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Solar Powered Water Security: An Enabler for Rural Development in Limpopo South Africa

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ABSTRACT This paper describes how the rural development of a small village was enabled through the improvement of water security. The rural village of Gwakwani in the Northern Limpopo province of South Africa was entirely dependent on a diesel powered borehole pump for their water supply. The cost and unreliability of the diesel supply resulted in limited opportunity for the development and growth of the village. As a rural community development enabler, a solar-powered borehole pump was installed in the village, which enhanced the availability and reliability of the water supply to the community. A second solar-powered borehole pump was installed, which allowed the establishment of small-scale drip irrigation farming enhancing economic activity. This paper presents the feasibility for the installation of solar-powered water pumps in rural areas, showing its advantage over diesel-powered water pumps. It is shown how the availability of a reliable water supply increased the production of subsistence crops. This paper concludes with a justification for installing high-tech solar pumping systems as a catalyst for developing rural communities.

INDEX TERMS Drip irrigation, rural development, solar water pump, water security.

I. INTRODUCTION

Sub-Saharan Africa is the second largest undernourished region in the world with 234 million people considered chronically hungry where the largest portion is living in developing countries [1]. The 1996 World Food Summit states that "Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [2]. A state of food security exists when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [1]. These food insecure populations are predominantly rural and frequently have to survive on social grants of less than $1 per person per day [3]. Although the main occupation of these people can be considered as subsistence farming, they spent a considerable portion of their available income on food [3]. In South Africa the number of social grants allocated have increased significantly since 1994 to over 16 million beneficiaries [4], but the lagging of children's nutritional status are still reported [5].

The importance of water security as an enabler for food security is emphasised in the book "The Human Face of Water Security" [6]. The National Water Resource Strategy sets out a strategy for the elimination of inequality, poverty and improve economic development through water security [7]. In a report from the South African Department of Water Affairs and Forestry it is stated that only 13 % of the nation's total water supply originate from groundwater. However, it is estimated that over sixty percent of community water supply is obtained from groundwater, making it a strategically important resource [8]. Furthermore, the report identified the lack of cost recovery for infrastructure maintenance which is attributed in part to the villager's perception that water is a "free" commodity which is enforced by the National Government's policy of providing free basic water of 25 litres as a human right to each citizen. The report concludes that rural water schemes work best when managed at the lowest level. It was often found that the rural water committees are mostly constituted of men in contrast with the rural communities' population of majority females resulting in a misrepresentation as in traditional context the woman are seen as the custodians of water resources.

This paper reports on the implementation of a solar powered water pumping scheme as an enabler for social and economic development in a rural village in the Limpopo province of South Africa. The village does not have utility electricity supply resulting in water insecurities and limited economic growth brought about by the diesel powered borehole pump. The paper also addresses the challenges of rural water supply and the difficulties of implementing a water tariff scheme to cover the infrastructure maintenance cost in a scheme of a communal water line where there is no individual usage metering available. The contribution of this paper is the reporting of the results from sustainable development of an off-grid rural village through the provision of water security offered by the installation of photovoltaic borehole pumping schemes. An argument is made for the sustainability of "high technology" photovoltaic borehole pumping schemes. The contribution of this paper is the demonstration of how the implementation of "high technology" solar water pumping enabled rural development in South Africa through enhanced water security.

The paper is structured as follows: In Section II the research methodology is presented followed by the results from the Baseline study in Section III. Section IV describes the two stage intervention of replacing the diesel borehole pump with a photovoltaic borehole pump and Stage 2 intervention of installing a second photovoltaic borehole pump enabling a drip irrigation system. The results from the interventions are presented in Section V. Section VI described the cultivation of community participation and relationships where the paper concludes in Section VII.

II. RESEARCH METHODOLOGY

The work group identified an opportunity to collaborate with the Gwakwani community when it was identified that the village does not have a sustainable water supply. The work group met with the village representatives to learn about and understand the community's social, technological and material needs, conduct impact assessments and secure social buy-in from the community members. After the needs assessment was conducted and the solution approved by the community, a solution was designed which entailed interventions discussed in Section IV.

Heads of 12 households in the community were interviewed on food security in 2016. Data gathered from this interview were utilised to determine the baseline discussed in Section III. A second set of interviews were held with members of the community who cultivated sustenance food gardens. This interview took place after Stage 1 of the intervention, to determine their farming activities and to determine the impact of Stage 1 of the interventions, discussed in Section VI. The success from the Stage 1 intervention led to the implementation of a drip irrigation plot to further the economic activity of the area, called Stage 2. After Stage 2 of the intervention, a community representative kept a detailed farming record of all the farming activities conducted on the drip irrigation plot. The data from this farming record were used to determine the impact of Stage 2 of the interventions, also discussed in Section VI.

III. BASELINE

A. GEOGRAPHICAL DESCRIPTION

Gwakwani is a small, rural village, located in the Northern part of the Vhembe district of the Limpopo province in South Africa with international borders with Botswana, Zimbabwe and Mozambique. The village is at an elevation of an average 350 m above mean sea level. One dirt road provides access to the village where the village is approximately 17 km from the nearest town and closest filling station.

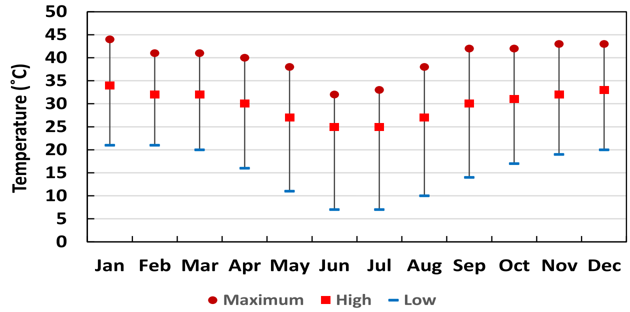

FIGURE 1. Average high and low temperatures per month [9].

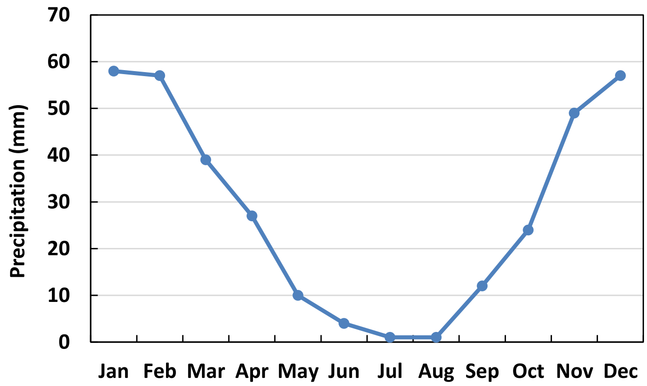

FIGURE 2. Average monthly rainfall per month [9].

B. WEATHER

The Gwakwani village is located in the warmer climatic region of South Africa. The average monthly high and low temperatures recorded over the period from 1961 to 1995 at the closest weather station in Musina, approximately 100 km away, are shown in Fig. 1. The maximum recorded temperatures for each month, indicated in the figure, ranges from an average of 27 °C in the winter to reaching an average temperature of 33 °C in the summer, peaking at approximately 40 °C.

The Vhembe district is a summer rainfall season which receives an average of 44 mm of rain in the summer and 6 mm of rain in the winter months. The average monthly rainfall over the period from 1961 to 1990 is indicated in Fig. 2. Days with rainfall are mostly separated with periods of very high temperatures.

C. WATER SUPPLY

In the Vhembe district only 7.5 % of people have piped water in their dwelling, 27.9 % have access to piped water at a distance further than 200 meters from their dwelling and 2.6 % are reliant on borehole water and sanitation for 60 % of the inhabitants consist of a pit latrine [9].

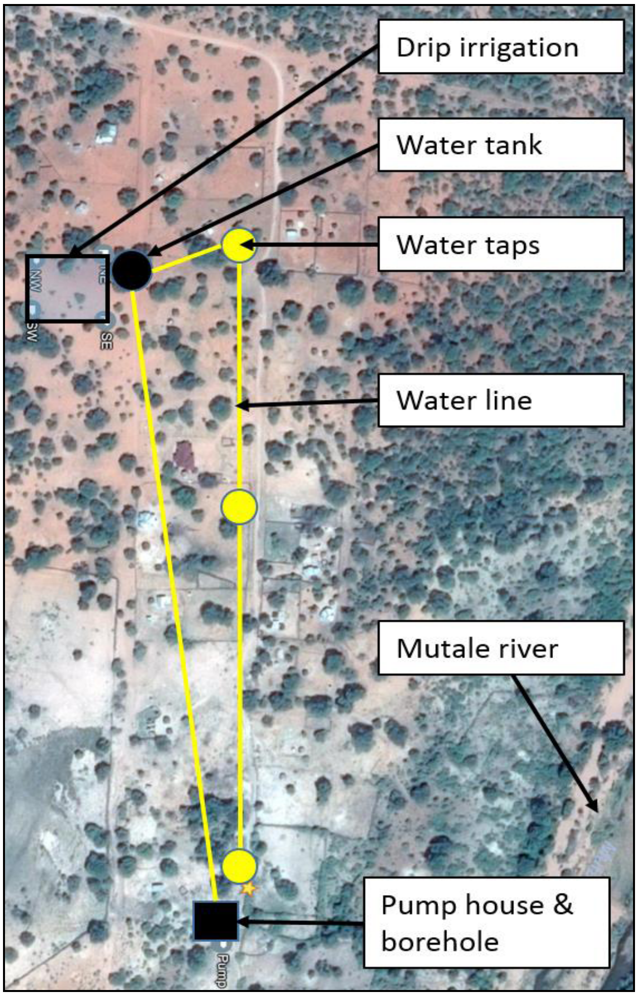

FIGURE 3. **Water supply distribution layout for the Gwakwani village.**

Before intervention, the main water supply of the Gwakwani village was obtained from a diesel driven borehole pump. Water from the borehole was pumped into a 10 000 litre reservoir tank located approximately 500 meters from the borehole situated on a geographically high point in the village. Water was distributed using gravity feed into a pipeline running along the main road through the village. Communal tap points are located at three different locations along the water supply line. The water distribution is graphically shown in Fig. 3.

Diesel was obtained from the South African Department of Water Affairs depot located approximately 14 kilometres away. Water was pumped into the reservoir tank approximately once a week only as long as the diesel supply lasted. Once the monthly diesel supply ran out, the villagers were responsible for collecting money to procure and collect the diesel for the pump resulting in limited and unpredictable water supply.

The price of diesel per litre in 2016 is shown in Fig. 4. During the winter months, which are also the driest months of the year, the diesel price increased to a maximum R 11.52 per litre (US $1 is approximately R14). The cost for 25 litres

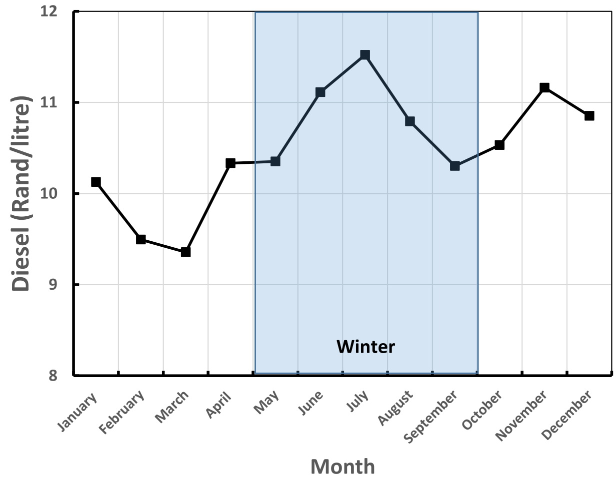

FIGURE 4. **Diesel price in rand per litre for the year 2016.**

of diesel supply at an average price of R 10.50 per litre cost the villagers R 263. This price excluded the cost of transport equalling the transport cost of the buyer and the 25 litre drum which is equivalent to the cost of one passenger. This supply of diesel would last for a month at a pumping rate of twice a week for 2 hours, yielding a water supply of about 10 000 litres per week. At the minimum demand of 25 litres per person, the total village demand would be approximately 8750 litres per week. The village hydraulic load would be 62 500 m^4/day. (50 villagers, 25 litre each at a head of 50 meters) or 1250 m^4/day/person.

A secondary water supply was available through a mechanical hand pump operated borehole. Hand pumps are best suited for hydraulic loads of 250 m^4/day (25 litres at 10 meter depth) which is much less than the 1250 m^4/day demand [10]. However, upon a site visit in Gwakwani the hand pump was found un-serviceable, removed from the borehole with the borehole clogged up due to long standing silt on the water surface forming a thick hard crust.

This limited water supply resulted in the villagers using the water only for cooking, drinking and very basic hygiene purposes. Although the Mutale River is situated approximately 500 meters from the village, collecting water from the river is a manual process involving the carrying of 25 litre plastic drums to and from their dwellings. Water from the river was therefore mainly used by the livestock and not for agricultural purposes. Surface water was not the best solution as the availability is highly seasonal and the quality not suitable for human consumption without some additional processing [8].

The cash economy in poor rural communities tend to shrink during drought periods as the productivity of animals and agriculture decreases and any possible markets break down in terms of trade. This highlights the major constraint associated with diesel powered watering systems: in the time when the community is most dependent on the water source it is also the time when they are least able to afford the extra cost of the diesel. This situation could be mitigated should a scheme be put in place where revenue collection in more favourable times could be used to support the community during times of severe drought. However, in very poor communities this seldom happens which is confirmed by the work of Banerjee who reported on how the poor lives on less than $1 a day (R 14) or R 420 per month [3]. The three main areas of water need in the village was identified as:

1) DRINKING WATER

According to South Africa's national regulations, everyone has the right to a minimum basic water [11]. According to regulation 3(b), the minimum supply for basic water is:

- a minimum amount of 25 litres per person per day or 6 000 litres (6 kilolitres) per household per month (a household is defined as everyone living on one stand);
- at a minimum flow rate of not less than 10 litres per minute;
- within 200 metres of a household; and
- with an effectiveness such that no consumer is without a supply for more than seven full days in any year.

2) LIVESTOCK

Watering needs for livestock is estimated at about 10 litres per day per goat, 50 litres per day per cow and 30 litres per day per donkey. Water for livestock in Gwakwani is primarily obtained from surface water from the Mutale River.

3) WATER FOR IRRIGATION OF SUBSISTENCE CROPS

Due to the hot dry climate of Gwakwani, crops have a high watering need. The watering need for tomatoes is estimated at 6 mm/day and for cabbage 4 mm/day over the growth period [12]. Based on the average rainfall figures presented in Fig. 2, the effective water availability for crop irrigation would reduce from 58 mm/month high value in January to an effective value of 26 mm/month in July [12] which is insufficient to sustain the need for tomatoes of 6 mm/day or 180 mm/month. This lack emphasises the need for an additional water supply not only in the rainy season but as an absolute necessity for the drier winter months which is the planting season for tomatoes.

D. SOCIAL

The population density of the Gwakwani area can be classified as less than 10 – 25 people per square kilometre [9]. There are about 2453 settlements with approximately 1 180 000 households in Limpopo, most not natural settlements (from an economic and demographic point of view) and very few have developed a sustainable local economic base. Households survive mainly on grants and contributions from breadwinners who migrate to urban centres. From a survey conducted in Gwakwani in 2016, the average age of the house owners are 51 years of age with an average household occupancy of 4 persons, shown in Fig. 5.

Diarrhea, bilharzia and malaria have been identified as some of the major health problems in Limpopo [9]. Water collection from the river is discouraged as the water quality is not fit for human consumption and exposure to malaria at the river is a real risk. Gwakwani is a low lying area approximately 300 m above sea level with Northern Limpopo classified as a moderate malaria risk.

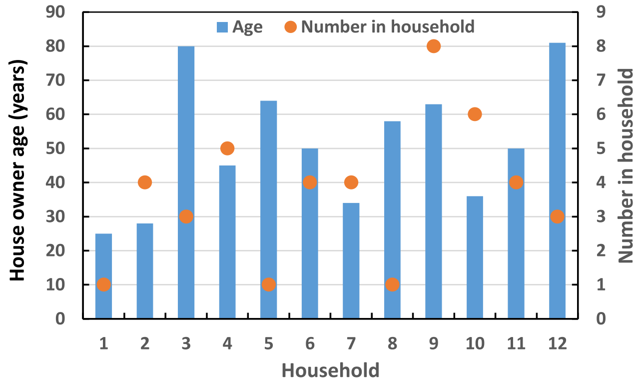

FIGURE 5. **House owner age and number of persons in the household.**

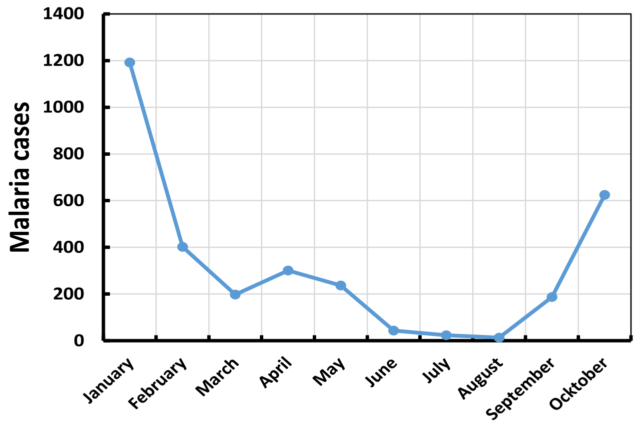

FIGURE 6. **Reported malaria cases in the Vhembe district for 2003 [9].**

Reported malaria cases in the Vhembe district for 2003 is shown in Fig. 6. During the summer period the reported malaria cases exponentially increased compared to the drier winter months from June to August.

In the Vhembe district, 73% of the energy for cooking comes from burning wood. For communication 54% rely on a public telephone and only 20% have cellular phones with 5% reported to have no access to a communication system [9]. In the Limpopo province there are more than 1.6 million people between the ages of 15 and 65 who are not economically active and of the economically active 49% are un-employed [9].

E. FOOD PRODUCTION

From the 2016 baseline survey conducted, the average diet of the villagers consists proportionally from maize (19%), spinach (12%), tomatoes (20%), cabbage (16%), mustard leaf (19%) and meat (14%). The amount of money spent on a monthly basis on food varied from R 400 to R 900 obtained from the social grant as these villagers are mostly un-employed. Food is procured from a mobile tuck shop at the

TABLE 1. Years to break even: Cumulative LCC for PVP and DP [10].

		Daily water (m^3 / day)			
		3	4	6	8
Head (m)	20	0	0	0	0
	40	0	0	0.2	0.5
	60	0	0.1	0.5	1.0
	80	0	0.3	1.0	1.7
	120	0	0.9	1.9	2.7

month end. Less than 25% of villagers consumed food grown from subsistence farming in their own gardens.

IV. SOLAR POWER

A. JUSTIFICATION FOR USING SOLAR TECHNOLOGY

"To summarize, renewable energy sources have created considerable opportunities for promoting rural development. For many communities, such systems can directly improve the quality of life, and help to foster the skills and experience needed to continue economic advancement in rural areas of developing countries", Argaw *et al.*, from Renewable Energy for Water Pumping Applications in Rural Villages [14].

A case study performed by Jordaan assessed a rural water supply situation where borehole water is 10 km from the closest municipal waterline. Two boreholes were sunk in close proximity to each other where it was found that even though the capital outlay for PVP would be ten times more than the diesel pump (DP), the diesel option turned out 85% more expensive than the solar solution. The study showed that it would in fact be over R1,8- million more expensive over a 50 year period, expressed in today's monetary terms [15].

Solar water pumping schemes can be considered as one of the best options for rural irrigation which is confirmed in a number of studies [16]–[18]. Lovejoy, in an article dated as early as 1985, predicted that the cost effectiveness of solar pumping would supersede that of diesel pumping [19]. Sako *et al.* took the analysis even further and showed that solar pumping is more efficient than grid extension for pumping systems with an energy demand less than 15 kWh day-1 [20]. The Namibian Ministry of Mines and Energy (MME) commissioned a report through the Namibian Renewable Energy Programme (NAMREP) to examine the cost effectiveness of solar water pumps or photovoltaic pumps (PVP) compared to diesel water pumps (DP) [10].

It was shown in [10] that for high hydraulic load Lifecycle Cost, the Lifecycle Cost for PVP can be less than 60% of the LCC of DP. For lower hydraulic load systems this value drop to a figure as low as 20%. The same report indicates the number of years to run a PVP to break even compared with the LCC of a DP as shown in Table 1. For the Gwakwani installation where the daily water supply need is 5 000 litres at a head of 70 meters the breakeven point, calculated from Table 1, would be less than 1 year.

South Africa is ideal for solar energy harvesting, as can be seen from the horizontal solar irradiation map shown in Fig. 7. Solar radiation over the Southern part of Africa has been studied and reported as far back as 1956 with a report from

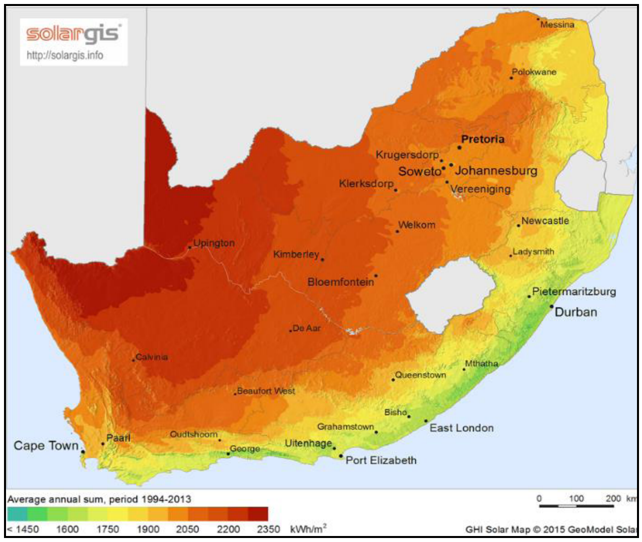

FIGURE 7. Horizontal irradiation map for South Africa from GHI Solar Map ľ2017 Solargis [22].

Drummond and Vowinckel [21]. From Fig. 7 it can be seen that the average annual sun energy progressively increases towards the North and North West of the country. In the Vhembe district, the horizontal solar irradiation is favourable with a yearly average higher than 2000 kWh/m^2.

Favourable conditions for the installation of solar powered borehole pumps, reported by McSorley *et al.*, are listed in Table 2 and compared to the installation in the Gwakwani village [23].

B. JUSTIFICATION FOR USING HIGH TECHNOLOGY SOLUTIONS

The United Nations Bruntland commission defines the complex notion of sustainability as: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [24]. The three dimensions of sustainability are economic growth, environment protection and social equality.

Holden in a follow up article expands the sustainability dimensions into four dimensions, safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intra-generational and intergenerational equity. Indicators are suggested with threshold values that need to be met for the development to be deemed sustainable [25]. Notably, the indicator used for intra-generational equity is the ratio of renewable power to the total energy requirement strengthening the case for using high technology renewable energy technology. Compared to exiting diesel operated borehole pumps, solar technology may be seen as a high technology solution. The feasibility of installing high tech solutions in rural areas are argued along the following points.

1) COST OF INSTALLATION

Although a PVP solution has a higher initial capital cost, the LCC for small installations are lower than DP installations

TABLE 2. Conditions for solar powered borehole pump installation.

Favourable Condition	Gwakwani
Depth of pumping ≤ 50 meters and total pumping head < 75 meters	Water depth in borehole < 50 m Total pumping head < 100 m
Panels installed within village which acts as a deterrent against theft.	Solar panels installed on the roof of the pump house located in the village.
Borehole yields in range of 2-5 m^3/hr.	Borehole yield > 1 m^3 per hour
Populations not exceeding 2000 people and without high demand from livestock.	Total population < 100 people. Livestock demand is low.
Average demand not exceeding 20m^3/day.	Average demand < 10m^3 per day.
Pumps and spares can be sourced in country	Pump sourced from Grundfoss represented in South Africa.
Favourable solar radiation.	Yearly average > 200 kWh/m^2

as shown in Table 1. PVP systems usually make use of plastic pipe which is cheaper and easier to use than the metal parts of a DP system. The risk of theft of the solar panels are reduced in deep rural areas where the installation is inside the village and there is a close relationship amongst the villagers exposing the presence of ''intruders''.

2) TIME/EASE OF INSTALLATION

The installation of a PVP solution can be affected without any specialized equipment or transport as would be required for the installation of a heavy diesel engine. PVP solutions do not require any specialized transport and can be installed in the same or less time than a conventional diesel engine. PVP solutions can be considered safer than DP solutions as the need for diesel storage at the pump is eliminated reducing the risk of water contamination and environmental pollution.

3) ENVIRONMENTAL IMPACT

Invariably, diesel spillage occurs at the diesel storage tanks when filling the pump which was the case at the diesel pump in the Gwakwani village. Diesel seepage was observed through the concrete wall of the pump house on the side located next to the diesel engine. Noise levels from the diesel engine in the confined space of the pump house were very high. As in the case of the Gwakwani village, the diesel pump operator were not issued with any hearing protective equipment. In comparison the PVP emits very low sound pressure levels and can be considered as quite operation.

4) MAINTAINABILITY

The argument posed that mechanical hand operated borehole pumps are a viable solution for water supply in rural areas as these pumps are easy to repair with locally available skills are refuted by Harvey and Reed [26]. They showed that more than 50% of these hand operated pumps are in a state disrepair, affirmed by the broken hand pump found at the second borehole in Gwakwani. The same report indicates that due to the cost benefit, these hand pumps are mostly sourced from outside the country of use, resulting in the inability to repair the pumps due to unavailability of imported spare parts.

The electronic nature of PVP solutions results in systems not being able to be repaired in the field by limited local skills except for the replacement of failed sub-system components. However, the superior reliability of PVP as compared to DP solutions make the PVP the solutions of choice. Once operational the PVP requires minimum maintenance and do not have operational cost as incurred by the DP.

5) URBAN vs RURAL SUSTAINABILITY

There exist an expectation that people living in a rural environment have to be highly self-sufficient, self-reliant and sustainable without support from outside the community. This expectation fuels the motivation for mechanical hand pumps to be maintained by the community. However, the notion of sustainability is seldom achieved in urban environments which have a huge environmental impact and large unpaid service bills [27], as example the R10.2 billion owed by municipalities to the electricity utility provider ESKOM.

The expectation that the individual living in a rural area must be able to supply his own needs, provide and maintain their own infra-structure when in contrast and individual living in highly developed urban areas needs highly organized systems to provide these basic services which in many cases cannot be afforded, is therefore unjustified/unfair/unrealistic.

V. INTERVENTION

The intervention followed a two stage approach as graphically presented in Fig. 8. Stage 1 consisted of the removal of the diesel driven borehole pumping system and the installation of a stand-alone solar powered borehole pumping system. The diesel driven borehole pump was located at a depth of 50 meters down the borehole and subsequently the Photovoltaic pump (PVP) was installed at the same depth. The total head to the water tank was determined to be about 70 meters. A remote monitoring system was installed to verify the operation of the PVP [13]. The aims of the PVP solution were to at least match the water load supplied by the DP, however at a reduced supply cost and improved availability.

The PVP installation consisted of a SQFlex 1.2-2 solar pump from Grundfos supplied from a 200 W photovoltaic array located on the roof of the pump house. The PVP is capable of supplying 0.5 m3/hour at a head of 70 meters or a hydraulic load of 35 m4/hour. At a pumping rate of 500 litres per hour the effective water supply per day is 2500 litres. The water level in the borehole was found to be at about 30 meters depth which increased the actual water supply to about 1 m^3/hour or 5000 litre/day as result of the reduced head.

Stage 2 of the intervention entailed the installation of a second PVP to supply the additional water load created by the drip irrigation plot. The PVP consisted of the installation of an sponsored Altivar 312 variable speed drive (VSD), for solar pumps with photovoltaic arrays, supplied by Schneider Electric coupled to a three phase 0.55 kW Grundfos submersible borehole pump matched to the VSD. This second PVP was installed in place of the broken mechanical hand pump.

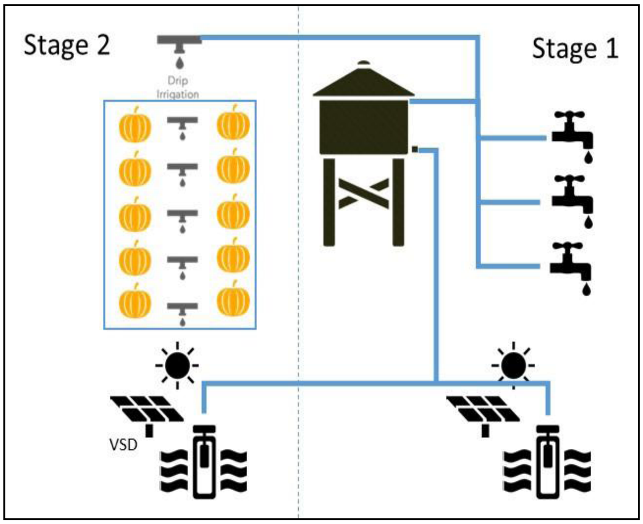

FIGURE 8. Water supply intervention implemented in a two stage approach.

The pump was placed at a depth of 30 meters down the borehole with a joint feed to the main line supplying water to the water storage tank as shown in Fig. 8. Since the solar supply voltage required by the VSD had to be at least 383 V DC, a solar photovoltaic array was installed consisting of 12 solar panels in a series string mounted on a dedicated solar panel mounting structure next to the borehole.

The addition of the second PVP increased the available water supply up to an additional 5 m^3 per day. The additional water supply enabled the creation of a 50 meter x 50 meter (2500 m^2) drip irrigation plot as shown in Fig. 8. The solution consisted of 2 main irrigation feeder lines running from the water tank to the plot. The main lines were connected to 50 meter lengths of drip irrigation lines laid 60 cm apart, totalling 2000 m of drip irrigation lines with drippers spaced 50 cm apart. The flow rate from the drippers were 500 ml per hour each resulting in a total watering demand of 2 m^3/hour. The drip irrigation plot was subdivided by the villagers to allow for amenable utilisation of the plot.

VI. INTERVENTION RESULTS

A. STAGE 1 RESULTS

A marked increase in subsistence agriculture was observed as result of the availability of a reliable water supply provided by the PVP installed on the first borehole. Small scale crops were planted around the dwellings watered by hand or in many cases with a hosepipe supplied from the nearest communal tap point. Table 3 gives an indication of the size of the plots and the crops being cultivated. At total of 542 m^2 of land are under cultivation as result of the water supply provided by the Stage 1 intervention.

B. STAGE 2 RESULTS

The following crops were planted in the drip irrigation plot: onions, peanuts, watermelons, green beans, green peppers, potatoes, spinach, tomatoes, cabbage, maize, chilies, and beetroot. The most successful of these crops under the growing conditions encountered in Gwakwani were the chilies, green beans, watermelons, potatoes and beetroot. Most of the successful crops were utilised for own use, which included the onions, watermelons, potatoes and beetroot. The cultivation of chillies proved to be very successful as the farmer produced and sold copious amounts of chillies on the local market.

TABLE 3. Plot size and crops cultivated after Stage 1 intervention.

Plot size	Crops cultivated
4 m x 7 m	Munge
5 m x 8 m 10 m x 8 m	Carrots, mustard leaves, spinach, tomatoes, marog, peanuts, maize
6 m x 12 m 3 m x 12 m	Beetroot, carrots, mustard leaves, spinach, tomato, sweet potato, maize, green beans, cabbage
5 m x 5 m	Spinach, mustard leaves, onions, tomatoes
7 m x 12 m	Spinach, tomato, peanuts, mustard leaves, sweet potato
4 m x 25 m	Maize, beetroot, spinach, onion mustard leaves, tomatoes
4 m x 7 m	Spinach, tomatoes, maize, munge
7 m x 7 m	Spinach, tomatoes, maize, munge, mustard leaves
Total size: 542 m^2	

C. CHALLENGES

The drip irrigation land was enclosed with a wire mesh fence to prevent the animal livestock of goats and donkeys access to the crops. A number of incidents of baboons raiding the drip irrigation crops have been reported especially in the dry winter season when the availability food in the veld has dwindled. The extreme high heat in the summer months combined with the high water demand during this time is believed to be a cause for limited growth of some crops under the drip irrigation. An example of this was the poor growth of the maize crops under drip irrigation compared to the maize crops under flood irrigation in the plots next to the dwellings.

VII. ENSURING COMMUNITY PARTICIPATION IN RURAL DEVELOPMENT

The utilisation of renewable energy sources, such as solar water pumping schemes, has been advocated as one of the best options to improve the quality of life of rural communities as discussed in Section VI. However, the success of such a project in a community depends highly on the social and cultural acceptance of the project within the community and securing community participation in the project [13], [27], [28]. In order to ensure acceptance and buy-in from the community, the initial focus of the work group was to engage with the heads of the community to establish a working relationship. Throughout the intervention, the work team considered the social aspects of the project as well.

Research by Botes and van Rensburg [27] describes nine obstacles (plagues) which can hinder development through community engagement. Botes argues that there exists institutional, socio-cultural, technical and logistical factors which may constrain community participation. These plagues are briefly introduced in Table 4. He further proposes twelve

TABLE 4. Nine plagues and addressing thereof in Gwakwani community [28].

	Plague	Description of plague	Implementation in Gwakwani
1	Paternalistic role of development professionals	Outsiders bring preconceived solutions to the community without seeking their input and knowledge.	Project was identified and initiated by a family member of a Gwakwani community member. Meetings were held with community to determine their problems and determine possible solutions. Community first identified possibilities of farming.
2	Inhibiting and prescriptive role of state	Projects are undertaken for political reasons and not mainly for the benefit of the community	A university working group with no political affiliations undertook the project.
3	Over-reporting of development successes	Project groups over-emphasize successes and fail to report on failures. Leads to a lack of understanding of lessons learnt from failures.	Failures identified throughout the project were not ignored. For example: it was determined that infrequent visits to the village led to maintenance issues. Project group has since appointed a community representative to manage correspondence and maintenance.
4	Selective participation	Project tend to only include particular groups, such as the most vocal, influential or educated and excludes less obvious community members.	Village is small enough to easily include all community members. Communal tap points are provided at different locations along the water supply line to ensure access for all members.
5	Hard-issue bias	Project focuses on hard issued (technological and financial), but lacks to address issues such as community involvement, decision-making procedures and empowerment.	The project focused on needs identification and trust development from inception. Community is involved in decision-making processes, such as subdividing and use of the drip irrigation plot.
6	Conflicting interest groups within end-beneficiary communities	Scarce resources and opportunities provided by the development is limited and often leads to prioritized and less-prioritised groups.	The provided water resources is sufficient to provide all villagers with sufficient water for daily use and irrigation purposes. Drip irrigation plot is large enough for all members to plant crops if they wanted to.
7	Gate-keeping by local elites	Community leaders or other dominant parties can place themselves between project groups and community members, disregarding the wider community interest.	Project group has regular meetings with community leaders, but also with all community members.
8	Excessive pressures for immediate results	In seeking immediate results to deliver a product or see results, projects groups often neglect community participation and relationship building.	The technical part of the project only started after the conclusion of initial meetings, needs analysis and community meetings. Community had time and opportunity to participate in the process.
9	Lack of public interest in involvement	Members may lack a willingness to participate due to disappointing past experiences or uncertainty of how participation will be in their best interest	The provision of water security in the village benefited all the members; therefore, all members were willing and excited about the project. Community communicated the interest in farming.

guidelines to facilitate participatory development in a community and address the nine plagues. The guidelines propose work groups to include and consider all community members; promote co-decision making; communicate both successes and failures; acknowledge the importance of soft issues; empower communities and facilitate development. Table 4 also includes a short discussion on how the project work group implemented the proposed guidelines to cultivate community participation.

VIII. CONCLUSION

Stage 1 of the intervention consisted of the removal of the unreliable DP and replacement with a PVP bringing about a reliable and secure water supply. Although the water supply was limited to 5000 litres/day the possibility for small scale subsistence agriculture (542 m^2) was created where it was previously not possible.

Stage 2 of the intervention consisted of the replacement of the mechanical hand pump with a VSD PVP supplying an additional 10 000 litres/day. The availability of a reliable second source of water supply allowed the creation of a drip irrigation plot of 2500 m^2 with various crops being cultivated by community members. These interventions demonstrated how a secure sustainable water supply enabled an off grid deep rural community to move towards food security.

A. FOOD SECURITY

Food security can be considered to consist of three components: (1) availability, or the existence of an adequate supply of food, (2) access, or the ability to obtain appropriate food, and (3) utilization, or the ability to benefit from the food [2]. The *availability* of the food supply in Gwakwani increased from mostly obtained by purchasing of a bag of maize meal using the social grant, to increased subsistence farming around the dwellings (542 m^2) expanding to a drip irrigation plot (2500 m^2).

The availability of locally grown basic food made the villagers less dependent on using their social grants for buying basic foods. Villagers bartering locally produced crops increased the available food diversity and improved *access* to food supply. The increased production from the drip irrigation plot allowed access to the local market for the selling of excess produce leading towards increased economic activity enhancing the *utilization* benefit.

B. SUSTAINABILITY

Sustainability can be considered to consist of the three dimensions: (1) economic growth, (2) environment protection and (3) social equality [24]. *Economic growth* was enhanced in Gwakwani through the installation of a reliable secure water supply enabling cultivation of crops in a drip irrigation plot. Produce from the drip irrigation plot were bartered and sold on the local market increasing the economic activity of the villagers. *Environmental protection* was achieved by the removal of the diesel pump, associated with diesel contamination, and replacement with the water pumps driven from renewable solar energy. Using traditional cultivation methods, non-reliant on chemical fertilizers, further enhanced the environmental protection allowing for sustainable development.

An indication of *Social equity* is considered by Holden *et al.* as the distribution of income [25]. In the

Gwakwani village most of the villagers are dependent on the social grants giving a fairly equal income distribution. The allocation of space for cultivation of crops in the drip irrigation plot were equally divided amongst the households allowing equitable income. The requirement for intergenerational equity is completely met as all the energy supplied to the village is obtained from renewable solar installations.

C. QUALITY OF LIFE

Apart from the aforementioned benefits of food security and sustainability, the quality of life in the Gwakwani village has improved as result of the intervention. Having a clean source of drinking water within a reasonable distance from the dwelling instead of scooping water from the river improved the lives especially of the elderly. The quality of the water improved compared to the water quality obtained from the river which is shared with the animals. The threat from being attacked by the occasional crocodile in the river is also mitigated. Cases of malaria in the village declined rapidly as result of villagers not having to go to the river at dawn and dusk which reduced the risk of exposure to the malaria mosquitos breeding in the puddles of water next to the river. "*You are seen as gods by the villagers. Gods bring hope, and with hope anything is possible.*" is a quote from the interpreter who is a student who himself grew up in a rural village in the Limpopo province. The effect of hope brought about by the sustainable water supply was evident in the overall appearance of the village. Fences were repaired, gardens kept, dwelling plots were allocated to new villagers seeking residence in the village. A goat farm was established and more residents had a pigsty with one or two pigs fed from the agriculture waste.

D. HIGH TECHNOLOGY SOLUTIONS

The appropriateness of installing high technology solar water pumping solutions compared to diesel or mechanical hand pumps have been demonstrated. The LCC of a PVP with the sustainability benefits thereof makes this solution the solution of choice as a catalyst for deep rural development.

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