Replacing Type "B" Bush Pumps With Solar Powered Pumps For Rural Water Supply

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Abstract/Summary
For close to a century now, Zimbabwe's rural areas have been served by the type B bush pumps and it is time that we consider changing to a technology that eases amount of work put into fetching water as well as facilitates the further development of rural communities like solar (PV) powered water pumps. The aim of this paper is to compare between the two pump technologies to justify the decision to replace type B bush pumps with PV water pumps. The summarised benefits of PV systems are low labour requirement, low operation and maintenance costs, universal access to water, improved productivity, improved access to education for girls and improved health. Though the initial costs can be high, they can be implemented for their return on investment in the long term in addition to their benefits earlier mentioned. It should be noted that optimum performance of PV systems is dependent on geographic and climatic conditions and so may be unsuitable for some areas.

Introduction
Just like in any other developing country, Zimbabwe has isolated rural areas which pose challenges to rural energy management and development due to poor road links to urban centres and remoteness from the national electricity grid. Thus the potential of the use of renewable energy becomes great in such areas. According to (Baumann et al., 2010), the climate in many developing countries is suitable for solar energy pumping making solar energy a valid option for small scale water pumping schemes. The applications of solar energy are growing at a steady rate all over the world. With an average radiation of 2 100kWh/m2 and 3 000 hours of sunshine per year (ZERA, 2015), Zimbabwe is deemed to have sufficient potential for solar energy and has already begun embracing this technology for water pumping. There are two solar powered water pumping systems in Bulilima district implemented by Troicare International (Sibanda, 2015), solar powered drip irrigation systems in Gwanda North implemented by Practical Action (Gono, 2016), a gravity fed irrigation system with solar powered water pumping system in Gutu and a solar-powered water pump for water supply at Mazuru Clinic, Gutu, implemented by Oxfam and Practical Action (Magrath, 2015), just to name a few.

Over the years, the communal areas of Zimbabwe have been largely served by a home-grown solution for water pumping, the bush pump for close to a century now. First designed in 1933 by Tommy

Murgatroyd, a water officer in Matebeleland, the bush pump underwent many refinements to make it more user-friendly and durable. The result was the type "B" bush pump which was adopted as the national standard model in 1989. As of 2011, over 40 000 type "B" bush pumps (Morgan, 2011) had been set up. Optimum performance of this unit can only be expected if the components are correctly manufactured and also correctly installed. Over the years, the service by these pumps has been characterized by high labour requirements, long walking distances to fetch water and frequent breakdowns. It is important to note however, that even with many replacements of pipes and fittings, some bush pumps installed in 1930s are still working. Therefore, the choice of replacing bush pumps with solar powered water pumps is a matter of the performance and benefits of the "B" type bush pump as compared to the latter.

Context, aims and activities undertaken

The aim of this paper is to compare the advantages and disadvantages of the use of solar powered pumps against the use of Type "B" bush pumps for water supply in rural areas in order to justify the decision of replacing Type "B" bush pumps with solar powered pumps. In order to achieve this, the authors consulted related literature and structured the information obtained as follows:

1. Background – this section covers the brief background of Type "B" Bush pumps and Solar powered pumps respectively.

2. Comparison between Type B bush pumps and solar powered pumps – this section covers the advantages and limitations of each technology in light of the other.

3. Conclusion – this section discusses the conclusion from the discussed issues.

Main results and lessons learnt

Background

Type "B" bush pump

The family of bush pumps is known to have served the rural communities of Zimbabwe for over 80 years now. First developed in 1933 by Tom Murgatroyd, a Water Supply officer (Morgan, 2011), there have been developments to this pump over the years. The pumps can be distinguished as type A and B. The type B was developed as further research was being done to ensure that the bush pump is more durable and user friendly. This development came about as an initiative by the National Action Committee (NAC) with combined efforts with District Development Fund, Ministry of Energy, Water Resources and Development and Ministry of Health and Child Welfare. The type B bush pump was adopted as the national handpump of choice in 1989 (Morgan, 2011). As of 2011, more than 40 000 type B bush pumps had been installed across Zimbabwe (Morgan, 2011).

The type B bush pump is categorised as a conventional lever action pump used to abstract water from a borehole. The type B bush pumps are usually fitted to communal boreholes or deep wells and are typically shared between 25 households, that is, about 250 users per pump. They can take water from depths ranging from 18 to 100m and the typical yield range ranges from 3l/min in the drier areas where the borehole depth might be 100m to 15l/min in wetter areas with shallow ground water (Guzha et al., 2007).An illustration of the type B bush pump is shown in Figure 1.

Morgan (2011) describes the "B" type bush pump as follows: The wooden block, which is made of teak, is attached to the pump stand and rotates around a large bolt called a pivot pin. The rods which connect to the piston within the cylinder below move up and down within a "string" of steel pipes (known as the "rising main"). The uppermost rod passes through a floating washer housing, where a set of 2 moving washers accommodate for the horizontal movements of the rod within the pipe. The uppermost rod is connected to the pump head through a "U bracket." The U bracket is attached to another pivot pin which passes through a forward hole in the wooden block. The wooden block has 2 sets of holes, a method derived from earlier Bush Pumps. When the first set of holes wears out, the second set can be put into use. The wooden bearing has a very long life. The "B" type pump head is used with standard "down-the-hole" components, comprising 50mm nominal bore galvanised steel rising main, 16mm mild steel pump rods, a 75mm diameter brass cylinder operating with a piston fitted with two leather seals and a heavy duty brass foot valve. These components are well tested and durable if correctly made and installed.

As de Laet & Mol (2000) quotes Morgan (1990): the Bush Pump operates on a lift pump principle, the reciprocating action being transferred from the pump head to the cylinder through a series of galvanised steel pump rods running inside a steel pipe (rising main). As far as maintenance is concerned, the basic requirement is keeping all bolts tight to ensure minimum wear of the working parts. Most of the maintenance that is required is linked to "down-the-hole" components. Seals on the piston need replacement from time to time. A rubber seal on a well-made heavy duty foot valve is made to last up to 10 years. Where the maintenance of down-the hole components is concerned, it requires that the pipes are removed to inspect the parts underground. These pipes are heavy and require special lifting tools.

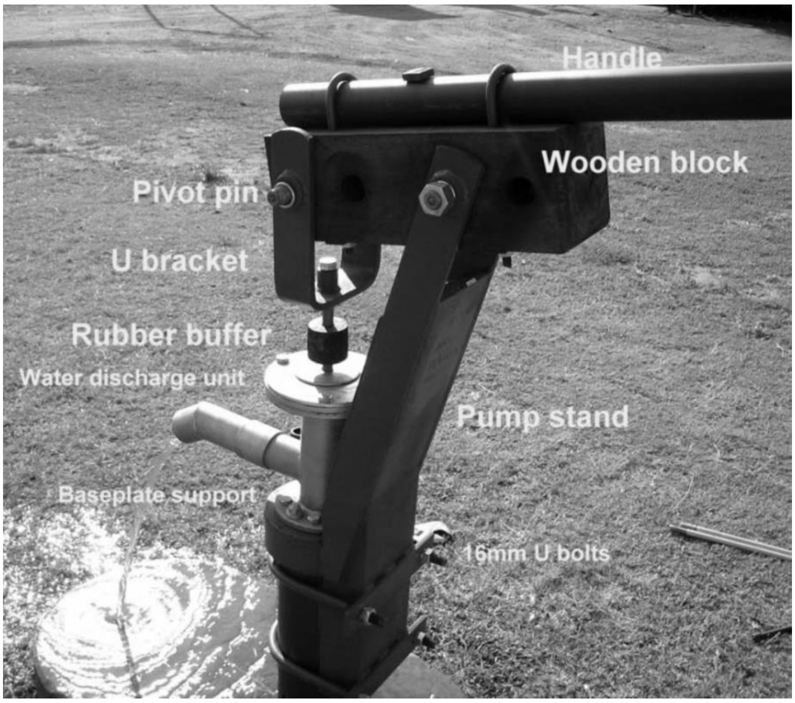

Figure 1: Type B bush pump (Morgan, 2011)

Solar (Photovoltaic, PV) pumps

Solar (PV) water pumps are used in Zimbabwe as well as other countries and regions where there is abundant sunlight. They have generally proven to be a reliable and cost effective solution in areas where:

i. there is widely spread water resources;

ii. no electricity grid is near, and;

iii. the fuel and maintenance costs are considerable.

According to (McNelis & Derrick, 1989), the early development of the solar technology was closely linked to water pumping. This is evidenced by a solar water pumping steam engine which was showcased at the Paris Exposition in 1878. Around 1967 one solar pioneer named Tabor wrote that solar cells and thermoelectrics may, some day, pump water for the African native but for the moment, power generators with moving parts appeared to be more practical. During those days solar technology was ideal were it not for the high price and low efficiency. PV modules have been in existence for more than 50 years and mass-production began in 1979. In 1989 a study carried out on 200 PV pumps installed in Mali showed that problems were experienced with early installations but those installed after 1982 were found to be reliable. With improvements in the manufacturing technology and economies of scale, the prices of PV modules have fallen by up to 90% (Baumann & Erpf, 2005). The reliability of PV systems is such that it is possible to typically have 20- to 25-year power warranties with the life expectancy of the system extending beyond 30years. Presenting a practical and financially and technically feasible solution, solar water pumping is becoming more common in agricultural as well as drinking water applications.

The PV modules, normally arranged in an array, generate direct current (DC) which is fed to the battery via a solar regulator to ensure that the battery is charged properly and is not damaged. It is also possible to have pumps which use alternating current (AC) for which the DC will have to be fed through an inverter. For a PV system, a water tank for storage becomes inevitable in order to ensure supply during the times that the pump is not running and also to balance daily (or even weekly) fluctuations in demand. In the presence of storage it becomes possible to have a distribution system installed. Since PV systems are considered to be "Hi-Tech Equipment", it is highly recommended to consult a solar power specialist before any procurement. An illustration of PV pumping system is shown in Figure 2. Solar pumps can lift up water from boreholes even up to 200m deep, though it is most economical up to a pumping head of 50m. In Africa, experience shows that the PV systems are economical at a pumping head of 50m yielding a hydraulic head equivalent of up to 800m4/day, that is equivalent to (Baumann et al., 2010). As far as maintenance is concerned the most that the community can do is keep the panels and water points clean. The maintenance of the system is done by skilled artisans which is why a community should sign a maintenance contract with the company that installed or the company employed to do so. Generally, the system is vulnerable to vandalism and theft due to the various applications of the solar panels (Hjalmarsdottir, 2012). However, some strategies are being devised to reduce incidences of theft and vandalism with one of the most common being community involvement in the development of such systems to foster sense of responsibility.

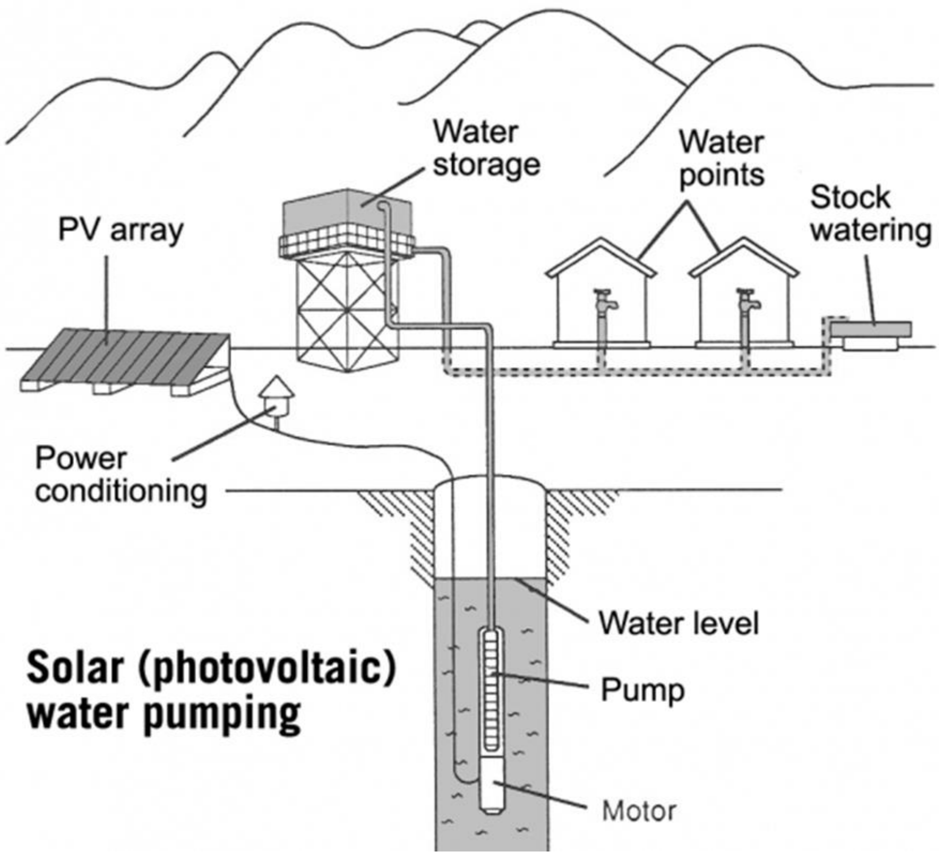

Figure 2: Solar (PV) water pumping system (http://www.zimsolar.co.uk/LI_rural_solar_systems.html)

During the early development of PV systems it was found out that most systems failed to operate reliably without continuous attendance by skilled technicians to undertake adjustments. This was in the late 1970s as a French company called SOFRETES was pioneering the commercialisation and development of PV systems (McNelis & Derrick, 1989). With further research and improvement over the years, PV systems are now known to be reliable. One such case is in the use of solar powered pumps for irrigation in Bangladesh. Farmers in the pilot area have been switching from diesel run to solar irrigation pumps because of the associated reduced cost of irrigation, reliability and easier maintenance as compared to diesel-run pumps (The World Bank, 2015). It should be noted however that the technical and financial feasibility of PV systems is dependent on quite a number of factors. These include geographic conditions, climate, institutional and social structures (Hjalmarsdottir, 2012). According to Baumann et al. (2010), the system becomes uneconomic for a hydraulic head equivalent of less than $200m^4$/day. Despite the system's boundary in terms of financial feasibility, the system has got many advantages in other circles like productivity and social life. These are explored in the section that follows.

Comparison between Type B Bush Pumps and Solar Powered Pumps

The comparison between the two pumps will be discussed under the following interrelated sub-topics:

1. <u>Energy</u>

Both systems do not require fossil fuels and are suitable in areas that have no grid power or erratic power supply and as far as emissions are concerned, both systems can be considered to be clean. The type B bush pump is a manual pump which requires manual labour to draw water and the PV pump makes use of the DC or AC generated by the PV modules. However the PV pump has the advantage of having low labour requirement as compared to the type B bush pump.

2. Operation and Maintenance

The PV system being a motorised pump has low chances of human interaction during operation and less moving parts which correspond to low frequency of maintenance. On the other hand, with the type B bush pump being a manual pump, the chances of human interaction are always and also there are a lot of moving parts in the system which requires maintenance quite often due to frequent wear and tear. The PV system has low frequency of maintenance and so low costs of operation and maintenance. On the other hand, the type B bush pump requires maintenance quite often thereby increasing operation and maintenance costs. In terms of operation the PV system is limited in that it does not perform well in the event of cloudy weather and short winter days. However, the installation of a storage tank helps with ensuring supply during such times. For both systems, maintenance of the systems requires well-trained personnel. For the PV system, the most the community can do is clean the solar panels and keep the water points clean. For further maintenance and repairs, the community can sign a maintenance contract with the supplier of the company employed by the supplier to provide technical backup. For the bush pump, the standard configuration has limited community management but it is very reliable and popular (Baumann et al., 2010). Besides the standard configuration is the open-top cylinder which makes simpler maintenance possible. In cases of breakdown, the solar powered system can be designed to have a storage tank which will act as a buffer during downtime whilst for the Type "B" bush pump people have to find alternative sources of water. It should be noted however, that the storage tank will allow for some time to get the pump system fixed before people start seeking for alternative water sources.

3. Costs

The major limitation of the PV system is the high initial capital cost. The investment cost of a PV system is dependent largely on the power requirement per litre and so it is proportional to the total pumping head and water flow. Usually the point at which the PV systems become economically viable depends on the application and geographic location. According to Baumann et al. (2010), the experience from most African projects has shown that for heads of up to 50m and about 800m4/day (product of output and head), the PV systems are viable. For applications of less than 240m4/day, handpumps (includes type B bush pump) become more economically viable (Baumann et al., 2010). Due to the high potential of the type B bush pump to be manufactured locally, the cost of setting up type B bush pump becomes lower. Normally, the economic viability is seen in the lifecycle costs. As highlighted earlier, PV systems have low maintenance costs as compared to the type B bush pump. Therefore, though with a high initial cost, the PV system can turn out to be the more economic option in the long run.

4. Ease of Access

Firstly, the labour requirement makes a huge difference between these two systems. Even though said to be reliable (Morgan, 2011), the type B bush pump being a manual pump requires a lot of labour meaning that it can be difficult for children and the elderly to access water unlike with the use of solar pumps which has low labour requirements being a motorised pump. The most you are required to do when using a solar pumping system is opening a tap to get water allowing for universal access of water. Also, whilst the high labour requirements of the type B bush pump limits the use of water to domestic use and livestock watering probably, the low labour requirement also make integrated use of water possible. The water abstracted can also be used for irrigation purposes in addition to domestic usage and livestock watering. With irrigation comes high probability of crop success and all-year farming becomes a possibility.

Secondly, the location of the water point is limited to the borehole when using the type B bush pump which can mean long walking distances to fetch water. However, with PV systems, it is possible to have a distribution network which allows water points to be brought closer to the households reducing walking distances. Lastly, the number of water points is limited to one in the instance of a type B bush pump corresponding to long waiting hours at the water points whilst in the instance of PV pumping systems the water points can be decentralised to have multiple water points at one location which reduces the waiting times at water points.

The time saved can correspond to increased productivity as the time can be allocated for other activities like:

1. **Education** – Research shows that, the burden of fetching water in rural areas fall mostly on women and girls in rural areas. Due to long waiting times and long walking distances, some girls have had to drop out of school. A story is told of Mrs Juliet Ngwenya of Manjolo village, Binga District, Matabeleland North Province in Zimbabwe, who dropped out of school at the age of 8, partly because she had to help her mother to fetch water from an unprotected well 5 km away (Nyamanhindi, 2015). Because of the location of the bush pumps, long walking distances to and fro can cause girls to drop out of school depriving them of education which is essential for individual as well as community development. With water access made easier by use of PV systems, girls can be able to help with fetching water and afterwards be in a position to go to school in the morning as well as fetch water after school.

2. **Farming** – due to the ease with which water can be accessed using PV systems, time and strength saved in getting water can be invested into farming activities. Coupled by the development of irrigation systems, there is increased likelihood of crop success. The livelihood of the community is bound to improve. This is highly unlikely with the use of type B bush pumps which require taxing labour and can be remotely located making it hard to convey water to farmlands as well as the livestock.

3. **Recreation** – due to time savings enabled by the use of PV systems, people can get time to engage in recreational activities such as sewing, knitting, reading a book and so forth. This contributes immensely to the emotional as well as physical well-being of the people and places people in a position in which they can focus more on their development and that of the community.

4. **Improved sanitation and hygiene** – If water can be accessed within short distances and reasonable time, as the case can be with the use of PV systems, then sanitation improves as well. One example is that people can afford to spare water to wash hands after toilet use as water is easily accessible. This will in turn help in the prevention of sanitation-related diseases thus improves health of the people in the community. Another improvement in health is that due to the ease access to water, nurses can focus more on their job rather than being concerned of where to find water for their work. In Gutu, Masvingo Zimbabwe, after the diesel pump at Mazuru Clinic had broken down; nurses had to walk long distances to fetch water before they began work each morning. As quoted by Magrath (2015), Ratiel Chikuvire of Mazuru Clinic, Gutu, Masvingo, Zimbabwe said that they always had problems with maintenance of the diesel pump and in early 2000 the pump broke down taking six years for it to be repaired. Therefore, the clinic's staff had to go to Dopota Primary School 5km away to get water before commencing work each morning. With the introduction of a PV water pumping system. Ms Chikuvire

went on to say: 'Ever since the solar water pumping system was installed we have never faced any water challenges. We switch the system on for an average of two hours per day and all the tanks will be filled with water, which can last for three days'.

5. **Other** – An additional advantage is that the same PV modules that are used for water pumping can also be used to provide electricity that can be used for lighting as well for the water points and even some surrounding houses.

In summary, the replacement of Type B bush pumps with solar-powered water pumps will bring certain overall development of a community.

Conclusions and Recommendations

From the above discussion there are points which stand above others. Viewing the issue of replacing Type B bush pumps with solar-powered (PV) water pumps will seem impractical from the initial investment point of view. However, other aspects such as improved livelihoods in the rural communities suggest that replacing type B bush pumps with solar (PV) water pumps is an investment for a worthy cause. The benefits of PV systems discussed earlier in the comparison the type B bush pump and PV pump can be summarised as:

- Low labour requirements;
- Low operation and maintenance costs
- Universal access to water;
- Improved productivity;
- Improved access to education for girls, and;
- Improved health.

With the introduction of PV systems, the stories of long walking distances and enduring long waiting hours can be a thing of the past bringing the much desired women empowerment as well as poverty alleviation. Even though susceptible to theft and vandalism, measures can be put in place to ensure that PV systems are kept secure. Over and above all, it is important to note that the performance of PV systems is dependent much on the geographic location and climatic conditions and so there will be areas where the system may be infeasible in terms of the costs and the output of the system. In such areas, it is encouraged that other types of pumps be explored. Zimbabwe has already begun the journey towards the transformation of lives by the introduction of solar-powered technology not only for water pumping but for electricity as well. Hopefully, this technology will continue to be replicated, thus ensuring that more people can enjoy the benefits of PV systems.

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References

Baumann, E. & Erpf, K., 2005. *Rural Water Supply Technology Options - Handpumps, Mechanised Pumps and Surface Water*. Rural Water Supply Network.

Baumann, E., Montangero, A., Sutton, S. & Erpf, K., 2010. *WASH Technology Information Packages - for UNICEF WASH Programme and Supply Personnel*. Copenhagen: UNICEF.

de Laet, M. & Mol, A., 2000. The Zimbabwe Bush Pump: Mechanics of a Fluid Technology. *Social Studies of Science*, 30(2), pp.225-63.

Gono, V., 2016. *Solar powered irrigation panacea to drought in Gwanda*. [Online] Available at: http://www.sundaynews.co.zw/solarpoweredirrigationpanaceatodroughtingwanda/ [Accessed 13 April 2016].

Guzha, E., Chimbunde, E., Smith, S. & Khoza, S., 2007. *Technologies for Multiple Use of Water Experience*. Harare: Mvuramanzi Trust.

Hjalmarsdottir, E.H., 2012. *Solar powered pumping technologies in Rural Water Supply: Case Study from Kunene Region, Namibia*. [Online] Practical Action Publishing Available at: http://www.practicalactionpublishing.org [Accessed 25 April 2016].

Magrath, J., 2015. *Transforming lives in Zimbabwe: Rural Sustainable Energy Development Project*. Oxfam.

McNelis, B. & Derrick, A., 1989. Solar Water Pumping: Clean Water for Rural Areas. In *2nd ASEAN Science and Technology Week*. Manila, 1989.

Morgan, P., 1990. *Rural WaterSupplies and Sanitation*. London: Macmillan.

Morgan, P., 2011. *The Zimbabwe Bush Pump (B type) Installation Manual with notes on maintenance*. Harare: Aquamor Pvt Ltd.

Nyamanhindi, R., 2015. *The burden of thirst: water challenges increase inequality among women in rural Zimbabwe*. [Online] Available at: http://www.unicef.org/zimbabwe/media_15918.html [Accessed 15 April 2016].

Sibanda, W., 2015. *Solar powered sand abstraction and borehole pumps technology*. [Online] Available at: http://www.bestclimatepractices.org/practices/solarpoweredsandabstractionandboreholepumpstechnology/ [Accessed 13 April 2016].

The World Bank, 2015. *Solar-Powered Pumps Reduce Irrigation Costs in Bangladesh*. [Online] Available at: http://www.worldbank.org/en/results/2015/09/08/solarpoweredpumpsreduceirrigationcostsbangladesh [Accessed 21 April 2016].

ZERA, 2015. Use of Renewable Energy as an alternative source of energy in the Farming sector. In *Farmers Indaba Workshop*. Harare, 2015. ZERA.

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