Cost-effectiveness Analysis
for
Solar Pumping System

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Introduction

The analysis is based on:

- Economic appraisal
- Technical and operational considerations

The parameters required for the economic appraisal will often be uncertain or variable, and some "costs" and "benefits" may not be considered because of the impossibility of their financial quantification. For instance, reliability and ease of use of the pumping system, availability of spare parts and maintenance skills, vulnerability to theft are some factors which have costs implications, but which are difficult to quantify into a cost analysis. At the same time, the emergency context is another factor which should be taken into consideration, but the relief provided by emergency projects is not possible to express in monetary value.

For this reason the analysis will be conducted appraising also technical and operational factors in order to obtain the most cost-effective system.

Taking into account the economic appraisal and the technical and operational considerations, cost-effectiveness analysis will be focused on the following criteria:

- Effectiveness in terms of degree of achievement of stated specific objective.
- Efficiency: cost, speed and management efficiency with which inputs are converted into results and the quality of results achieved considering financial cost (life-cycle costs and benefits), human resources (staff, contractor) and time/duration.
- Acceptability by donors, institutional and social actors
- Sustainability taking into consideration the following aspects: institutional/line governmental bodies, environmental, technological, financial/economic soundness and long term risks.

Solar pumping system

The already accomplished Coopi Project in Aloi Camp, Lira District, where a solar powered borehole was constructed with the objective to increase the access to safe water for IDPs, will be our case-study in order to assess outputs coming from the implementation of such a pumping system. The main assumption which has affected the project achievement is the potential of groundwater in Lira and broadly speaking in Lira District. In fact, the aquifer of that area has an average yield of 2.5 cubic meters per hour. The borehole yield is the initial parameter to be kept in mind.

Effectiveness

The project objective was to supply a minimum quantity of safe drinking water aiming at reducing the morbidity of water and sanitation related diseases. In Aloi the project objective is achieved with supply of 10 litres of water per person per day.

Efficiency

Despite the first cost or capital cost is high in comparison to petrol, diesel and electric motor driven pumps, this system requires no fuel to run the pump and little or no maintenance as recurrent costs (operation and maintenance costs). With regard to operation, it is ideal for remote or unattended locations since there is no need of pump or motor attendants.

For a better understanding of life-cycle costs and benefits, cost-benefit analysis is the technique used for making the economic appraisal and the results are contained in ANNEX 1. *Discounted Cash Flow* is the method used to compare the notional value of money in the future with its value today. Therefore, the life cycle costs and benefits are discounted to their present value using 10% discount rate. The hypothesis are: a) system size of 1200 watts; b) the lifetime is 10 years; c) pumping system delivers 40000 litres of water per day; d) there is no cost of operation and maintenance except the replacement of the pump and controller by half of lifetime's pumping system. To be worthwhile, a pumping system's *net present value* should be positive. The cost-benefit analysis assumes two types of payment which may be interpreted as water fees applied during emergency phase and development phase. During the emergency, the water fee equals to 200 Ugandan Shilling per household per month, then the present value of the cash flow benefits minus total costs is negative and the solar pumping system is not worthwhile. Whereas the water fee is assumed to be 1 Ugandan Shilling per litre, based on an average between the National Water and Sewerage Corporation- NWSC Uganda rates and the market prices, the net present value is positive and the pumping system is worthwhile.

The installation of the solar array, which is comprised of photovoltaic modules and controller, does not require particular skills and may be accomplished by qualified personnel available at the site.
As mentioned above there is no need of pump or motor attendants, instead tap attendants are employed to help the users during the queue and fetching phases. In Aloi camp, the pump attendants are volunteers.

The case-study of Aloi camp has a daily flow smaller than the 40 m^3/day considered in the economical appraisal mentioned above, but the operation's characteristics may be the taken as example for solar system. In Aloi, the water supply time table is from 10-11 am up to 5 pm when the discharge of the helical rotor pump is lower and can not guarantee the delivery of water from 8 taps. The average *daily flow* is around 22 m^3/day. The opening time in the morning is depending on the need to fill partially up the tank to get enough storage and pressure to delivery water at distribution points, operation that may be delayed by cloudy weather.

Acceptability

Water projects foreseeing the use of solar energy met the interest of donors as Italian Cooperation-Ministry of Foreign Affairs, EC-Echo and Unicef. The former funded the projects of Aloi and Barr camps and the latter have funded the ongoing water projects for Lira and Pader Districts which comprises 7 motorized boreholes equipped with solar pumping systems.

Water District Office (DWO) of Lira District considers Aloi borehole adequate to the objective of supplying water to a large number of IDPs with the perspective to improve the availability of safe water, whenever the borehole yield is about 5 cubic metres per hour, through the increase of the amount of water stored in tanks.

Boreholes provided with solar pumps address IDPs' need of water. The users of Aloi solar system borehole expressed satisfaction about the advantages of a system provided with stored water and distribution points. They underlined the ease to collect water without efforts although the average time of queuing is around two hours; the water is clean and safe; availability of water at secure place without the necessity to fetch from springs located outside the camp.

Sustainability

Institutional/Line governmental bodies

For continuing the project's results, DWO required tools for the *follow up* of the pump's maintenance, spare parts like taps and collaboration in drawing up the guidelines of operation and minor maintenance of the water point. The latter issue regards the responsibilities assigned to the established water committee for the operation and maintenance like cleaning of water tank and solar array, periodical check of electrical wiring and grounding system, cut of vegetation that may limit the sun exposure. DWO technicians instead may inspect the pump end (helical rotor), if the performance drops, provide the replacement of the pump end or the whole pump, replace the solar modules damaged, if the system uses a solar tracker, lubricate the bearings and check mounting bolts and mechanism. To be enabled to accomplish these tasks, DWO asked COOPI to train their technicians on installation and maintenance of solar pumps.

Technological

Solar water pumping is the process of pumping water with the use of power generated by sunlight. This technology is ideal for remote and unattended locations because the system is very reliable and requires little or no maintenance. The power generation is a static process (photovoltaic is the process of solar electric cells converting sunlight directly into DC power. This DC power is then used to run a pump) and the only moving parts are in the pump and motor. The system is regulated by a controller which consists of two electronic parts:

● Maximum Power Point Tracker (MPPT) controls the voltage of the array and the DC voltage to the motor controller.
● The Solar Motor Controller (SMC) converts the variable DC voltage from the MPPT into a type of three phase voltage to suit the brushless DC motor.

Solar pumping systems require no fuel and very little attention during operation.

Generally, when water is needed most, is when the sun shines the brightest. Solar panels generate maximum power in full sun conditions when larger quantities of water are typically needed. At tropical latitudes these conditions are met during the dry season. The rainy season is affecting the system's performance with lower flow rate. The problem may be overcome increasing the storage of water or, when the groundwater potential is low, over sizing the solar array assembly compared to the actual power absorbed by the pumping system. At the same time, storing water in tanks is less expensive and more efficient than storing power in batteries. In fact, batteries have a number of disadvantages in pumping systems. First, they reduce the efficiency of the overall system. Second, they are another source of problems and maintenance. Third, they add cost to the system.

The solar tracking array, compared to an equivalent sized stationary array, increases the daily output of water by as much as 30%. A GPS (Global Positioning Satellite) sensor built into the controller provides precise latitude, longitude and time. This is all that the controller needs to calculate the exact position of the sun and correctly position the solar array. With regard to rainy season, GPS tracking array does not depend on the light and will track in overcast condition. The tracking array maximises the power generated by the array and attains more consistent flow of water using fewer solar panels.

Furthermore, the borehole is equipped with *helical rotor pump* which maintains high efficiency and lift capacity even at low rotational speeds and low flow rates. This allows the pump to function in low sunlight conditions.

To the question if the solar pump system, after the emergency phase, will meet the need of water of the settlers, DWO answered that when the location of this type of system is matching with the existence of a trading or administrative centre, school or health centre, the improvement of the living conditions of the beneficiaries is assured during the lifetime of the water points. Hence the solar pump system is also seen as an opportunity to reach the development goal of increased access to safe water.

Environmental

The solar pumping system are noise and pollution free. It requires no fuel, then no green-house gas of combustion is produced with preservation of atmosphere.

Financial/economic soundness

So far, the capital cost have been funded by international aid institutions. Then, this appraisal is assuming that the return on investment on pumping systems for IDPs camps may be ignored.

During the emergency phase, the water committees, established at camp level for each water source, are authorized to collect water fees. They are free to set their own charges with variation from 100 to 500 Ugandan Shillings. The service is supposed to be affordable for the beneficiaries but the committees encountered some problems to manage the collection of fees because of scarce economic resources of IDPs and lack of knowledge of committee's members on management of water sources. The committees' capabilities should be strengthen through training course on accountancy.

Besides the water committees' funds, the Line Departments are allocated of funds for water source's management and maintenance. They will likely make them available for replacement of the submersible pump.

Long term risks

The key stakeholders were interviewed and a questionnaire was distributed to determine the risk analysis, in terms of perception and management, for the use of solar panels for borehole's pumping system in Lira District.

The analysis pointed out three major risks:

- ✓ Theft of solar modules
- ✓ Disconnection of electrical wiring
- ✓ Broken panels

The panels as well as the pump may be target of thieves or rebels operating in the zone. Removing some of the panels without reconnecting the electrical wiring would definitely put out of order the system. Anyway, after reconnecting the electrical wiring, an assembly designed to supply a certain power (borne in mind that the assembly of 1200 watts is composed by at least 8 modules) will be affected by the theft of some panels and in consequence the system's performance will be lowered. Instead the theft of the pump can be considered a common risk of motorized borehole without differentiating the type of driven system. The gravity of the impact may be determined as high. On the other hand, the acceptability of this particular risk is resulting from the security conditions assured by watchmen or soldiers controlling the area.

As action to be taken for risk's reduction, it was stated that solar panels can be placed on a high stand and can be made difficult to manage the attachment of the panel using large size bolts. To prevent the theft of the pump, the wellhead can be locked.

Some of electrical wires are exposed and can be subject to vandalism or actions of children playing near the panels array causing disconnection or damage of electrical wiring. Moreover, another risk might be digging and cutting an electrical wire placed underground. The impact would be stop of the pump and shock hazard caused by exposed electrical wires. A short circuit or loose connection will produce an arc that can cause serious burns. As far as the gravity of the impact on pumping system might be considered of medium degree, the acceptability of the risk relates to possibility of serious electric shock.

The actions pointed out to reduce the risk are that the systems with accessible wires are fenced or the wires are placed inside conduits, better iron pipes, as well as underground lines are laid in conduit.

The last risk concerns broken panels due to falling objects. The impact would be reduction of the pumping system's effectiveness. A low degree of gravity might be determined for this specific risk. With regard to the acceptability of risk, it seems necessary to take this risk because any protection screen to prevent damage of panels will reduce the direct irradiation causing a decrease of array performance. In fact, shading a small portion of a photovoltaic (PV) array will cause the pump to slow or stop. Each PV module contains a series of solar cells. Every cell that is shaded acts like a resistor, reducing the output of the entire array.

Hence, no action is suggested to reduce the risk.

For all risks the probability of occurrence was stated as low.