benoit Collin.

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The Aquarius technical issue papers are available on the Aquarius website : http://www.cc.cec/dgintranet/echo

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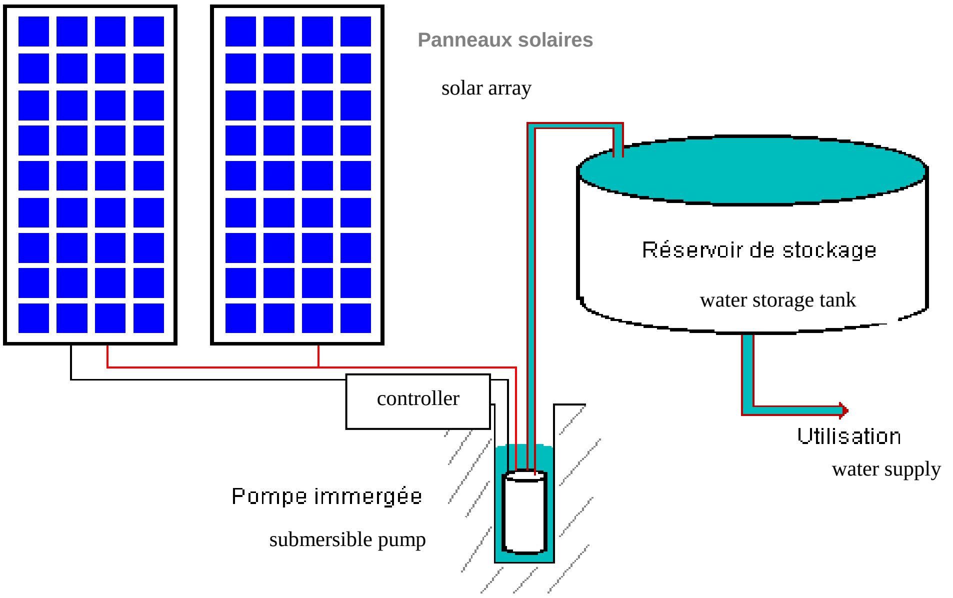
Overview of the technology



Basic Operation

- A solar system comprises: 1- stationary or tracking solar array; 2- controller; 3- electric motor and pump.
- The system pumps water with the use of power generated by the sunlight.
- Solar electric cells convert sunlight directly into DC power (*photovoltaic process)*
- The controller converts the variable DC voltage into three phase voltage to run a pump. A converter can be added to convert DC in to AC (Alternating Current).
- The production of electricity depends on the surface of photovoltaic modules exposed to sun light and on the light intensity, the hours of sunshine, the cell temperature. Production depends then mainly on the meteorological conditions and greatly varies with latitude, seasons and location.
- The energy can be used directly by the pumps, or stored in batteries to allow pumping when there is no light. Batteries add to the cost of the system; alternatively and for continuous water supply, water can be stored in tanks for use when there is no sunlight and/or during peak hours.
- The submersible pumps used with solar systems are similar to the ones used with fuel generators systems but the engine has been adapted to allow pumping at low speed in case of low level of sunlight.

Main Advantages

- Solar systems are reliable and easy to use
- They need little regular maintenance, they do not use any fuel reducing daily recurrent costs.
- The systems are set up in modules, allowing increase in number of panels, following population increase and increase in demand of water.
- They can be a real alternative solution for remote communities where there is no regular supply of fuel.
- The equipment is durable and can be expected to last: 25 – 30 years for the solar arrays; 7 – 10 years for the controller; 5 – 10 years for the motor, as for any other submersible pump. The expected lifespan of the solar arrays is much longer than that of a generator.
- Use of batteries in the system increases the costs of the solar system unnecessarily. It is preferable instead to increase the water tanks storage capacity so that water can be supplied at any time of day, using off-peak demand periods to fill the tanks.

Panels on solar tracking array

Detail of connection between solar tracking array and controller

Solar system controller

Main Disadvantages

- The initial cost is high compared to fuel powered pumping systems.
- Solar systems offer less flexibility in terms of daily flow compared to generator systems. Especially, where high flow is required for peak periods and storage capacity is limited.
- The pumping rate (and hence volume pumped) depends very much on climatic conditions and is generally low compared to other systems.
- The technology is not yet common so spare parts are not widely available and installation and repair need specific skills (there needs to be a critical mass of systems in place to create a market for spares and repair services).
- Solar panels are highly desirable and there is a risk of theft of solar panels especially in areas without mains electricity supply.
- While regular maintenance may not be needed, pump repair (as for any other system) / change of controller and/or solar panels are very expensive so a management system has to be put in place to ensure that funds are available when repairs and replacements are needed. The long interval without use of the funds makes users reluctant to make regular contributions.

Lessons Learnt:

- on the Feasibility

The feasibility of using solar power for pumping ground water is not always established before the system is installed. This leads to disappointment from the beneficiaries when the supply does not meet their expectations. Key lessons learnt in establishing feasibility includes:

- Solar may not be the best option, and alternative power systems are available
- It is important to calculate the solar radiation available and select the number of panels accordingly to provide enough power to drive the pump.
- The feasibility of the solar option has to take into account the volume of water required per day (demand) and the total height of pumping necessary (from the water level in the borehole to the raised storage tank). If either of these is too high (e.g number of users > 2000) solar powered pumping is most likely not the preferable option.

- on the Installation and Maintenance

- The high establishment cost of the system is borne by the donating agency. But reducing the operation and maintenance burden to occasional high repair costs rather than regular maintenance costs may undermine the motivation of users to pay regular users fees.
- Modern solar systems automatically turns the solar arrays with the sun during the day (tracking), always optimizing the absorption of sunlight by the array. The output energy improves considerably using such tracking systems and fewer panels are required.
- Solar systems are not totally maintenance free, systems will break down. Given the uniqueness of the technology, more than for any other energy supply system; there is a need to have already spare parts and technical expertise for the maintenance available in the region where the system is going to be installed.
- Maintenance should not be considered as free of costs for the communities, as there will be a need to replace the controller and the pump over the time. There is a tendency to present a solar system free of maintenance costs as an advantage, but such an approach would create a high risk to see the system being badly maintained as it will not require regular attention by the beneficiaries (fuel, spare parts, etc.)
- In term of possibility for sustainability, the message needs to be clear: ***compared with conventional water delivery technologies, solar technology requires a community to be more committed to contributing funds to meet the occasional high cost of repair and replacement parts.*** The necessary capacity building component should be clearly visible in the proposal submitted by the partner.
- Water storage capacity can be increased to provide water to meet 1 or 2 days of demand, the panel surface extended (additional 30 % compared to the needs) and a solar tracking array can be selected / installed to ensure that water will be available even at time when solar radiation is not maximum (rainy season) or when it decreases (important demand of water in morning and during late afternoon hours)
- If needed but pending on the type of submersible pump installed, a small generator can be added to the system to allow continuous pumping in emergency.

References:

- *Photovoltaic water pumps – GTZ Technical information E4e / Andreas Hahn - 2000 – 4p.*
- *Water lifting – SKAT / Erich Baumann – 2000 – p. 28-29*
- *Water, Sanitation and hygiene for population at risk – ACF – 2005 – p. 348-349*
- *Solar (photovoltaic) water pumping – ITDG technical brief – 9 p.*
- *Engineering in Emergencies – RedR / Jan Davis & Robert Lambert – 2002 – p 450-451*

Recommendations for Use in ECHO Funded Operations

The support of for solar pumping system in emergency or post emergency context would only be justified if certain conditions are met:

In general

The water availability in the well/borehole should be adequate for the installation of a submersible pump[1]: the partner has adequately calculated the yield of the borehole, checked the depth of the water level in the borehole, the demand of the beneficiaries (volume of water required per day) and established the relative efficiency of a solar powered system compared to a hand pump or fuel powered system.

Specifically:

1. **On the population and water demand**: The number of users < 2,000 beneficiaries or the hydraulic burden[2] (water demand x total height of pumping necessary from the water level in the borehole to the raised storage tank) < 2000m^4. The population and then, the water demand evolves in the time, the design of the system should be able to follow this evolution.
2. **On the sustainability of the system**: Availability of spare parts and technical repair services with adequate skills is assured in the country.
3. **On the sustainability of the system** (cont)**:** The software component of the project will adequately prepare the users to take on responsibility for the high cost of repairs in future, as solar water supply systems are exposed to the same risk of pump breakdown than any other water supply system a using submersible pump.
4. **In IDP / refugees camps**: High yield solar powered water supply systems are installed in a permanent structure / facility (i.e. not intended only for temporary use by refugees or IDPs). The advantages of such solar pumping regarding cost effectiveness can only be realised over the long term
5. **In case the water demand can fluctuate greatly during the year**: The daily flat energy supply rate of the solar system might not meet the pumping demand of users during a peak period (e.g. drought). Generator pumping systems are better in this context.

Comparison of Investment Costs:

- A kit with the submersible pump and the generator for a yield of **200m^3/day at 60 m deep** (8 hours pumping) costs around 10.000 €. *(source: ICRC catalogue - 2005).*
- A kit with the submersible pump and the solar system for a yield of **22m^3/day at 35 m deep** (flat yield) costs around 13.500 €. *(Source COOPI in Aloi camp, Uganda – 2005)*.
- Under the same conditions of yield and total height of pumping, a solar system providing **6m^3/hr** would have an initial cost of 14.700 € while a generator system for the same water supply system would initially cost 8.700 €. *(Source: Concern in Awere camp, Uganda – 2006).*
- Under the same conditions of yield and total height of pumping, a solar system providing **8.75m^3/hr** using 2 wells (and pumps) would have an initial cost of 30.500 € while a generator supply system for the same water system would initially cost 15.250 €. *(Source: Concern in Pajule camp, Uganda – 2006).*

NB: in the last two cases, the daily volume of water potentially available using solar systems would also be less, compared to generator systems.

Comparison of Costs vs Time:

See the graphs annex. Assumption made for fuel powered system: 3ltrs/hr of diesel consumption; filters changed every 250 hrs, same maintenance costs for the pump for each systems; same manpower-caretaker costs, pumping time is 6 hours daily to match the solar system activity, same water – gravity conditions.

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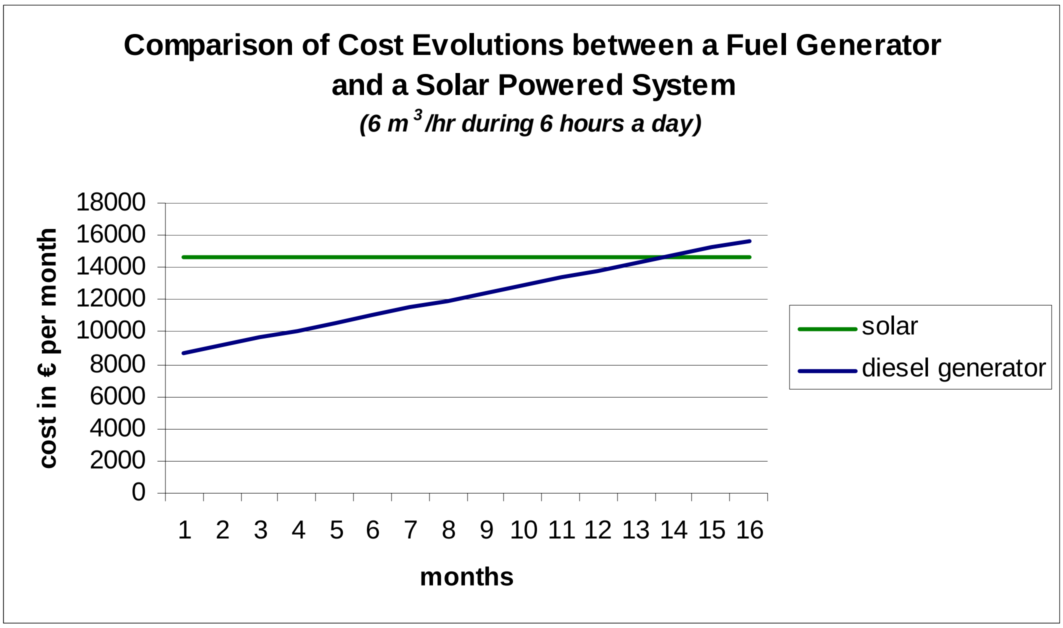
[1] *As a rule of thumb, a yield which is lower than 1.5 m^3/hr should lead in priority to a hand pump installation rather than to a submersible pump.*

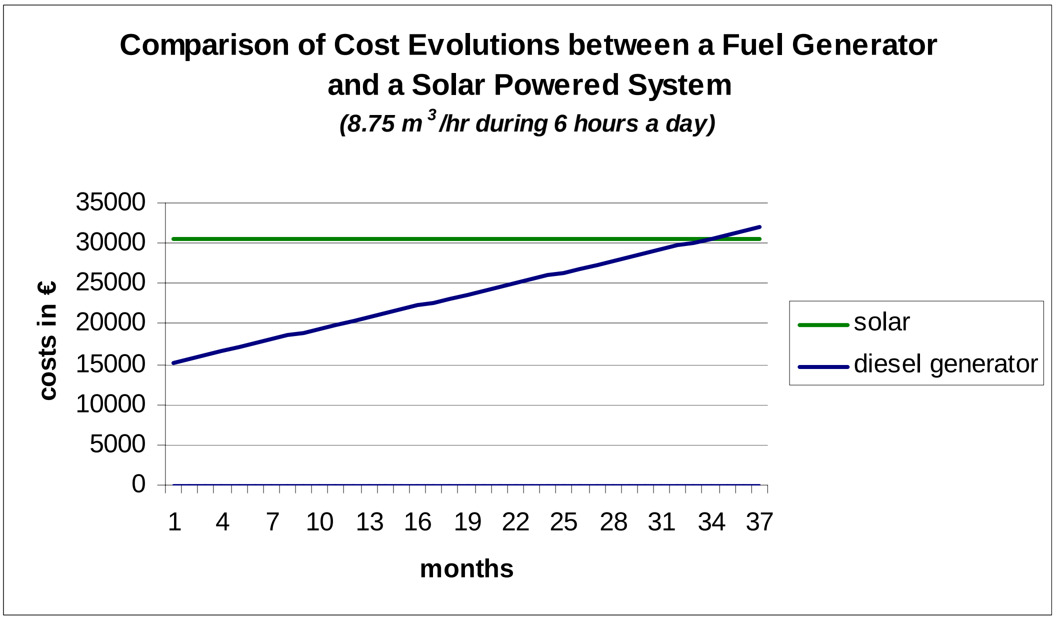
[2] *The formula for calculation of the hydraulic burden (HB) is: daily volume (m^3)* **x** *Total Height (m)= HB (m^4)*

ANNEX 1:

In the conditions corresponding to the description of the assumptions made, a break even point is reached after approximately 1 year at 6m^3/hr, 6 hrs pumping a day[3]; or 2.75 years at 8.75m^3/hr, 6 hrs pumping a day and; in line with the first condition mentioned in the recommendations, the higher the water demand, the longer it takes to reach a break even point regarding cost – effectiveness between the 2 types of power supply.



<u>Source:</u> *Concern - water supply system for Awere IDP camps - Uganda - 2006*



<u>Source:</u> *Concern - water supply system for Pajule IDP camps - Uganda - 2006*

[3] *The pumping time for the diesel powered system has been put at 6 hours daily to match the solar system activity*