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Feasibility study of solar pumps for irrigation purposes in Budalangi, Kenya.

Mulighetsstudie for solpumper til irrigasjon i Budalangi, Kenya.

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Preface

This is it. The last obstacle, the last challenge. Every course, lab work, assignment, exam has been a step in order to write this master thesis. Not everything I have learned has been relevant for this thesis, still knowing what is not relevant is in itself important. This is where I prove my worth, prove that everything I have done the last 5 years has surmounted to something. At times I have felt incapacitated, the pressure has been enormous. To sum up all your failures and achievements into one document is scary. Nonetheless for better or worse, I have finished. This is it.

Despite the struggles I have finished and the list of people I have to thank is long. First and foremost I would like to thank my supervisor, dr. Razak Seidu. Almost two years ago an eager student went into his office to talk about his ambitions and they talked and dr. Seidu helped the student achieve some of his dreams. That student was me. Throughout the time we've talked about my dreams, aspirations, whims and ideas I've grown to consider dr. Razak Seidu not only as mentor but also a friend.

Further on a big thank has to be given to Engineers without borders for giving me this opportunity to write a thesis for them. My dreams and aspirations has always been to do something substantial with my life, do something with a purpose. Needless to say, to get the opportunity to write a master with purpose was perfect to me. I would like to use this opportunity to thank everyone in Engineers without borders that helped me. That would be: Sveinung Fossnes, Christine Spiten, Luke Dokter, Mona Ellingsen, Joe Aloka K'Odingo, Tommy Fernandes, Haykush Olsen and Bjørn Nissen.

Our partner organization Kenyahjelpen deserves tremendous amounts of thanks. Kjell and Wenche Bjørnstad, Samuel Njogi, Karen Shem and all the other people. Thank you for your hospitality and help throughout my fieldwork.

As per requirement from Engineers without borders I had a mentor with me during my fieldwork. This person was to provide support and companionship. That he did. Mikael Bue from Multiconsult, you have my thanks. The fieldwork was a lot more enjoyable because I had you there with me.

Thank you to all the people I talked to that helped me just because you wanted to. Thank you Bruce Cameron for that you agreed to come and demonstrate you're excellent solar pump in Budalangi for free. Thank you Andre Olchewski, Sean Furey and Kerstin Danert at Skat foundation for developing the Technology Applicability Framework (TAF) and for letting me come to St. Gallen, Swizerland to talk about TAF and my thesis in general. Thank you Tor Steinar Rafoss for letting me come to Dala Rieko and look at your solar pump system. Thank you every farmer, government official, chieftain, every person that I interacted with during my thesis.

As I write this I realize that this thesis is not only an accumulation of my experiences from school, but it is also an accumulation from all the people that helped me because they wanted to do something good. My sincere thank you.

Last, but not least. I would like to thank my parents for raising me with values and principles that has made me the person I am today and for giving me the opportunity to follow my dreams. Not everyone in this world is that lucky, for that I am truly thankful.

Abstract

The history of aid is a troublesome one. Despite the good intentions, the effort has often been in vain. It has become apparent that sustainability in development projects are imperative. The purpose of the study is the assess the feasibility of solar pumps for irrigation purposes in Budalangi, Kenya. This study is not only looking if solar pumps are technological feasible, but it looks into other aspects too. Such as economical feasible, environmental, social etc.

Budalangi is a flood-prone, poor, food insecure constituency in Kenya. Solar pump has been suggested to help alliviate poverty and hunger.

The water quality in Budalangi varies a bit, some of the ground water is simply not possible to use for agriculture. Out of 76 tests 7 found to have an EC of over 3 (dS/m). Which has an severe effect on applicability of the water.

10 out of 76 test had an E. coli concentration of 200 CFU/100ml or more. Which is higher than the strictest guideline. The microbial water quality does not effect the productivity thus it does not receive a lot of attention.

The economical capacity for the farmer is insufficent for them to buy a solar pump without subsidies or loans. It is also a completly unknown techonolgy to them, so some training is required. Luckily the solar pump is low maintenance. In addition the producer of the solar pump is lacking in their capacity to support buyers of the solar pump.

Despite the identified issues, the solar pump is a feasible technology for Budalangi. Long hours of sun and available water are excellent conditions for the solar pump. A solar pump could potentially increase the yield of a farm manifolds. It creates the opportunity to harvest during the dry season.

The demand for vegetables is high, 90% of the vegetables are imported from Uganda. Also with the opportunity to sell crops out of season the income could also increase manifold.

Sammendrag

Historien om bistand har vært trøblete. Til tross for gode intensjoner har innsatsen vært til ingen nytte. Det har blitt åpentbart at bærekraftighet i bistands prosjekt er veldig viktig. Målet med denne studien er å vurdere gjennomførbarheten for solpumper for irrigasjon in Budalangi, Kenya. Denne studien skal ikke bare se på den tekniske gjennomførbarheten, men den skal også se på andre aspekt også. Som økonomisk gjennomførbarhet, miljømessig gjennomførbarhet, sosial, etc.

Budalangi er en flomutsatt, fattig, food usikkert kommune i Kenya. Solpumper har blitt foreslått for hjelpe å mot fattigdom og sut.

Vannkvaliteten i Budalangi varier litt, noe av grunnvannet er det ikke mulig å bruke til agrikultur. Av 76 tester hadde 7 tester elektrisk konduktivitet på over 3 dS/m noe som vil påføre en alvorlig begrensning på hva vannet kan brukes til.

10 av 76 tester hadde en E. coli-konsentrasjon på 200 CFU/100ml. Som er høyere enn den strengeste rettningslinjen. På den andre side så påvirker ikke den mikrobiologiske vannkvaliteten produktiviteten, så den får ikke så mye oppmerksomhet.

Til tross for disse barrierene så er solpumper i Budalangi gjennomførbar teknologi. Mange timer emd sol og tilgjengelig vann er utmerkede forhold for sol pumper. En solpumpe kan potensielt øke utbyttet mye. Solpumper gjør det mulig å høste under tørketiden.

Etterspørselen etter grønnsaker er stor, 90% av grønnsakene kommer fra Uganda. Og med muligheten for å selge grønnsaker utenfor sesongen kan inntektene øke mye også.

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List of abbreviations

TAF - Technology Applicability Framework

NGO - Non-governmental organization

CBO - Community based organization

EC - Electrical conductivity

CDF - County Development Fund

PALWECO - Programme for Agriculture and Livelihoods in Western Communities of Kenya

EWB - Engineers without borders

O&M - Operation and maintenance

Introduction

Foreign aid has a reputation of being terribly ineffective. Chauvet, Collier and Duponchel claims over half of the World bank aid projects in Africa have failed. (2010) An example that hits closer to home is the Lake Turkana fish processing plant project, funded by the Norwegian Government, that was closed days after its completion (Associated Press, 2007). Needless to say, one must be careful while endevoring a new development project. In the WASH (water sanitation and hygiene) sector, the goto strategy for introducing new technology has often been trial and error, understanding the principle of what makes introductions succeed has been lacking (Olschewski & Casey, 2013).

Thanks to strong external support for many years the rope pump was successfully introduced in Nicaragua (Olschewski & Casey, 2013). Seeing the success in Nicaragua, many people wanted transfer the success to African countries, such as Ghana (Olschewski & Casey, 2013). The success story did not follow to Ghana. Multiple challenges occurred such as; low quality of the product, high costs, poor image, lack of strong government support, lack of viable supply chain, over-usage, etc. (Water Aid, 2004; Gomme & Sutton, 2009; Olschewski & Casey, 2013)

Food insecurity has been an issue in Sub-Saharan Africa for a long time, still today there is an significant amount of people suffering from food insecurity. (FAO, IFAD and WFP, 2014) In addition, with the challenges that the world is facing, it becomes even more important to tap into the vast potential that lies within the developing world.

Inventing new ideas, reinventing old ones and implementing them in an appropriate fashion are all key factors to order to face the challenges. One of these ideas that has been reinvented are solar pumps. However to prevent oneself to fall into previous pit falls one has to ask. Are solar pumps feasible?

Research aim and objectives

The aim is to establish if solar pumps is an appropriate technology for irrigation purposes in Budalangi, Kenya. In accordance with the aim, the specific objectives are:

- Assess the feasibility of introducing solar pumps in Budalangi, Kenya.
- Identify potential barriers.
- Suggest future actions

Background

Thesis Background

This thesis is a collaboration with Engineers Without Borders Norway, The Norwegian University of Life Sciences and Kenyahjelpen. Engineers Without Borders (EWB) Norway is one of many independent EWB divisions throughout the world. One of EWB Norway's goals is to build knowledge, competence and experience in humanitarian aid and development for their members. (Fossnes, 2014) It is through this capacity that EWB Norway has developed the Master with Purpose-program. A Master with Purpose is a master thesis facilitated by EWB Norway and with a humanitarian or environmental theme.

Kenyahjelpen is a NGO (non-governmental organization) and CBO (community based organization) which main focus is helping orphans and their caretakers in Budalangi, Kenya. In addition they concern themselves with the general development of Budalangi as a whole. Among their projects are; agricultural training, water supply for Nyambare nursery, vocational training, etc. (Kenyahjelpen, 2014)

Requirements

Engineers without borders has certain requirements in order to write a master with purpose. The most important one is that you need to have a mentor with you. This is an individual who is already an engineer and has experience with similar projects which can guide and help during the fieldwork. (Fossnes, 2014)

The mentor in question was Mikael Bue, currently working for Multiconsult in Oslo as a water and technology engineer. He has experience in conducting water quality analysis.

Figure 1: Mikael Bue - the mentor from Multiconsult

Geography and climate

Budalangi constituency is an electoral constituency part of Busia County. It is situated in the western part of Kenya at the shores of Lake Victoria. Nzoia River is meandering through Budalangi floodplain and every year floods are occurring; killing livestock and destroying croplands. (Huho & Ang'awa, 2008) Budalangi has an average rainfall of about 800 mm per year. (Huho & Ang'awa, 2008) The rainfall at the floodplain is insufficient to cause the flooding. Rather it is heavy rainfall in the upper and middle part of the Nzoia catchment that causes the flooding. (Huho & Ang'awa, 2008)

The rain is distributed between two rain seasons; a long rainy season that starts in March and lasts until May and a short rainy season in August until October. Dry spells starts from December and lasts until February. (Kenya RedCross, 2003; Government of Kenya, 2002) Vertisol (black cotton soil) is the prevalent soil type. When wet, vertisol can have a moisture content as high as 40%, but the infilatration rate and hydraulic conductivity becomes very low. (Muku & Nyandwaro, 2013) Dry vertisol on the other hand become extremly hard and is prone to erosion. Thus it is imperative to manage the soil moisture. (Jutzi, 1988)

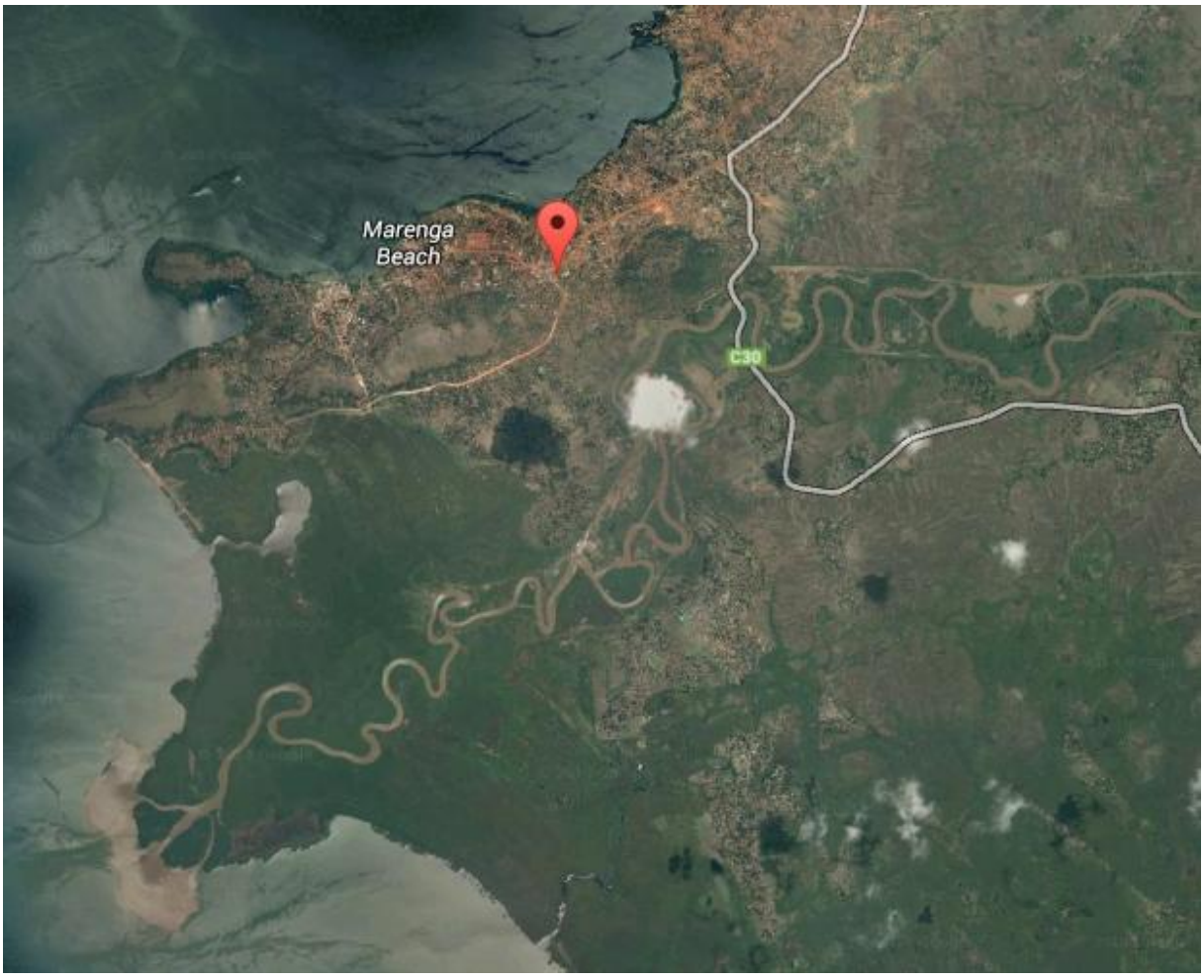


Figure 2: Satellite picture of Budalangi, Port Bunyala indicated on the map (Adapted from: http://www.google.com/maps)

Despite that vertisols can be very productive (Eswaran & Cook, 1988), Budalangi floodplains has very low food production. (Huho et. al., 2011)

Table 1: Relevant climatologically data from Port Bunyala (adapted from: Weatherbase (2014))

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (^{o}C)	22.6	22.9	23.2	23.3	22.8	22.4	21.9	21.7	22	22.2	23.1	22.6	22.7
Precipitation (mm)	56.4	71.3	138.4	203.5	203.5	151.1	54.8	38.2	54	60	83.5	125	88.8
Average direct solar radiation (Mj/m^2)	21.2	24.5	24.9	22.3	19.8	20.2	20.1	18.5	19	21	20.3	20.2	23.7

Demography

The population of 67323 is mostly rural (Kenya National Bureau of Statistics, 2010) and the most important economic activities are agriculture and fishing. (Onywere, et al., 2011) Almost 90% (Kenya National Bureau of Statistics, 2010) of the population lives in rural settlements and 70% of the total population lives below the poverty line, among the poorest constituencies in Kenya. (Central Bureau of Statistics, 2005)

Literature review

Solar pumps

Solar pumps (photovoltaic powered pumps) are based on semiconductor technology that converts sun energy to electricity to run a water pump. (Meah, et al., 2008) The photovoltaic array has a varying power point depending on a few factors such as; solar radiation, temperature, connect load and connection type. (Meah, et al., 2008)

Solar pumps for agricultural use are by no means a new idea, the onset was the high oil prices in the late 1970s, which prompted interest in other energy sources (Parker, 1991). For a long time solar pumps (or photovoltaic powered water pumps) have been seen as the *"harbinger of a new era in water provision for rural and developing communities"* (Short & Thompson, 2003).

Theft of solar panels is regarded as one of the biggest obstacles for solar pumps. Solar panels are in constant demand and is thus easy to sell. (Hjalmarsdottir, 2011)

Table 2: Comparison of pumping options (adapted from: Oi (2005) and Thomas (1987))

System Type	Advantages	Disadvantages
PV Powered System	✓ Low maintenance ✓ Unattended operation ✓ Reliable long life ✓ No fuel and no fumes ✓ Easy to install ✓ Low recurrent costs ✓ System is modular and closely matched to need	▪ Relatively high initial cost ▪ Low output in cloudy ▪ weather
Diesel (or Gas) Powered System	✓ Moderate capital costs ✓ Easy to install ✓ Can be portable ✓ Extensive experience ✓ available	▪ Needs maintenance and ▪ replacement ▪ Site visits necessary ▪ Noise, fume, dirt problems ▪ Fuel often expensive and ▪ supply intermittent
Windmill	✓ No fuel and no fumes ✓ Potentially long-lasting ✓ Works well in windy sites	▪ High maintenance ▪ Seasonal disadvantages Difficult find parts thus ▪ costly repair ▪ Installation is labor ▪ intensive and needs special ▪ tools
Manual	✓ Low cost ✓ Simple Technology ✓ Easy maintenance ✓ Clean ✓ No fuel requirement ✓ Applicable to hand-dug wells	▪ Regular maintenance ▪ Low flow ▪ Absorbs time and energy that might be used more productively elsewhere ▪ Uneconomic use of expensive borehole

Agricultural water quality

Salinity

The available water that the plant can transpire is directly related to the salinity of the water. Ions in the water-soil exerts an affinity to the water, resulting in the adsorption force from the plant yielding less water. Water availability and crop productivity is directly related. Thus, the crop production decreases as the electrical conductivity increases. (Ayers & Westcot, 1985)

Salinity is measured by the electrical conductivity (EC_w) of the water. The most common unit is deciSiemens per meter at 25°C (dS/m).

Table 3: Crop tolerance of salinity of selected crops (adapted from Ayers & Westcot (1985))

	Crop yield reduction				
	0 %	10 %	25 %	50 %	100 %
Crop	EC_w (dS/m)				
Sorghum *(Sorghum bicolor)*	4.5	5	5.6	6.7	8.7
Rice (paddy) *(Oriza sativa)*	2	2.6	3.4	4.8	7.6
Corn (maize) *(Zea mays)*	1.1	1.7	2.5	3.9	6.7
Bean *(Phaseolus vulgaris)*	0.7	1	1.5	2.4	4.2
Tomato *(Lycopersicon esculentum)*	1.7	2.3	3.4	5	8.4
Sweet potato *(Ipomoea batatas)*	1	1.6	2.5	4	7.1
Onion *(Allium cepa)*	0.8	1.2	1.8	2.9	5
Orange *(Citrus sinensis)*	1.1	1.6	2.2	3.2	5.3

Table 4: General guidelines for salinity hazard of irrigation water based upon conductivity. (source: Bauder, et al., (2014))

Limitations for use	Electrical Conductivity
	(dS/m)*
None	≤0.75
Some	0.76 - 1.5
Moderate[1]	1.51 - 3.00
Severe[2]	≥3.00

pH

Normally the pH itself is not a problem. A range between 6.5 and 8.4 in pH is considered normal. The pH value is useful in its ability to warn about other issues. The biggest hazard from an abnormal pH value in water is its corrosive ability and the impact it can have on irrigation equipment. (Ayers & Westcot, 1985)

Microbial water quality

There has not been a huge focus on microbial water quality for irrigation purposes. This is despite the fact that irrigation water with poor quality is presents as a risk of disease transmission. (Steele & Odumeru, 2004) There has been a number of documented cases in the developed world of outbreaks that has its origin from contaminated irrigation water (Beuchat, 1998; Beuchat, 2002; Long, et al., 2002; Seymour & Appleton, 2001). In the developing world the statistics are not available, but considering the amount of endemic diseases in the developing world (Hotez, et al., 2007), it is only reasonable to assume that it is higher.

The threshold values vary, for instance the U.S Environmental Protection Agency (EPA) manual *Guidelines for Water Reuse* (2004) recommends complete absence of fecal coliforms in wasterwater used to irrigate crops that are to be eat uncooked. On the other hand the WHOs *Revised Guidelines for the Safe Use of Wastewter and Excreta in Agriculture and Aquaculture* (Blumenthal, et al., 2000) allows up to 1000 fecal coliform per 100 ml of water.

Table 5: Partial list of different microbial water quality guidelines for irrigation water (source: Steele & Odumeru (2004))

Guideline refrences	Criteria	Water type
	For crops eater raw	
6	<77 E. coli (CFU/100ml)	All
	Irrigation of areas open to the public or to livestock grazing	
6	<385 E. coli (CFU/100ml)	All
	For general irrigation	
6	<1000 E. coli (CFU/100ml)	All
170	<200 E. coli (CFU/100ml)	All

Strategy to reduce risk

There are several strategies to reduce the risk of disease transmission from fruits and vegetables that are contaminated. Restrict poor quality water to crops that are not likely to be consumed raw, treating the water before applying the water to the field and postharvest washing of fruits and vegetables. (Steele & Odumeru, 2004)

Nango Solar mobile solar pump

Nango Solar is a private company based in Kisumu specializing in renewable energy solutions. They have made a mobile solar pump, it comes in two versions. The standard version that has two 80-watt solar panels and two electric pumps, and a half-size version with two 40-watt panels and one pump.

The standard version has a capacity of at least 6000 liters of water per day, but amounts up to 10000 liters per day are achievable.

Conceptual framework

Technology Applicability Framework will be the basis for the conceptual framework. The TAF *"is a decision support tool on the applicability, scalability and sustainability of a specific WASH technology to provide lasting services in a specific context and readiness for its introduction."* (Olschewski, 2013a)

Table 4: The steps in the TAF (source: Oschewski a (2013))

Preparation	**1. Analysis of the objective of the assessment** (e.g. which technology, context, experiences so far, need, partners)
	2. Setting up of Study team
Step ❶	**3. Screening**, mostly desk work
Step ❷	**4. Preparation of field work**: e.g. contextualization of questionnaires incl. data on costs needed (e.g. CapEx for indicator 4), training of study team on TAF, logistics, orientation of partners in field including districts and villages to be visited
	5. Formal orientation of partners in the field, including districts and villages to be visited, training on TAF methodology, logistics incl. translation for local languages
	6. Field visits: interviews and data collection, using Focus Group Discussion, bilateral interviews with randomly chosen households and site visits
	7. Processing and validation of data, maybe in a workshop
	8. Scoring workshop; attended by all relevant actors, moderated by an experienced and **neutral** facilitator
Step ❸	**9. Presentation of all results** (screening, field visits, scoring) in the workshop
Step ❹	**10. Interpretation of results** in the workshop and **documentation**

Contextual differences and other limitations, the TAF will merely be a basis for the conceptual framework. The conducted approach will diverge from the approach described in the TAF. The main difference is there will be no scoring workshop.

TAF indicators

The TAF identifies six dimensions:

- Social
- Economic
- Environmental
- Legal, institutional and organizational
- Skill and knowledge
- Technological

In addition there are three actors considered in the TAF.

- User/buyer
- Producer/provider
- Regulator, investor and/or facilitator

Table 5: The TAF indicators (Source: Olschewski a(2013))

Perspective / Sustainability Dimension	User / buyer	Producer / provider	Regulator investor facilitator
Social	(1) Demand for the technology	(2) Need for promotion and market research	(3) Need for behavioural change and social marketing
Economic	(4) Affordability	(5) Profitability	(6) Supportive Financial Mechanisms
Environmental	(7) Potential for benefits or negative impacts for user	(8) Potential for local production of product or spares	(9) Potential for negative impacts or benefits for natural resources on a larger scale
Legal, institutional, organisational	(10) Legal structures for management of technology and accountability	(11) Legal regulation and requirements for registration of producers	(12) Alignment with national strategies and validation procedures
Skill and knowledge	(13) Skill set of user or operator to manage technology including O&M	(14) Level of technical and business skills needed	(15) Sector capacity for validation, introduction of technologies and follow up
Technological	(16) Reliability of technology and user satisfaction	(17) Viable supply chains for product, spares and services	(18) Support mechanisms for upscaling technology

The TAF is designed to assess the applicability of one product, in this thesis the Nango Solar mobile pump will be the basis conducting the TAF.

Assessment indicator sheet

In the TAF an assessment indicator sheet has been developed. It is meant as a basis, and has to be further developed so that it fits each situation. It is for the workshop and is meant to be asked to the relevant actor to give a score of the relevant indicator. (Olschewski, 2013a) The indicator questions are:

Social - user

"Is there a strong demand from target users for the services provided by this technology AND a willingness to pay for capital expense, operational expenses and capital maintenance expenses?"

Social - producer

"Do the producers have resources and effective mechanisms in place to do targeted market research, promotion, product development and follow up as needed?"

Social - regulator, investor, facilitator

"Is the introduction of this technology possible without any effort of behavioural chages? Do providers and facilitators have the necessary skills and resources to bring about changes to perceptions, attitudes and behaviours for this technology to be sustainable and scalable?"

Economic - user

"Is the amount of money that users should pay to cover CapEx, OpEx and CapManEx of this new technology affordable for them on a long term basis?"

Economic - producer

"Is there a likely chance that the producer/provider can generate sufficient revenues from sales to cover costs of product development, promotion, supply chain development and after-sales support?"

Economic - regulator, investor, facilitator

"Will subsidies or supportive funding be available for this technology?"

Environmental - producer

" Is there any indication that there might be a risk that negative impacts could result from the use of this new technology?"

Environmental - producer

"Is a local production of this technology possible at national or local level? Is there a likely chance that production of this technology at national level would impact negatively on the environment?"

Environmental - regulator, investor, facilitator

" Is this technolgy able to perform under varying conditions and are any agencies actively monitoring environmental impacts of this technology with a remit to enforce corrective action?

Legal, institutional, organizational - producer

"Can the required O&M structure for this technology realistically be managed by the water user group only? If not, are local government institutions or utilities willing or able to provide users with technical, management and financial support for O&M in the long term within existing legal frameworks?"

Legal, institutional, organizational - producer

"Is regulation of producers/providers and the quality of technologies/spares they deliver transparent, enforced and effective?"

Legal, institutional, organizational - regulator, investor, facilitator

"Is this technology aligned with national standards and strategies, and is it in compliance with national quality standards? Are there sufficient capacities in place at national and local level to exercise quality control of this technology?"

Skill and knowledge - producer

"Based on the current level of skills and capacity within the target user group, will the users, caretakers or local mechanics be able to manage the technology and to provide O&M on a regular basis?"

Skill and knowledge - producer

"Does the producer/provider of this technology have sufficient technical and business skills to introduce this technology using a cost model that ensures competitive, affordable rates but also profitability?"

Skill and knowledge - regulator, investor, facilitator

"Are current capacities and financial resources sufficient at national and district level to provide adequate technical advice and support for the introduction of this technology, including coordination, management, M&E, market research and follow-up?"

Technological - producer

"Considering current service levels provided by other technologies, is there a likely chance that the new technology might meet or exceed user expectation and be of interest for the all user groups??"

Technological - producer

"Is there potential to set up a viable supply chain for this technology and spares in this target region, and is there any mechanisim for follow-up with users after technology introduction?"

Technological - regulator, investor, facilitator

"What is the level of supportive structures for this water technology, in particular for funding further innovation and development to bridge the 'Valley of Death' and to pass the tipping point (see TAF Manual)?"

(Olschewski, 2013b)

Scoring

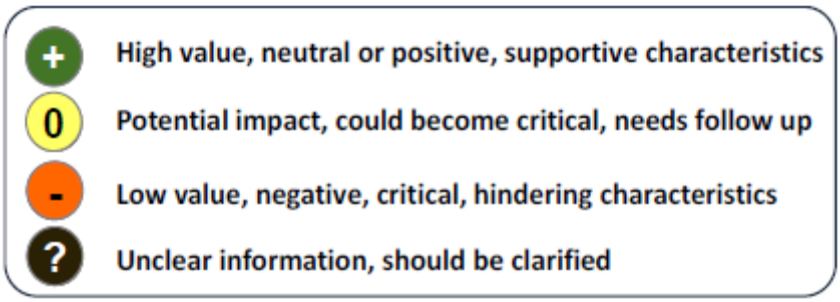


Figure 3: Scoring rules in the TAF (source: the TAF manual (Olschewski, 2013a))

Graphical profile

By graphically representing the assessment it is easier to identify areas where there are barriers.

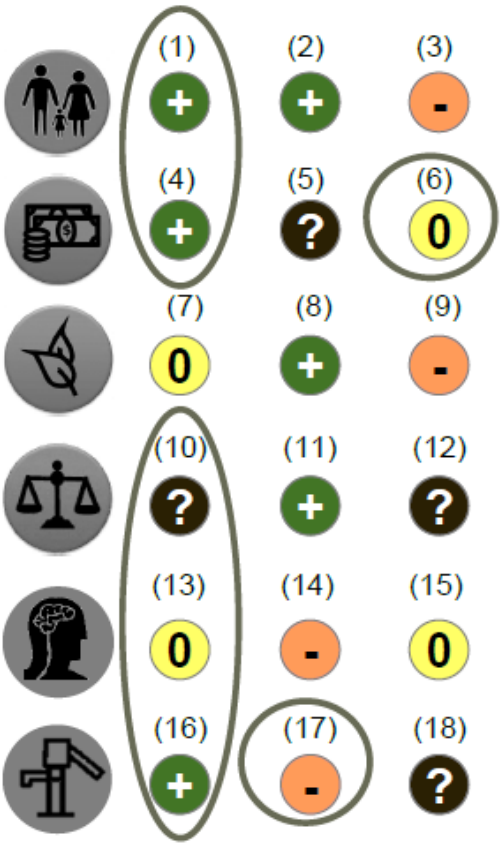


Figure 4: Example of graphical profile (Source: Olschewski (2013a))

Methodology

Measuring electrical conductivity (EC), pH and temperature

The Multi 3420 from WTW was used to measure the EC, pH and temperature.

Figure 5: The Multi 3430 from WTW (source: www.wtw.de)

Only the sensors for pH and electrical conductivity were connected. There is a sensor for the dissolved oxygen, but it was deemed as unimportant. When arriving at a water source, the sensor was rinsed in the water that was to be sampled. This to eliminate impurities.

Figure 6: Rinsing the sensors with the water that was to be sampled

A little cup was used to contain the water while the measuring was conducted. It was first rinsed with the water from the water point before it was used. The sensors had to stay for a while in the water for the measurement to stabilize. Multi 3430 has the AutoRead function, which tells you when the measured value has stabilized. (WTW, 2011) This makes the measurements easily comparable and reproducible.

After the measurements were done the sensors and the cup were cleaned with some paper and then put back into the suitcase.

Figure 7: A little cup was used to hold the water while the sensors were measuring

Figure 8: Cleaning the sensors

Assessing microbial water quality

The method of assessing the microbial water quality has been in compliance with the "practical method for rapid assessment of bacterial quality of water - a field-based guide". (UN-Habitat, 2010)

Sampling

First the whirl-pak is taken opened and filled with water from the water source. A metal cord goes through the top of the whirl-pak and the is used to close the pak. The cord is twirled three times to ensure that the sample is sealed.

Figure 9: Sampling water from a well

The sample is brought back where the analysis can be conducted. Analysis should be conducted within 6 hours from the sampling time.

Figure 10: Whirl-pak being twirled

Figure 11: The whirl-pak has to be twirled three times to ensure it being properly sealed

Figure 12: A Whirl-pak properly sealed

Microbial water quality analysis

The microbial water quality analysis is done with IDEXX Colilert Presence/Absence test and the 3M Petrifilm E.coli/Coliform Count Plate test. The Petrifilm is used to enumerate the concentration of E.coli and coliform bacteria, while the Colilert is more sensitive and is used to confirm presence/absence. (UN-Habitat, 2010)

Colilert test

The colilert uses two indicators in its substrate. The ONPG (Ortho-nitro-phenol-beta-D-Galactopyranoside) which is colorless - but coliform bacteria can produce the beta-galactosidase enzyme (Frampton & Restaino, 1993) that can break the indicator into ONP which has a bright yellow color. (UN-Habitat, 2010)

The other indicator is MUG (4-methyl-umbelliferone-beta-D-Glucoronide) and E. coli is the only bacteria among the coliform bacterias that is able to produce the enzyme that can break it down. Once again the beta-glucuronidase enzyme (Frampton & Restaino, 1993) hydrolyzes MUG, and is split into MU (methylumbelliferone) which fluoresces blue when shone with UV light with a wavelengthof 340nm. (UN-Habitat, 2010)

A sterile pipette was opened

Figure 13: Opening the sterile pipette

Figure 14: Water is being injected into the Colilert tube

Figure 15: Ensure that the substrate and water is mixed

The water was injected into the Colilert tube until it reached the mark (10mm)
The Colilert tube was incubated for 24 hours with body heat to ensure good bacterial growth. After 24 hours presence/absence of Coliform and E.coli was confirmed with UV-light

Figure 16: A set of tests - Most test were (unsurprisingly) confirmed of having coliform bacteria in them

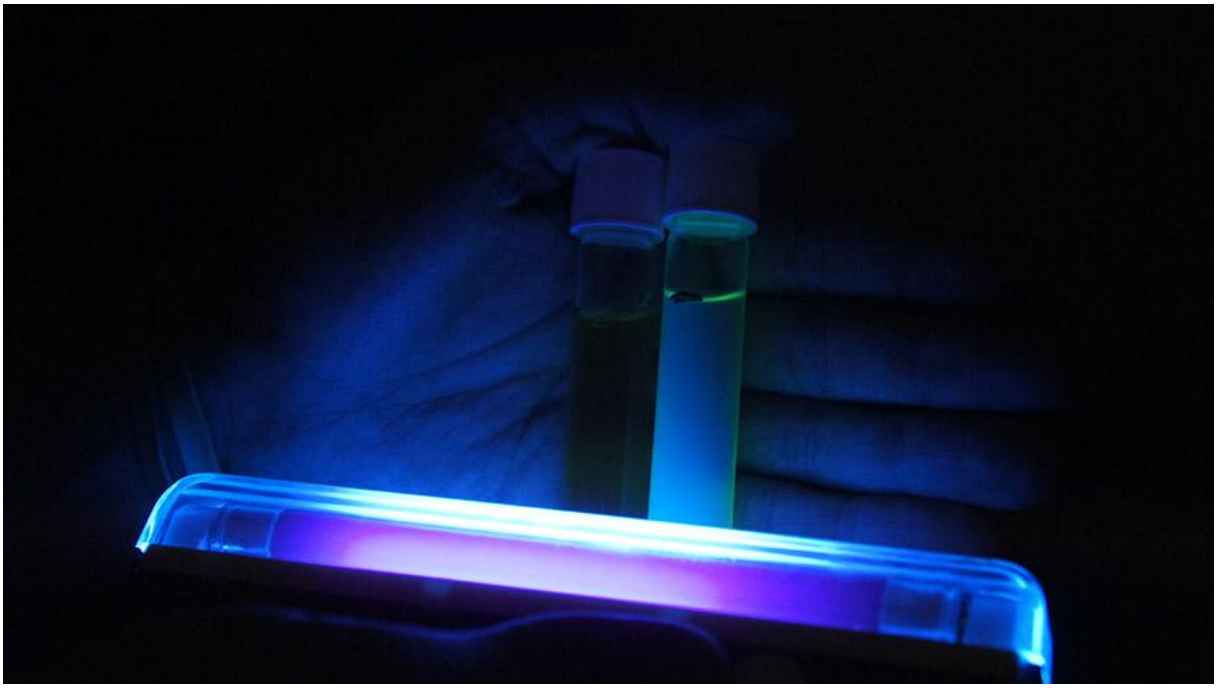


Figure 17: Two Colilert tubes being exposed to UV light, the one on the right fluoresces and thus presence of E.coli is confirmed

Petrifilm test

The E. coli Count Petrifilm is widely used in food industry to sample meat, seafod and poultry. (UN-Habitat, 2010) Like the Colilert, E. coli Count Petrifilm uses an indicator to identify E. coli. The indicator BCIG (5-bromo-4 chloro-3 indolyl-beta D Glucoronide) is just like the MUG hydrolyzed with the presence of enzyme glucuronidase. (UN-Habitat, 2010) BCIG hydrolyzes into BCI which produces a blue precipitate around the colony so that it can be told apart from other colony forming bacterias. (UN-Habitat, 2010)

In addition E. coli Count Petrifilm contains violet red bile nutriens with lactose, which prevents Gram positive bacteria to grow (Coliform bacteria are Gram negative). The lactose confirms coliform bacteria due to the fact that all coliform bacteria produce gas bubbles. (UN-Habitat, 2010)

One milliliter was abstracted from the whirlpak with the pipette that was previously used for the Colilert test. The E.coli Count Petrifilm was inoculated with the water.

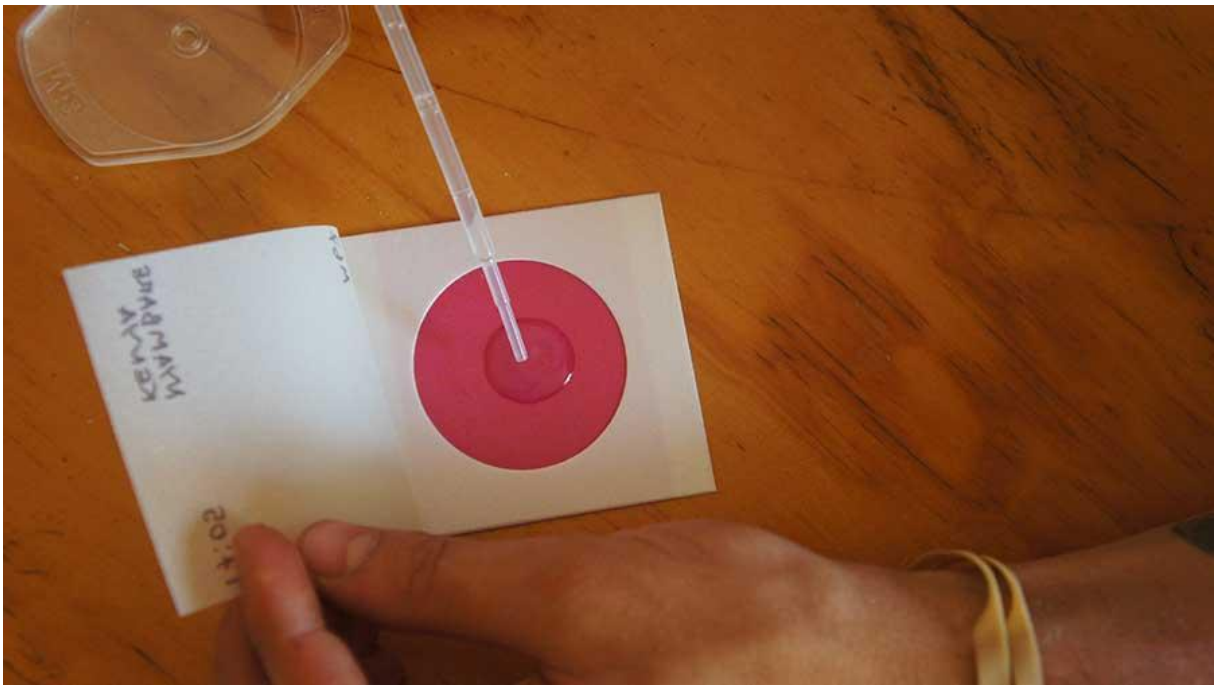


Figure 18: Inoculating the petrifilm

To evenly distribute the water, a spreader was used.

Figure 19: Using spreader to distribute the water

The E.col Count Petrifilm was incubated with body heat for 24 hours and the next day the result could be checked.

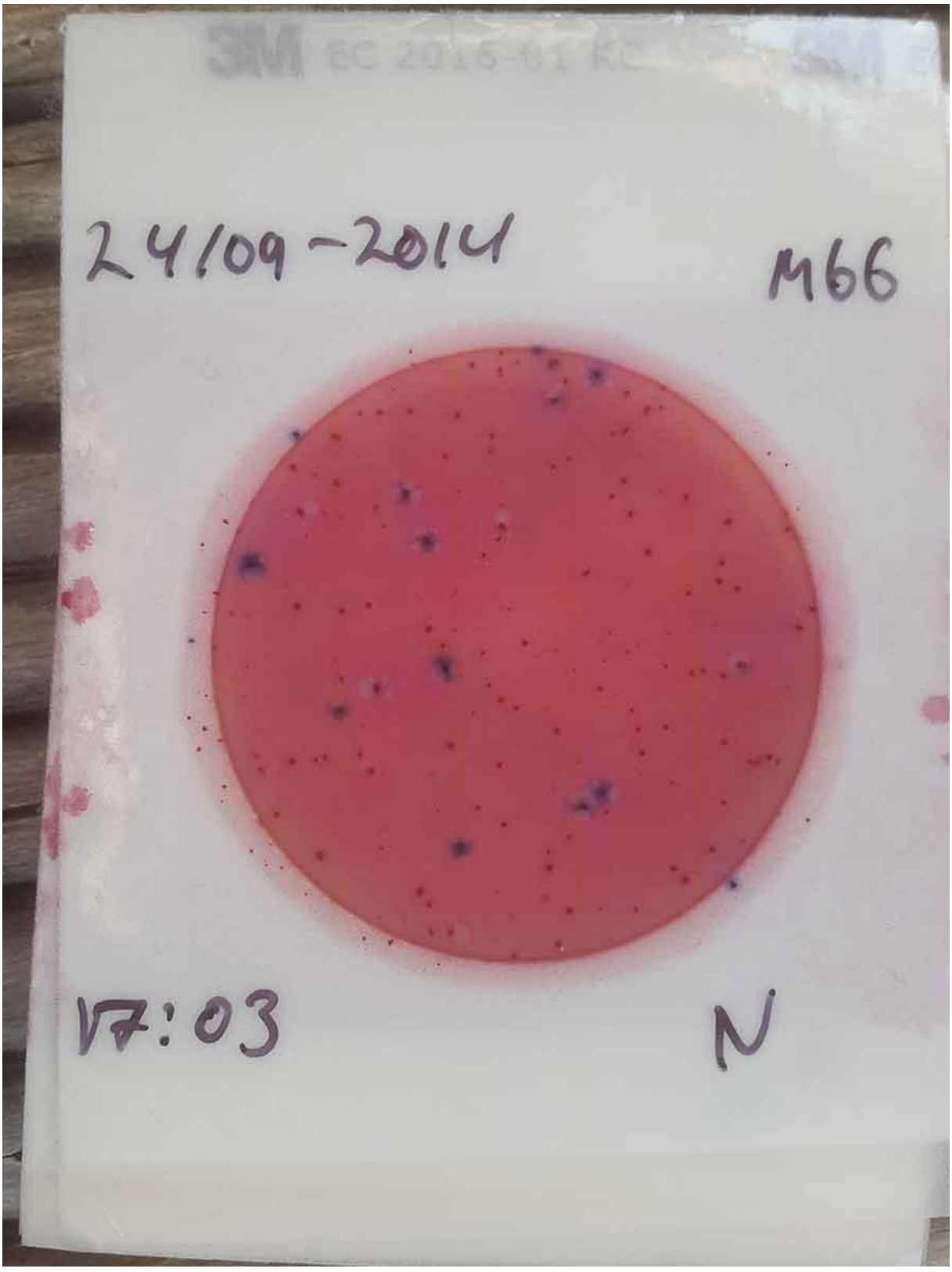


Figure 20: Example of an E.coli Count after incubation - date, time and identification number at top right to associate it with a specific water source - the blue dots are E.coli colonies

Interviews

The interviews was designed in order to answer the question in order to conduct the TAF, as a substitute for the workshop.

Semi-structured interviews

The semi-structured interview (sometimes called informal interview) is a verbal exchange where questions are predetermined but the interview unfolds in a conversational manner and gives the interviewer and interviewee opportunity to elaborate and bring up other issues. (Clifford, et al., 2010)

Focus group interviews

Individuals are selected to discuss about a particular topic in an informal setting. (Wilkinson, 2004) The focus group methodology is good for exploring the issues of importance without applying to much pressure on the participants to reach a conclusion. (Liamputtong, 2011) The focus group interview was conducted after the demonstration of the Nango Solar 160 Watt mobile solar pump and that and the TAF was the basis for the questions asked.

Questionnaires

In order to find an answer to the TAF indicators questionnaires has been developed, while there has been developed template questionnaires, it is important to develop the questionnaires to fit in the a specific situation with. (Olschewski, 2013) As the TAF is developed for domestic use water supply and not water supply for agricultural use some of the questions do not apply and some questions need to be added.

Results

Microbial test results

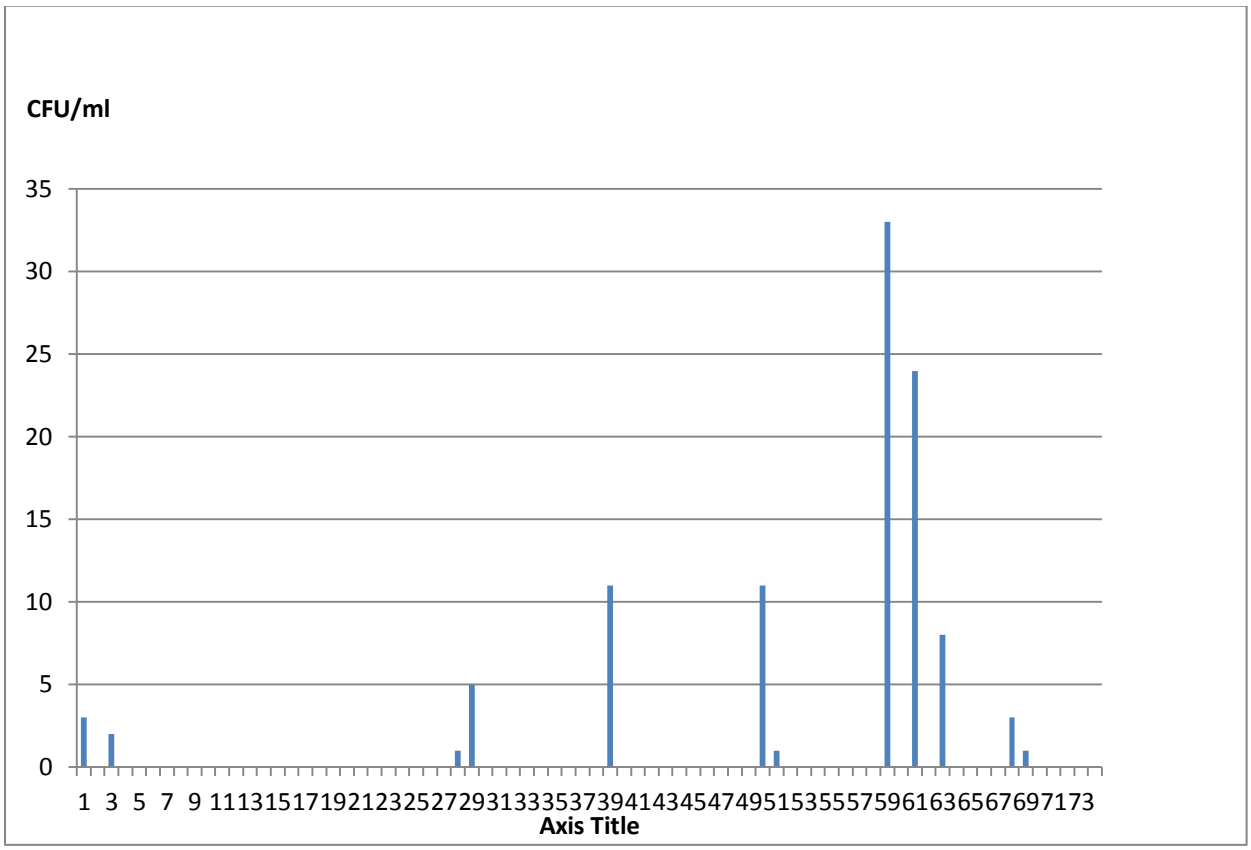


Figure 21: test results of petrifilm CFU/ml of E. coli - 12 of 76 had at least 1 CFU/ml of E. coli

In total there were 13 test out 76 that grew colonies on the Petrifilm test, with the highest value being 33 CFU/ml, which was from a water sample from the river. 35 out of 76 conducted Colilert test showed presence of E. coli, thus 22 tests had E. coli in the sample but did not enough for it to have an impact on the Petrifilm test.

3 of the water point were assessed to have a very high risk level, 8 were assessed as high and 24 as moderate.

See Appendix 2 with a table with all of the results.

Electrical conductivity tests

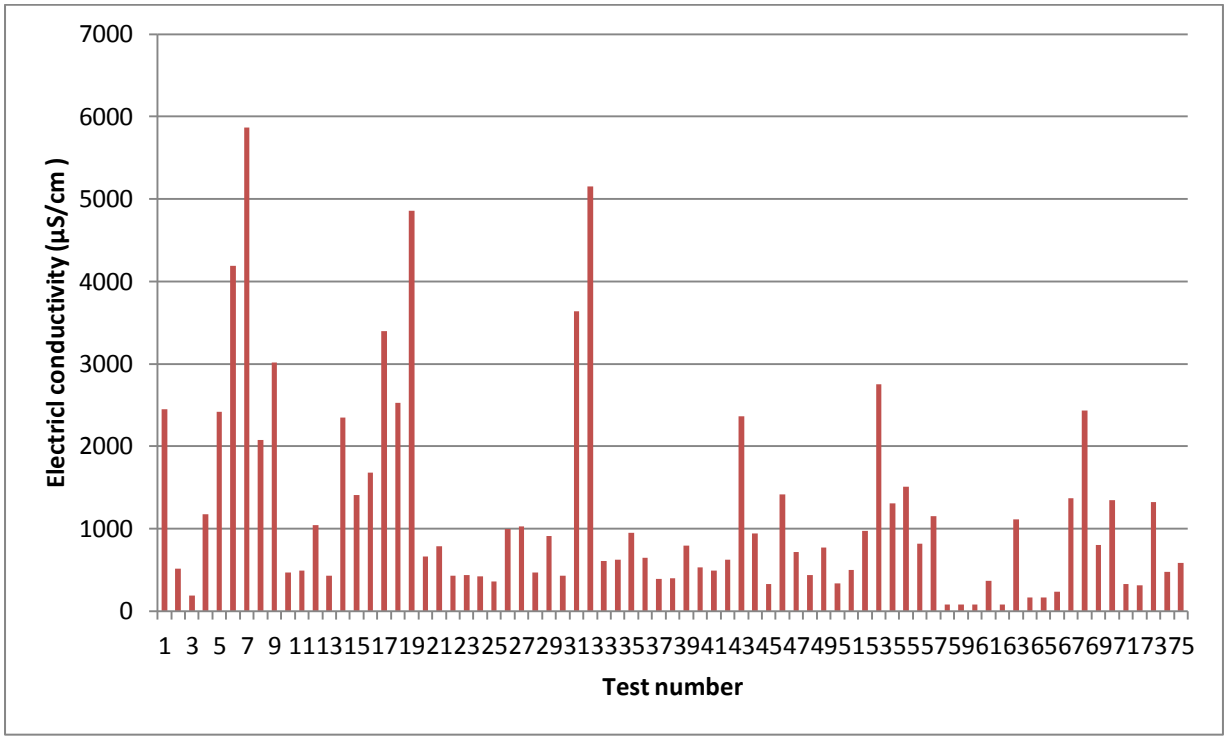


Figure 22: Test results of electrical conductivity measurements

The highest EC was 5870 µS/cm with the lowest being 77.5 µS/cm and the average being 1199.696 µS/cm. See Appendix 1 for all results.

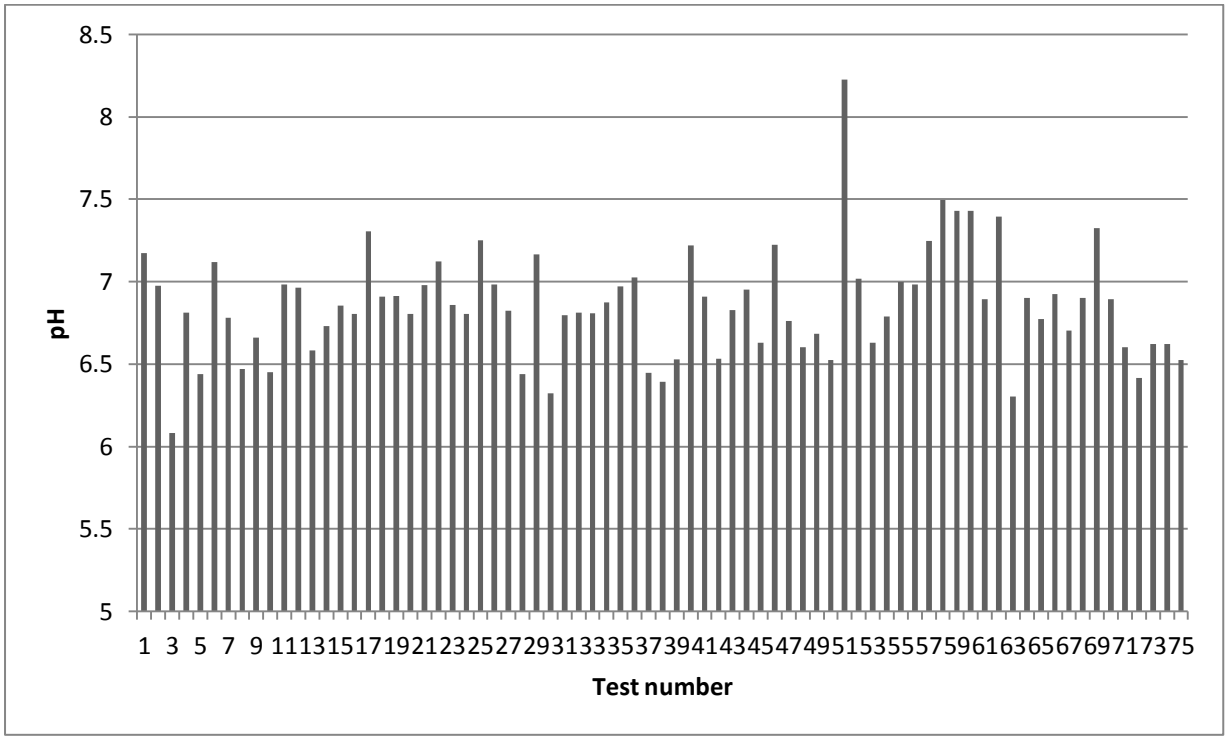


Figure 23: Test results of pH measurments

The highest pH was 8.23, the lowest 6.08 and with an average of 6.85. See Appendix 1 for all results.

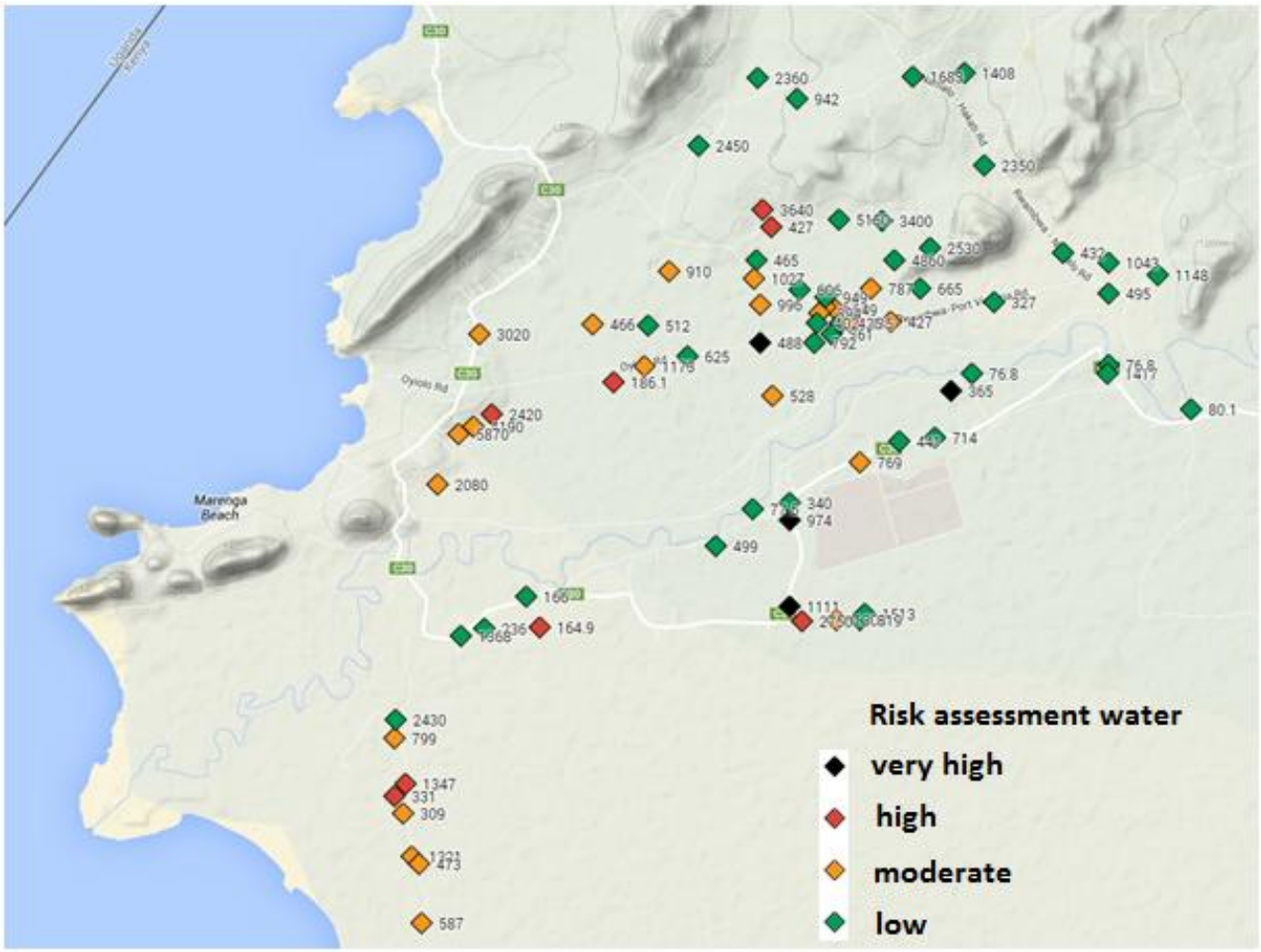


Figure 24: Points where the tests were conducted number is EC (dc/cm)

Pump demonstration

Everyone had a positive impression of the Nango Solar mobile solar pump, no one had ever heard of a solar pump before. Some people were concerned with the capacity of the solar pump. The combustion water pump often has an output 50 times higher. Regardless they were positive because they realized that the pump could run day in and day out without fuel as an input.

Figure 25: Local farmers gathered for demonstration of the Nango Solar mobile pump

Figure 26: Focus group interview after the demonstration

Figure 27: Farmers checking out the Nango Solar mobile pump

Present at the demonstration were also local authorities, such as the agricultural extension office and the procurement officer of PALWECO.

Focus group interview

The Focus group interview was conducted in the 5 places after the demonstration of the solar pump was conducted. They all confirmed that there was a demand for irrigation water and were quite interested in the solar pump. No one was able to buy the solar pump. The amount they could afford was between 12000 and 30000 ksh. See appendix 4 for full summary of the focus group interview.

Figure 28: The group of farmers in Budalangi present for the demonstration and the focus group interview

Interviews

Perhaps the most interesting result from the interviews were with the sub-county ward. There has been a devolution of government in Kenya, where the income from taxes are being allocated to the county government. Thus, there now was a big opportunity to receive funding for projects.

See Appendix 6 for summaries of all the interviews.

Household interviews

See Appendix 5 for transcripts of the interviews.

23 households were interviewed, all of them had been at the demonstration. The farmers reported to have an income varying from 1500 Kenyan shillings (KES) to 20000 Kenyan shillings in an average month. Their answers averaged out is 5636.364 Kenyan shillings.

The reported crops that they were planting were:

- Rice
- Tomato
- Sukuma wiki
- Sweet potato
- Legumes
- Corn
- Beans
- Millet
- Ground nuts
- Banana
- Kasawa

All of the farmers though the solar pump was a good idea and they requested if it was possible to use the solar pump for wells, as they lived too far from the river to utilize it as a water source. No one had the capital to buy the solar pump, they were willing to pay from 80000 Kenyan shillings to 2000 Kenyan shillings.

Most of the households had little opportunity to borrow money either from organizations or banks. The majority said that it was impossible. Regarding owning the pump as a group, surprisingly most people were quite negative towards owning it as a group. The main issues were:

- Lack of ownership
- Irresponsible management of equipment
- Free riders - join the group, but do not contribute
- Selfishness - give back equipment after their allotted time is over
- Fraud - there one experience of a group where the leaders stole money

The majority of the households irrigate by manual means, either by carrying buckets or by using a foot pump (the moneymaker). Quite a few people found it quite useful if the solar pump could be used to charge mobile phones, while those that had power at the house did not find it useful.

Technology Applicability Framework

Indicator: **Social - user** 	
Indicator question: *"Are potential target users interested in the services the new technology can provide to the extent that they would be willing to pay for CapEx, OpEx and CapManEx?"*	
Reasoning: From the results of the Focus group interviews, the household interviews and interviews with the local government there is without doubt a high demand to produce more food in Budalangi. Samuel Owino an agricultural officer in Budalangi said that 90% of the vegetables were imported from Uganda (see Appendix 6). The question is if they are willing to pay the capital expenses? The maintenance and capital expenses are negligible. Some farmers were very excited about the solar pump as it could possibly increase their productivity significantly, possibly having 3-5 harvests (depending on the type of crop) in a year, instead of just one.	
SCORE	

Indicator: **Social - producer** 	
Indicator question: *"Do the producers have resources and effective mechanisms in place to do targeted market research, promotion, product development and follow up as needed?"*	
Reasoning: As Nango Solar is quite a small company, the answer. They are growing though, the goal of the company has for the time being only to be self-sustainable. While this has not been the case, it is has in recent times starting being just that. Thus they are looking to expand their services.	
SCORE	

Indicator: **Social - regulator, investor, facilitator** 	
Indicator question: *"Is the introduction of this technology possible without any effort of behavioural changes? Do providers and facilitators have the necessary skills and resources to bring about changes to perceptions, attitudes and behaviours for this technology to be sustainable and scalable?"*	
Reasoning: There are no apparent reasons that this technology would need any behavioural changes.	
SCORE	

Indicator: **Economic - user** 	
Indicator question: *"Is the amount of money that users presently pay sufficient to cover CapEx, OpEx and CapManEx of this technology/service level? If not, would this water technology still be affordable?"*	
Reasoning: If the farmer is using a motorized pump the solar pump will be economical in the long term. The problem is the high investment cost. They are not able to afford it.	
SCORE	

Indicator: **Economic - producer** 	
Indicator question: *"Can the producer/provider generate sufficient revenues from sales to cover costs of product development, promotion, supply chain development and after-sales support?"*	
Reasoning: It is not feasiable for Nango Solar to drive from Kisumu (about 2-3 hour drive) to Budalangi to support the owners of the solar pumps. It would be necessary for local people to be trained in order to handle simple support. For this to be feasiable it requires a certain amount of farmers to have solar pump. (Cameron, 2014)	
SCORE	

Indicator: **Economic - regulator, investor, facilitator** 	
Indicator question: *"Are subsidies or supportive funding available or expected to be available in the short term?"*	
Reasoning: There are different opportunities in order to get funding. There are the CDF, the community development fund. The recent devolution of the government, where the funding has been moved from Nairobi to the counties has sprung quite some enthusiasm to get funding. A problem is that the farmers does not know how to apply for funding. In addition professional proposal writer has a bad reputation in Kenya for applying for funds and then stealing the money. In addition there are organizations like PALWECO (Programme for Agriculture and Livelihoods in Western Communities who also has shown an interest in solar pumps (see Appendix 5)	
SCORE	

Indicator: **Environmental - user** 	
Indicator question: *"Is there a risk that negative impacts could result from the use of this technology?"*	
Reasoning: Over-abstraction is possible, but not very likely. The river Nzoia has quite a significant flow. With an average flow of 118 m^3/s (Sangale, et al., 2012). On the other hand there are a lot of environmental benefits, such as the benefits from going away from petrol fuel.	
SCORE	

Indicator: **Environmental - producer** 	
Indicator question: *"Is a local production of this technology possible at national or local level? Is there a likely chance that production of this technology at national level would impact negatively on the environment?"*	
Reasoning: The Nango Solar mobile pumpe is produced in Kisumu, about 2-3 hours from Budalangi. It is hard to imagine any negatively impacts on the environment from producing the Solar Pump.	
SCORE	

Indicator: **Environmental - regulator, investor, facilitator** 	
Indicator question: *"If this technology is scaled up, could there be negative impacts on the environment, and are any agencies actively monitoring possible impacts with a remit to enforce corrective action?"*	
Reasoning: There could be over-abstraction, if the water comes from ground water more so, but otherwise. No.	
SCORE	

Indicator: **Legal, institutional, organizational - user** 	
Indicator question: *" Can the required O&M structure for this technology realistically be managed by the water user group only? If not, are local government institutions or utilities willing or able to provide users with technical, management and financial support for O&M in the long term within existing legal frameworks?"*	
Reasoning: Operation and maintenance of a solar pump is a lot easier than other water technologies. Simple maintenance such as washing the filter and cleaning the solar panel can be expected to be done by the users or local representatives from Nango Solar, but that has to be put in place. Heavier repairs probably has to be done by Nango Solar.	
SCORE	

Indicator: **Legal, institutional, organizational - producer** 	
Indicator question: *"Is regulation of producers/providers and the quality of technologies/spares they deliver transparent, enforced and effective?"*	
Reasoning: Data not available	
SCORE	

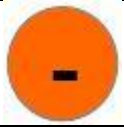
Indicator: **Legal, institutional, organizational - regulator, investor, facilitator** 	
Indicator question: *"Is this technology aligned with national standards and strategies, and is it in compliance with national quality standards? Are there sufficient capacities in place at national and local level to exercise quality control of this technology?"*	
Reasoning: PALWECO which is a programme run by the government of Kenya has ongoing project with Solar pumps which shows that it is a strategic plan for Kenya to use solar pumps. It is also in their strategic plan to increase food production. This question is more relevant for water regarding domestic use. Increasing the use of solar power alligns with Kenyas policies, though they are not specifically targetting solar pumps. (Ministry of Energy and Petroleum, 2014)	
SCORE	

Indicator: **Skill and knowledge - user** 
Indicator question: *"Based on the current level of skills and capacity within the target user group, will the users, caretakers or local mechanics be able to manage the technology and to provide O&M on a regular basis?"*
Reasoning: Operation and maintenance of a solar pump is a lot easier than other water technologies. Simple maintenance such as washing the filter and cleaning the solar panel can be expected to be done by the users or local representatives from Nango Solar, but that has to be put in place. Heavier repairs probably has to be done by Nango Solar. PALWECO which is a programme run by the government of Kenya has ongoing project with Solar pumps which shows that it is a strategic plan for Kenya to use solar pumps. It is also in their strategic plan to increase food production. This question is more relevant for water regarding domestic use. Increasing the use of solar power alligns with Kenyas policies, though they are not specifically targetting solar pumps. (Ministry of Energy and Petroleum, 2014)

SCORE	

Indicator: **Skill and knowledge - producer** 
Indicator question: *"Does the producer/provider of this technology have sufficient technical and business skills to introduce this technology using a cost model that ensures competitive, affordable rates but also profitability?"*
Reasoning: Nango Solar has been struggeling with having a profit, though it seems that lately they have been turning it around.

SCORE	

Indicator: **Skill and knowledge - regulator, investor, facilitator** 	
Indicator question: *"Are current capacities and financial resources sufficient at national and district level to provide adequate technical advice and support for the introduction of this technology, including coordination, management, M&E, market research and follow-up?"*	
Reasoning: There are the Agricultural extension service, but their capacity is very limited. PALWECO has an implementation framework which includes follow up and capacity building but more is needed.	
SCORE	

Indicator: **Technological - user** 	
Indicator question: *"Considering all user groups, what is the current/expected level of user satisfaction with regard to the current/envisaged performance of this water technology?"*	
Reasoning: The farmers are very interested in this technology. It provides an opportunity to have several harvests in one year without having to pay a high operational cost.	
SCORE	

Indicator: **Technological - producer** 	
Indicator question: *"Do viable supply chains exist or can they be developed for this technology and spares in this target region, and is there any mechanisim for follow-up with users after technology introduction?"*	
Reasoning: The Nango Solar mobile pump has been produced, all the different parts are available in Kisumu. There are follow-up after technology introduction, but with a higher scale of introduction more support will be provided. (Cameron, 2014)	
SCORE	

Indicator: **Technological - regulator, investor, facilitator** 	
Indicator question: *"What is the level of supportive structures for this water technology, in particular for funding further innovation and development to bridge the 'Valley of Death' and to pass the tipping point (see TAF Manual)?"*	
Reasoning: There is PALWECO who have ongoing projects with Solar pumps for irrigation, but probably more effort is in order if the technology uptake is to be wide scaled.	
SCORE	

Graphical profile

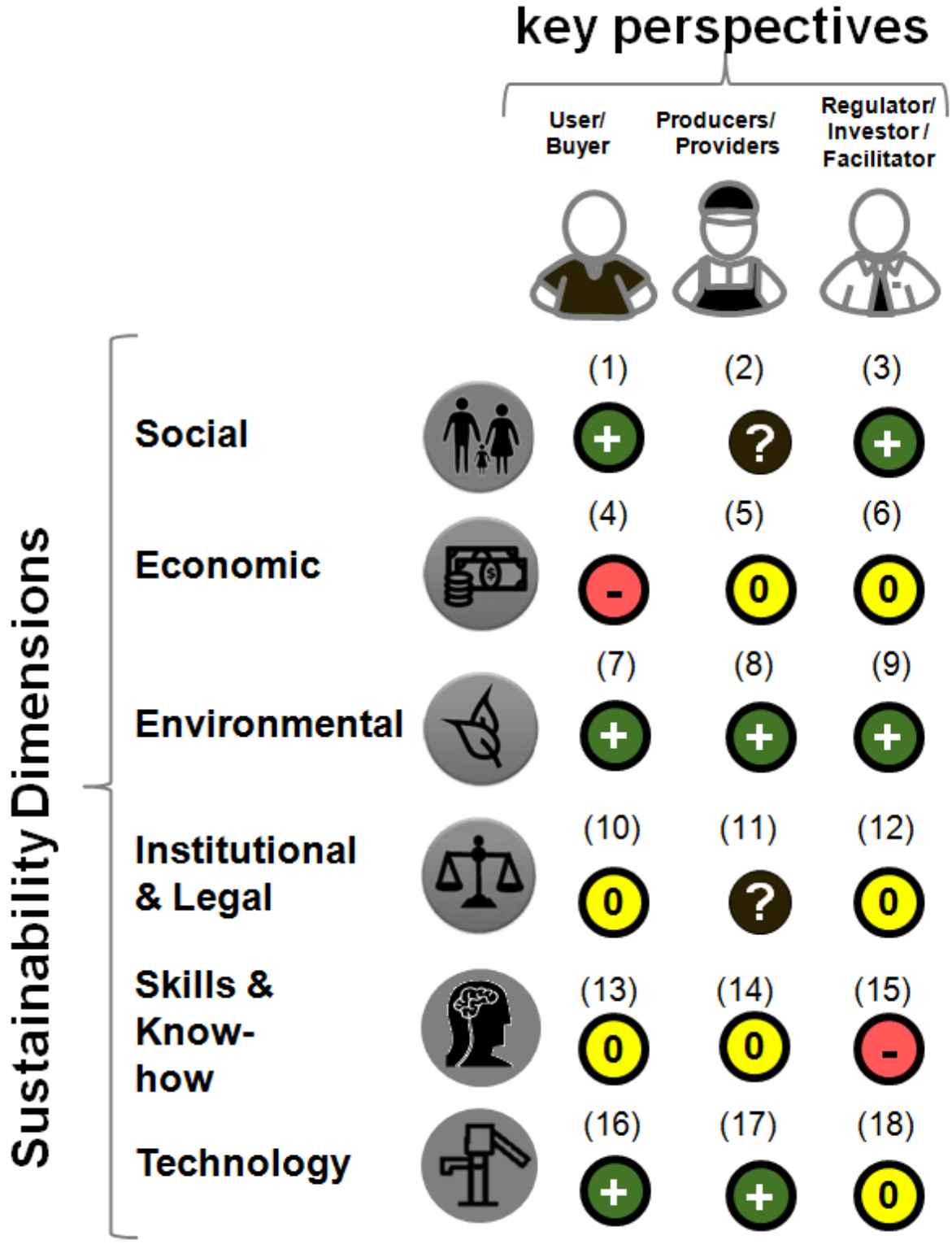


Figure 29: Graphical representation of the TAF assessment

Discussion

The solar pump has the potential to change the lives of user for ever. With the pump then it is possible to irrigate during the dry seasons, effectively increasing the food security and the potentially the income also. As irrigating during the dry seasons enables the farmer to sell during off-season the potential of extra income is huge.

The Nango Solar mobile pump is excellent, it is flood resilient as it can used at a floodprone site and thus can be easily moved if there is a risk fo flooding. In addition the fact it is mobile effectively removes the risk of it getting stolen, which is considered to be a big problem.

Electrical conductivity varies quite a bit. Perhaps the most direct impact is the EC, with a high EC the yield can be reduced significantly. For example with an EC of 2.4 dS/m the yield of beans decreases with 50% (Ayers & Westcot, 1985). The highest measurement was 5.87 dS/m[1], you cannot expect any yield at all from beans. 37 out of 76 water points has an EC lower than 0.75 dS/m and according to Bauder, et al. (2014) there are no limitations of use for water with that EC. From 0.76-1.5 (dS/m) there are some limitations, leaching is required (Bauder, et al., 2014). With 1.51-3.0 there is a need for good drainage and some plants that are sensitive may have trouble with germination.

While this is only a concern if the water source is ground water. The river has more or less the same chemical composition as rain and is stable at 0.1 dS/m. This might deter from using groundwater as a water source for irrigation, but there are quite a few sources that are applicable, but if they should be tested before deciding to use it as a water source for irrigation.

According to the strictest guideline the amount of E. coli in water for irrigation purposes should not exceed 200 CFU/100ml. Out of 76 test, 10 water samples had a E. coli concentration of 200 CFU/100ml or more.

One interesting observation is that the two highest measurements of E. coli were both from the river Nzoia. On the other hand, the two other tests conducted on the river showed no presence of E. coli. It is important to think sensible of this though. Generally, parameters such as this are not a concern in developing countries. Not producing food is often not an alternative for a farmer, especially when the effect is something as intangible such as this. Nonetheless it should be taken into consideration. It is possible to restrict the type of crops, perhaps suggest planting fruit trees.

Another point is that presence of E. coli is not necessarily dangours. E. coli is an indicator organism, E. coli is used to prove fecal contamination. Just because there is E. coli in the water, does not mean that it could make you sick or contaminate the food. In Budalangi there and in Kenya in general there are a lot of grazing cows. The E. coli could easily been from cows. Knowing if water is contaminated by fecal matter from a cow or a human changes the risk associated with that water a lot.

Regarding deficiencies (see figure 28), two dimensions stand out. The economic and the skills and know-how. There is simply not possible for the farmers to buy a solar pump. Some kind of subsidy or loan is required. The way to fund has to been thought through. It is absolutely imperative that the user is expected to pay for the expenses from operation and maintenance. This is in order to ensure sustainability. One positive discovery is that there are funds available in Kenya.

[1] Converting from µS/cm to dS/m you simply divide by 1000

The skills and know-how of the user is quite weak. No one of the farmers had ever heard of solar pumps before. Training of how to use and maintain the solar pump should be conducted. The support that Nango solar can provide is also at the moment lacking, even though there are plans to provide more support, provided there is enough owners in an area.

Conclusion

This study shows that solar pumps in Budalangi, Kenya is feasiable. That is not to say that there are not challenges. The water quality is not that good at some water sources, there are some lack in knowledge and capacity of both producer, facilitators and institutions. To have a successful widespread uptake strong external support is needed.

Further investigation is recommended to look at the groundwater recharge, potentially how much can be sustainably abstracted. A thourghou economical analysis of a solar pump introduction project, with payback period, cost/benefit analysis etc.

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Appendix 1 - Test results electrical conductivity

Test results from Multi 3430						
S/No	**EC (µS/cm)**	**pH**	**Name of water point**	**Village**	**Sub-location**	**Location**
6	2450	7.174	Bujwanga 'A'	Bujwanga 'A'	Mudembi	Bunyala east
28	512	6.976	Bulagu	Bulagu	Budalangi	Bunyala east
31	186.1	6.08	Bulagu Mukhuyu	Bulagu	Budalangi	Bunyala east
159	1173	6.81	Buchiriba	Buchiriba	Budalangi	Bunyala east
147	2420	6.439	Idokho	Idokho	Bulemia	Bunyala north
40	4190	7.117	Mundekwe	Mundekwe	Bulemia	Bunyala north
42	5870	6.78	Bukalama	Bukalama 'A'	Bulemia	Bunyala north
43	2080	6.47	Bukalama	Bukalama 'B'	Bulemia	Bunyala north
20	3020	6.66	Sibuka Pri. School	Sibuka	Mudembi	Bunyala east
23	465	6.45	Makina	Makina	Budalangi	Bunyala east
9	495	6.981	Busidia	Busidia	Mudembi	Bunyala east
64	1043	6.965	Lwahanga	Lwahanga	Rwambwa	Bunyala east
62	432	6.581	Buhuhiro store	Buhuhiro store	Rwambwa	Bunyala east
10	2350	6.731	Budunyi	Budunyi 'A'	Mudembi	Bunyala east
x	1408	6.853				
12	1683	6.803	Namuyama	Namuyama	Mudembi	Bunyala east
3	3400	7.304	Nandekwe	Nandekwe	Mudembi	Bunyala east
70	2530	6.907	Nayera 'A'	Nayera 'A'	Rwambwa	Bunyala east
65	4860	6.914	Pangara	Pangara	Rwambwa	Bunyala east
59	665	6.804	Bujumba	Bujumba	Rwambwa	Bunyala east
2	787	6.977	Mumoni	Mumoni	Mudembi	Bunyala east
1	427	7.124	Busweti	Busweti	Mudembi	Bunyala east
19	435	6.858	Mudembi Market	Mudembi	Mudembi	Bunyala east
18	425	6.805	Kwa Ass. Chief	Mudembi	Mudembi	Bunyala east
1	361	7.25	Busweti	Busweti	Mudembi	Bunyala east
24	996	6.984	Lwarimba	Lwarimba	Budalangi	Bunyala east
25	1027	6.823	Sipala	Sipala	Budalangi	Bunyala east
29	466	6.44	Nagoba	Nagoba	Budalangi	Bunyala east
16	910	7.166	Mumbaya	Mumbaya	Budalangi	Bunyala east
5	427	6.321	Namonye	Namonye	Mudembi	Bunyala east
2	3640	6.796	Mumoni	Mumoni	Mudembi	Bunyala east
x	5150	6.81				
6	606	6.809	Bujwanga 'A'	Bujwanga 'A'	Mudembi	Bunyala east
8	624	6.874	Mangongo	Mangongo	Mudembi	Bunyala east
68	949	6.97	Mangongo	Mangongo	Mudembi	Bunyala east

x	649	7.025				
9	394	6.448	Busidia	Busidia	Mudembi	Bunyala east
165	402	6.391	Busidia	Busidia	Mudembi	Bunyala east
10	792	6.53	Budunyi	Budunyi 'A'	Mudembi	Bunyala east
11	528	7.218	Budunyi	Budunyi 'B'	Mudembi	Bunyala east
163	488	6.907	Khugimini	Khugimini	Mudembi	Bunyala east
13	625	6.531	Mulua	Mulua	Mudembi	Bunyala east
5	2360	6.828	Namonye	Namonye	Mudembi	Bunyala east
4	942	6.952	Nandekwe	Nandekwe	Mudembi	Bunyala east
60	327	6.629	Bukhoba	Bukhoba	Rwambwa	Bunyala east
69	1417	7.222	Ruambwa	Ruambwa	Rwambwa	Bunyala east
74	714	6.761	Buyuku	Buyuku 'B'	Magombe east	Bunyala central
73	441	6.601	Buyuku	Buyuku 'A'	Magombe east	Bunyala central
81	769	6.684	Busagwa pri. Sch	Busagwa	Magombe east	Bunyala central
84	340	6.524	Makombe market	Makombe	Magombe east	Bunyala central
90	499	8.225	Nanjomi/burangasi	Burangasi	Magombe central	Bunyala central
85	974	7.018	Hulugingo	Hulugingo	Magombe east	Bunyala central
86	2750	6.63	Mubwayo sch.	Mubwayo	Magombe central	Bunyala central
95	1305	6.79	Mungoma	Mungoma	Magombe central	Bunyala central
x	1513	6.997				
x	819	6.984				
x	1148	7.245				
River	76.8	7.497				
River	80.1	7.428				
River	76.8	7.428				
76	365	6.892	Odoke	Huluchi	Magombe east	Bunyala central
River	77.5	7.395				
94	1111	6.302	Mubwayo	Mubwayo	Magombe central	Bunyala central
x	166	6.903				
108	164.9	6.771	Magabira	Magabira	Lugale	Khajola
113	236	6.924	Lugale Primary School	Lugale 'B'	Lugale	Khajola
x	1368	6.702				
x	2430	6.903				
142	799	7.326	Mabinju-Beach	Mabinju	Mabinju	Khajula

137	1347	6.893	Budala primary school	Budala	Rukala	Bunyala south
134	331	6.604	Khadundu	Khadundu	Rukala	Bunyala south
136	309	6.414	Rukala dispensary	Rukala	Rukala	Bunyala south
158	1321	6.623	Ikobo	Ikobo	Rukala	Bunyala south
157	473	6.623	Sidokho	Sidokho	Rukala	Bunyala south
138	587	6.525	Runyu Primary school	Runyu	Rukala	Bunyala south

Appendix 2 - microbial water quality

S/No.	Risk	Name of water point	Village	Sub-Location	Location	Petrifilm	Colilert
6	Low	Bujwanga 'A'	Bujwanga 'A'	Mudembi	Bunyala east		
28	High	Bulagu	Bulagu	Budalangi	Bunyala east	3	1
31	Moderate	Bulagu Mukhuyu	Bulagu	Budalangi	Bunyala east		1
159	High	Buchiriba	Buchiriba	Budalangi	Bunyala east	2	1
147	Moderate	Idokho	Idokho	Bulemia	Bunyala north		1
40	Moderate	Mundekwe	Mundekwe	Bulemia	Bunyala north		1
42	Moderate	Bukalama	Bukalama 'A'	Bulemia	Bunyala north		1
43	Moderate	Bukalama	Bukalama 'B'	Bulemia	Bunyala north		1
20	Low	Sibuka Pri. School	Sibuka	Mudembi	Bunyala east		
23	Low	Makina	Makina	Budalangi	Bunyala east		
9	Low	Busidia	Busidia	Mudembi	Bunyala east		
64	Low	Lwahanga	Lwahanga	Rwambwa	Bunyala east		
62	Low	Buhuhiro store	Buhuhiro store	Rwambwa	Bunyala east		
10	Low	Budunyi	Budunyi 'A'	Mudembi	Bunyala east		
Outside budalangi	Low						
12	Low	Namuyama	Namuyama	Mudembi	Bunyala east		
3	Low	Nandekwe	Nandekwe	Mudembi	Bunyala east		
70	Low	Nayera 'A'	Nayera 'A'	Rwambwa	Bunyala east		
65	Low	Pangara	Pangara	Rwambwa	Bunyala east		
59	Moderate	Bujumba	Bujumba	Rwambwa	Bunyala east		1

2	Moderate	Mumoni	Mumoni	Mudembi	Bunyala east		1
1	Moderate	Busweti	Busweti	Mudembi	Bunyala east		1
19	Low	Mudembi Market	Mudembi	Mudembi	Bunyala east		
18	Low	Kwa Ass. Chief	Mudembi	Mudembi	Bunyala east		
1	Moderate	Busweti	Busweti	Mudembi	Bunyala east		1
24	Moderate	Lwarimba	Lwarimba	Budalangi	Bunyala east		1
25	Moderate	Sipala	Sipala	Budalangi	Bunyala east		1
29	Moderate	Nagoba	Nagoba	Budalangi	Bunyala east		1
16	High	Mumbaya	Mumbaya	Budalangi	Bunyala east	1	1
5	High	Namonye	Namonye	Mudembi	Bunyala east	5	1
2	Low	Mumoni	Mumoni	Mudembi	Bunyala east		
Not on list	Low						
6	Moderate	Bujwanga 'A'	Bujwanga 'A'	Mudembi	Bunyala east		1
8	Low	Mangongo	Mangongo	Mudembi	Bunyala east		
68	Moderate	Mangongo	Mangongo	Mudembi	Bunyala east		1
not on list	Moderate						1
9	Low	Busidia	Busidia	Mudembi	Bunyala east		
165	Low	Busidia	Busidia	Mudembi	Bunyala east		
10	Moderate	Budunyi	Budunyi 'A'	Mudembi	Bunyala east		1
11	Very high	Budunyi	Budunyi 'B'	Mudembi	Bunyala east	11	1
163	Low	Khugimini	Khugimini	Mudembi	Bunyala east		
13	Low	Mulua	Mulua	Mudembi	Bunyala east		
5	Low	Namonye	Namonye	Mudembi	Bunyala east		

4	Low	Nandekwe	Nandekwe	Mudembi	Bunyala east		
60	Low	Bukhoba	Bukhoba	Rwambwa	Bunyala east		
69	Low	Ruambwa	Ruambwa	Rwambwa	Bunyala east		
74	Low	Buyuku	Buyuku 'B'	Magombe east	Bunyala central		
73	Moderate	Buyuku	Buyuku 'A'	Magombe east	Bunyala central		1
81	Low	Busagwa pri. Sch	Busagwa	Magombe east	Bunyala central		
84	Low	Makombe market	Makombe	Magombe east	Bunyala central		
90	Very high	Nanjomi/burangasi	Burangasi	Magombe central	Bunyala central	11	1
85	High	Hulugingo	Hulugingo	Magombe east	Bunyala central	1	1
86	Moderate	Mubwayo sch.	Mubwayo	Magombe central	Bunyala central		1
95	Low	Mungoma	Mungoma	Magombe central	Bunyala central		
Not on list	Low						
Not on list	Low						
Not on list	Low						
River	Low						
River	Low						
River	Very high					33	1
76	Low	Odoke	Huluchi	Magombe east	Bunyala central		
River	Very high					24	1
94	Low	Mubwayo	Mubwayo	Magombe central	Bunyala central		
New	High					8	1
108	Low	Magabira	Magabira	Lugale	Khajola		
113	Low	Lugale Primary School	Lugale 'B'	Lugale	Khajola		
New	Low						
7m deep	Moderate						1
142	High	Mabinju-Beach	Mabinju	Mabinju	Khajula	3	1
137	High	Budala primary school	Budala	Rukala	Bunyala south	1	1

134	Moderate	Khadundu	Khadundu	Rukala	Bunyala south		1
136	Moderate	Rukala dispensary	Rukala	Rukala	Bunyala south		1
158	Moderate	Ikobo	Ikobo	Rukala	Bunyala south		1
157	Moderate	Sidokho	Sidokho	Rukala	Bunyala south		1
138	Low	Runyu Primary school	Runyu	Rukala	Bunyala south		

Appendix 3 - Focus group interview - question guide

Questionnaire	
User - social	
Is there a demand for irrigation water?	
Are you interested in this technology?	
Is 6000 l/d enough water to satisfy your needs?	
Are you willing in investing in the capital expenses? (How much percentage?)	
Are you willing to carry out upkeep activities and pay for O&M?	
User - economic	
Can you afford the full capital cost for this water technology? (What percentage could they cover?)	
Can you afford to pay for the operational and maintenance cost?	
Can you afford to pay for a major repair?	
What is the average income per household?	
Are poor households who cannot pay excluded?	
User - legal, institutional, organisational	
Could the management system of how a water point is managed be used and would it be adequate for this technology?	
What is the likelihood for that it will work?	
Can the O&M be managed by the water user group only? Is there any backup from local government, institutions etc?	
User - Skills and knowledge	
Are you familiar with this kind of technology?	
Do you think you have the necessary capacities to carry out O%M on this technology?	
User - technological	
Is the amount of water tat this technology provides satisfactory for you?	
Would you be satisfied with what this technology delivers?	
User - Other	
Have you heard about this technology before?	
How do you get irrigation water now?	
Questions on the spot!	

Appendix 4 - Focus group interview results

Questionnaire	Bokoma
User - social	
Is there a demand for irrigation water?	Yes
Are you interested in this technology?	Yes
Is 6000 l/d enough water to satisfy your needs?	Yes
Are you willing in investing in the capital expenses? (How much percentage?)	No, 20000 ksh
Are you willing to carry out upkeep activities and pay for O&M?	Yes
User - economic	
Can you afford the full capital cost for this water technology? (What percentage could they cover?)	NO
Can you afford to pay for the operational and maintenance cost?	Yes
User - Skills and knowledge	
Are you familiar with this kind of technology?	No
User - technological	
Is the amount of water that this technology provides satisfactory for you?	Yes
Would you be satisfied with what this technology delivers?	Yes
User - Other	
Haver you heard about this technology before?	No
How do you get irrigation water now?	By hand, motorized pump

Questionnaire	Nandikinya
User - social	
Is there a demand for irrigation water?	Yes!
Are you interested in this technology? (Changed to is this technology useful?)	Yes!
Is 6000 l/d enough water to satisfy your needs?	That is enough
Are you willing in investing in the capital expenses? (How much percentage?)	Cannot afford the total capital expense. 25% or 30000ksh
Are you willing to carry out upkeep activities and pay for O&M?	Yes
User - economic	
Can you afford the full capital cost for this water technology? (What percentage could they cover?)	No
Can you afford to pay for the operational and maintenance cost?	Yes
What is the average income per household?	5000 ksh
User - Skills and knowledge	
Are you familiar with this kind of technology?	no
User - technological	
Is the amount of water tat this technology provides satisfactory for you?	Yes
Would you be satisfied with what this technology delivers?	Yes
User - Other	
Haver you heard about this technology before?	No
How do you get irrigation water now?	Motorized pump, moneymaker, buckets

Questionnaire	Sisenye
User - social	
Is there a demand for irrigation water?	Very, very much.
Are you interested in this technology?	Yes, as you are not reliant on petrol
Is 6000 l/d enough water to satisfy your needs?	Not enouh, for some it is enough
Are you willing in investing in the capital expenses? (How much percentage?)	30%, 30000ksh, 5000ksh
User - economic	
Can you afford to pay for the operational and maintenance cost?	yes
Can you afford to pay for a major repair?	
What is the average income per household?	3000 ksh
Are poor households who cannot pay excluded?	can rent
User - Skills and knowledge	
Are you familiar with this kind of technology?	No
User - Other	
Haver you heard about this technology before?	No, but have heard of wind powered
How do you get irrigation water now?	Motorized pump, moneymaker and carrying jerry cans

Questionnaire	Monami
User - social	
Is there a demand for irrigation water?	Yes 100%
Are you interested in this technology?	Yes
Is 6000 l/d enough water to satisfy your needs?	Yes, it is enough for small-scale
Are you willing in investing in the capital expenses? (How much percentage?)	Yes, can pay 20%
Are you willing to carry out upkeep activities and pay for O&M?	Yes
User - economic	
Can you afford the full capital cost for this water technoology? (What percentage could they cover?)	No.
Can you afford to pay for the operational and maintenance cost?	Yes.
Can you afford to pay for a major repair?	Yes.
What is the average income per household?	2000-3000 ksh
Are poor households who cannot pay excluded?	No.
User - legal, institutional, organisational	
Could the managment system of how a water point is managed be used and would it be adequate for this technology?	Yes
What is the likelihood for that it will work?	It works
Can the O&M be managed by the water user group only? Is there any backup from local government, institutions etc?	Commitee enough
User - Skills and knowledge	
Are you familiar with this kind of technology?	No
Do you think you have the necessary capacities to carry out O%M on this technology?	Yes
User - technological	
Is the amount of water tat this technology provides satisfactory for you?	Could be improved.
Would you be satisfied with what this technology delivers?	Some yes, some no.
User - Other	
Haver you heard about this technology before?	No
How do you get irrigation water now?	Motorized pump, manually from well
Questions on the spot!	
5 people feels it is enough	
8 people feels it too little	

Questionnaire	Budalangi
User - social	
Is there a demand for irrigation water?	Yes, very much so!
Are you interested in this technology?	
Is 6000 l/d enough water to satisfy your needs?	Yes.
Are you willing in investing in the capital expenses? (How much percentage?)	Willing as a group - 12000 ksh
Are you willing to carry out upkeep activies and pay for O&M?	Yes
User - economic	
Can you afford the full capital cost for this water technoology? (What percentage could they cover?)	x
Can you afford to pay for the operational and maintenance cost?	Yes
Can you afford to pay for a major repair?	Yes
What is the average income per household?	200 ksh
Are poor households who cannot pay excluded?	No
User - legal, institutional, organisational	
Could the managment system of how a water point is managed be used and would it be adequate for this technology?	Yes
What is the likelihood for that it will work?	Yes
Can the O&M be managed by the water user group only? Is there any backup from local government, institutions etc?	Just the water user group enough.
User - Skills and knowledge	
Are you familiar with this kind of technology?	No.
Do you think you have the necessary capacities to carry out O%M on this technology?	Yes.
User - technological	
Is the amount of water tat this technology provides satisfactory for you?	Yes
Would you be satisfied with what this technology delivers?	Yes
User - Other	
Haver you heard about this technology before?	No
How do you get irrigation water now?	Using moneymaker or doing it manually
Questions on the spot!	
How big are the shambas?	3-4 acres some 5 acres

Appendix 5 - Household interviews

Interview guide

What did you think of the solar pump?	
Would charging phones be a useful feature for the solar pump?	
Would the solar pump be useful for you?	
Is 6000 l/d enough water for you?	
Can you afford to buy the solar pump?	
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	
How much can you afford to pay for the solar pump?	
Could a group of people go together and buy it?	
Do you irrigate now? And if, how?	
What is your monthly income?	
What kind of crops do you have?	

Nandikinya - transcript

Bonface Khakoma

What did you think of the solar pump?	Solar pump is good, especially usable for horticulture.
Would the solar pump be useful for you?	Yes
Is 6000 l/d enough water for you?	Yes
Can you afford to buy the solar pump?	No
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	There are, but they are not easy to get.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	It is possible
Do you irrigate now? And if, how?	Yes. Manually with buckets.
What kind of crops do you have?	Vegetables, tomatoes etc.

Benjamin Makokha

What did you think of the solar pump?	Solar pump is good. Good for farming which leads to bigger profits. It is also good for lighting and charging phones.
Would charging phones be a useful feature for the solar pump?	Yes, charging phones are part of what you can explore with a solar pump. Not everyone has power so you can get an extra income by charging other peoples phones.
Would the solar pump be useful for you?	Yes. Very useful. Last season the yield was very poor, with a solar pump that can be avoided.

Is 6000 l/d enough water for you?	Yes, that would be enough.
Can you afford to buy the solar pump?	That is very impossible.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Yes but it is not easy to get. You can get credit for fertilizer. If you made a group you could maybe get a loan from microfinance.
How much can you afford to pay for the solar pump?	30000 ksh.
Could a group of people go together and buy it?	That is a bit difficult. When a group comes together, some come with nothing at all and in a group no one feels ownership for the equipment.
Do you irrigate now? And if, how?	Yes, manually with buckets.
What is your monthly income?	5000 ksh
What kind of crops do you have?	Horticulture and rice

Pamela Anyango

What did you think of the solar pump?	I came late, but what I saw impressed me.
Would charging phones be a useful feature for the solar pump?	Very valuable
Would the solar pump be useful for you?	Yes, very!
Is 6000 l/d enough water for you?	Yes, satisfactory.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Yes, some groups, but cannot get. -> What are the groups? -K-REP -FSA -Banks - KCB - Equity
How much can you afford to pay for the solar pump?	30000 ksh
Could a group of people go together and buy it?	Can buy. But people in a group are not reliable. In a group no one feels ownership. -> What is preferable? Prefer alone
Do you irrigate now? And if, how?	Yes - using motorized pump -> How often? Twice a week for 10 l of fuel
What is your monthly income?	5000 ksh
What kind of crops do you have?	

Petronilla Ouma

What did you think of the solar pump?	Good idea.
Would charging phones be a useful feature for the solar pump?	Would not use it for charging. I have a charger at home.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No, if we had a good harvest last time, we could have. -> Could you afford it in the future? It is possible, if we have a good harvest.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Yes, there are some table banks. Like K-REP and FAS. We joined but were unable to pay so we became discontinued.
How much can you afford to pay for the solar pump?	I do not have any money right now, but after the harvest I will know. -> If you could afford it would you buy it? Yes
Could a group of people go together and buy it?	Yes -> Would there be any problems? Might be a problem or not, depends on the leader. If there is a fair schedule that is being followed.
Do you irrigate now? And if, how?	Yes, I use a motorized pump.
What is your monthly income?	2000-5000 ksh
What kind of crops do you have?	Rice, horticulture (sukuma wiki, corn, beans)

Alex Ojiambo - secretary of the Nandikinya group

What did you think of the solar pump?	It is good. Easy to maintain and no operation expenses.
Would charging phones be a useful feature for the solar pump?	It is important. Could use it for lighting in the house for a chicken incubator.
Would the solar pump be useful for you?	Yes, for my shamba. I would also use it in my house.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	Cannot, it is somehow expensive.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	There are banks and microfinancing.
How much can you afford to pay for the solar pump?	Through some effort 30000 ksh. With a loan I would pay it all.
Could a group of people go together and buy it?	We can. With microfinance we can afford to finance. -> Could there be any problems? We need to convince people to pay a operation and maintenance fee. Decide where we should store the pump. People get careless with shared

	equipment. But it is easier to own in a group. It is an opportunity to change ideas of people. People can give advice.
Do you irrigate now? And if, how?	Yes, I use a moneymaker.
What is your monthly income?	2000 ksh
What kind of crops do you have?	Horticulture - Tomato, cabbage and water melon

Budalangi - transcripts

Auma Emelly Usiko

What did you think of the solar pump?	Good, it makes work easier.
Would charging phones be a useful feature for the solar pump?	That would be very useful, I would charge the phones of my neighbours.
Would the solar pump be useful for you?	Yes, the solar pump can help me personally. Women are a bit weak.
Is 6000 l/d enough water for you?	That water is more than enough.
Can you afford to buy the solar pump?	Cannot buy the pump alone. Maybe if she could pay in installments.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Yes, here are organizations to get loans, but I am not a member of one. It is hard to get a loan.
How much can you afford to pay for the solar pump?	20000 ksh, with time half the money 60000 ksh.
Could a group of people go together and buy it?	They can buy a solar pump as long as they can agree. But it is difficult to agree? Because collective ownership is hard. -> What is preferable? To own it as individuals are preferred. Responsibility in groups are problematic. For instance our group were given a moneymaker pump (manual foot pump) and there was a war of who could use it. When it was broken no one took responsibility to fix it. The solar pump is a delicate so it can be easily damaged if not handled correctly, thus it is more important that the users take care of it properly.
Do you irrigate now? And if, how?	Yes, I carry buckets, jugs etc. -> Do you irrigate during the dry season? Yes.
What is your monthly income?	On average 6000-7000 ksh
What kind of crops do you have?	Horticulture - tomato, sukuma wiki, sweet potato

Johannes and Everine Nekesa

What did you think of the solar pump?	The pump was very good and could change our life forever.
Would charging phones be a useful feature for the solar pump?	Very helpful. It could charge our phones and will save us time (It will not be necessary to go to a shop to charge the phones). It will give us some extra income.
Would the solar pump be useful for you?	Read first question
Is 6000 l/d enough water for you?	Yes, the amount of water is enough for our farming.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	There are, but we cannot access them.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	It is possible if we come together and can agree. -> What problems could there be? Some people are selfish, the group needs a schedule, but some people will not share. Taking care of it is an issue and people will start blaming others if it becomes damaged.
Do you irrigate now? And if, how?	No.
What is your monthly income?	2000 ksh
What kind of crops do you have?	Farming - legumes, corn, beans, millet, kazawa, sweat potato

Anastacia Odidi

What did you think of the solar pump?	A good thing, makes our work easier. You are not dependent on fuel, only sun.
Would charging phones be a useful feature for the solar pump?	
Would the solar pump be useful for you?	Yes, very useful.
Is 6000 l/d enough water for you?	Yes, it is enough.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Maybe. There are ways, only if there is a donor we can repay slowly.
How much can you afford to pay for the solar pump?	20000 ksh
Could a group of people go together and buy it?	Not possible. Tried many groups but people are not responsible. Even paying as a group might be impossible. I would prefer to own it as an individual. -> Can you elaborate on the failed groups? Joined a horticulture group before we

	moved here. There was an idea, and people were brought in. A proposal was written and we got money from grants and loans, but the leaders embezzled the money. They were taken by the police because it was a loan and not a grant.
Do you irrigate now? And if, how?	We irrigated before with a moneymaker that we had with a group. Someone took it and did not want to share. We have a motorized pump, but we lack hoses.
What is your monthly income?	20000 ksh
What kind of crops do you have?	Sukuma wiki, tomatoes, corn, beans

Laurencia Khayoko

What did you think of the solar pump?	A good thing.
Would charging phones be a useful feature for the solar pump?	Yes it will be useful as it adds income.
Would the solar pump be useful for you?	Yes it would be useful for me, I would make a fish pond of it and do horticulture.
Is 6000 l/d enough water for you?	Yes would be ok as a start. As I grow as a farmer I might need a bigger one.
Can you afford to buy the solar pump?	I cannot.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	There are some sources, but I do not have any way to pay back the loan as it has to be paid back within a month.
How much can you afford to pay for the solar pump?	10000 ksh
Could a group of people go together and buy it?	It depends, if the group is likeminded . If proper rules and procedure are laid down. -> Are there any problems with a group having a solar pump? A challenge is that many people are not committed. The rest are free riders. Groups fail in such circumstances. As an individual you work harder as you reap direct benefits.
Do you irrigate now? And if, how?	No.
What is your monthly income?	2000-3000 ksh
What kind of crops do you have?	Corn, beans and ground nuts.

Bukoma - transcripts

Agnes T. Muhyobi

What did you think of the solar pump?	Good. It is a good idea. It would be a great advantage for the farmers.
Would charging phones be a useful feature for the	Yes it is useful, will bring extra income.

solar pump?	
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	No, it is not possible. A group does not have enough money.
Do you irrigate now? And if, how?	Yes, with jerry cans.
What is your monthly income?	4000 ksh
What kind of crops do you have?	Sukuma wiki. Also doe some small business like sell oranges and sugar canes at the side of the road.

Caroline Achigno Ouma

What did you think of the solar pump?	Very good idea.
Would charging phones be a useful feature for the solar pump?	Ok. It is an advantage, but a lot of people here has electricity.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	No. It takes a lot of time. It is hard to organize.
Do you irrigate now? And if, how?	Yes, we are carrying buckets.
What is your monthly income?	10000 ksh
What kind of crops do you have?	Tomatoes and sukuma wiki.

David Malo

What did you think of the solar pump?	It is good.
Would charging phones be a useful feature for the solar pump?	Very useful, it will be extra income.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes. 6000 would be enough.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No possibility. Used to be in a group, but the group disowned me.
How much can you afford to pay for the solar pump?	2000-3000 ksh
Could a group of people go together and buy it?	We have a group, but we cannot buy as we have just started and are not financially stable.
Do you irrigate now? And if, how?	Yes, I carry jerry cans.

What is your monthly income?	3000-4000 ksh
What kind of crops do you have?	Sukuma wiki, tomatoes, beans.

Sebastian A. Kechula

What did you think of the solar pump?	The solar pump itself is good. Because it uses solar energy and do not use fuel.
Would charging phones be a useful feature for the solar pump?	
Would the solar pump be useful for you?	Indeed it would be useful to me for my farming activites.
Is 6000 l/d enough water for you?	Right now it is enough. I do it alone.
Can you afford to buy the solar pump?	No, because the type of work I do is not advancing. Because of problems. -> Why? My area is sometimes flooded by the river and also wild animals destroy my shamba(plot).
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	I have not tried.
How much can you afford to pay for the solar pump?	30000 ksh
Could a group of people go together and buy it?	Many groups has been formed but it takes a lot of time. Some people join farming groups without having any intention of farming because they want to be empowered.
Do you irrigate now? And if, how?	I use the moneymaker. Sometimes I hire a motorized pump.
What is your monthly income?	15000 ksh
What kind of crops do you have?	Right now I have only tomatoes. I had sukuma wiki but they were taken by the flood. I irrigate during the dry season. The flood are sometimes in April, August and October.

Consulata Obwori

What did you think of the solar pump?	It is a good thing.
Would charging phones be a useful feature for the solar pump?	I have electricity in my house, so it would not be very helpful.
Would the solar pump be useful for you?	Yes it would be useful. Because she has a big farm, I irrigate with jerry cans and it is very cumbersome.
Is 6000 l/d enough water for you?	Yes. That would be enough.
Can you afford to buy the solar pump?	No. That is a lot of money.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No there is no possibility of getting funding. We just started a group. And we need to be a good group to get funding.
How much can you afford to pay for the solar pump?	30000 ksh

Could a group of people go together and buy it?	No.
Do you irrigate now? And if, how?	See question 3.
What is your monthly income?	10000 ksh
What kind of crops do you have?	Sukuma wiki, I am waiting with tomatoes because I am afraid of flooding.

Patrick

What did you think of the solar pump?	Good. Surprised because it makes work very easy.
Would charging phones be a useful feature for the solar pump?	That would be good. Extra income.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	Yes it is possible? -> Could there be any problems with owning it as a group? People can be selfish. Leaders will not share. There is no proper responsibiliy. If it breaks no one fixes it. In the schedule everyone wants to be the first one.
Do you irrigate now? And if, how?	Yes, I use a motorized pump.
What is your monthly income?	3000-4000 ksh
What kind of crops do you have?	Banana, tomato, sukuma wiki, irish potato

Sisenye - transcripts

Morton Nafula

What did you think of the solar pump?	It is very good.
Would charging phones be a useful feature for the solar pump?	It would be very useful.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	It is enough.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	10000 ksh
Could a group of people go together and buy it?	It is difficult because of mistrust, some will feel that others benefit more. Collective responsibility is an issue too.

Do you irrigate now? And if, how?	No.
What is your monthly income?	3000 ksh
What kind of crops do you have?	Kasawa, beans and potatoes.

Caroline Nadwire

What did you think of the solar pump?	Good.
Would charging phones be a useful feature for the solar pump?	
Would the solar pump be useful for you?	Yes it would be very helpful for me. MY shamba is right next to the water.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	No it is not possible. A group will not have enough money to buy one.
Do you irrigate now? And if, how?	Yes, I do it manually.
What is your monthly income?	3000-4000 ksh
What kind of crops do you have?	Sweet potatoes

Night Arambe

What did you think of the solar pump?	It is a good one.
Would charging phones be a useful feature for the solar pump?	Yes, very. More so in the house to listen to radio or play music.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	
How much can you afford to pay for the solar pump?	5000 ksh
Could a group of people go together and buy it?	Difficult to get people to agree. At the demonstration some said we could use it other said we cannot.
Do you irrigate now? And if, how?	Yes, manually with buckets.
What is your monthly income?	1500 ksh
What kind of crops do you have?	Sukuma wiki, sweat potato, corn, beans, indigenous vegetables. Also get an income from selling tea to fishermen.

Moses Namuye

What did you think of the solar pump?	It is a good thing.
Would charging phones be a useful feature for the solar pump?	I will not use it for charging.
Would the solar pump be useful for you?	Yes, as an individual.

Is 6000 l/d enough water for you?	Yes, I have an acre, so that is enough.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	Yes. At K-REP. -> Have you done this before? Yes. -> Is it hard? No. -> How much did you borrow? 15000 ksh
How much can you afford to pay for the solar pump?	80000
Could a group of people go together and buy it?	Yes. -> Would there be any problems? No. -> What do you prefer? To have it in a group.
Do you irrigate now? And if, how?	Yes, I use a motorized pump
What is your monthly income?	7000 ksh
What kind of crops do you have?	Sukuma wiki and tomatoes - I also do fishing.

Monani - transcripts

Martin Ekesa

What did you think of the solar pump?	It is good.
Would charging phones be a useful feature for the solar pump?	I have electricity at my house.
Would the solar pump be useful for you?	Yes, I would use it on a well. 20 feet deep.
Is 6000 l/d enough water for you?	Can be enough.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No.
How much can you afford to pay for the solar pump?	50% - 60000 ksh
Could a group of people go together and buy it?	It is possible, can contact neighbours if they are willing. -> Could there be any problems? No.
Do you irrigate now? And if, how?	No, I do it manually.
What is your monthly income?	4000 ksh - I just started farming. I have done it for 2 years now, so far it is just to practice.
What kind of crops do you have?	Sukuma wiki, tomatoes and onions. -> How big is your shamba? 1/4 of an acre

Nicholas Mukudi

What did you think of the solar pump?	Solar pumps are very important for farming. Also very important that no fuel is being used.
Would charging phones be a useful feature for the solar pump?	That is very useful, because I could charge my phone.
Would the solar pump be useful for you?	Yes.
Is 6000 l/d enough water for you?	Yes it will be enough because it could pump the whole day.
Can you afford to buy the solar pump?	Cannot afford to buy it. It is too expensive.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	The issue with loans is that you need security. I do not have any.
How much can you afford to pay for the solar pump?	15000 ksh
Could a group of people go together and buy it?	It is not easy. It is costly so it is hard to get another person to buy with you.
Do you irrigate now? And if, how?	Yes - I carry jerry cans.
What is your monthly income?	5000 ksh
What kind of crops do you have?	Sukuma wiki only right now. I also have a fish pond for the first time and I also sell milk.

Samuel Sukuma

What did you think of the solar pump?	It is a good pump, but here we do not have surface water.
Would charging phones be a useful feature for the solar pump?	I can charge phones and earn something small.
Would the solar pump be useful for you?	Yes, if I could access surface water.
Is 6000 l/d enough water for you?	Yes.
Can you afford to buy the solar pump?	No.
Are there any opportunities to get financing like microfinance, loaning groups, banks etc?	No. I do not have a bank account.
How much can you afford to pay for the solar pump?	10000 ksh
Could a group of people go together and buy it?	Yes. -> Could there be any problems with that? Maintenance will be a problem. People have different background and someone can be careless. I prefer to own it as an individual.
5000Do you irrigate now? And if, how?	Yes, I irrigate manually.
What is your monthly income?	2000-3000 ksh
What kind of crops do you have?	Tomatoes, sukuma wiki, corn, beans, kasawa, sweat potato, bananas.

Appendix 6 - interviews with local government and facilitators - Summaries

Ministry of Water and Irrigation - Deputy Sub-County Water Officer

Pascal - 0715060190

Pascal could tell us that the potable water coverage in Budalangi was quite poor, with a coverage of just 45%. Budalangi has 4 big water sources, the rest are from borehole, wells and the river. There are more than a hundred community water points, Pascal was kind enough to provide us with a list of all the water points. He could also tell us that to get hydrological data it is possible to get that from the National Water Conservation in Kisumu and ask for the Lake Basin Hydrological Data. Meteorological data was possible to get from the local authorities, they have an office just bllow the Ministry of Water and Irrigation.

Ministry of Agriculture -

Samuel Owino - 0723211899

The agricultural officer could tell us the there was practically no food security in Budalangi at all. People have food here when they harvest. Otherwise they have to buy it. Almost 90% of the vegetables is imported from Uganda. Last year it rained to early, and not when the farmers needed it, the harvest was almost a total failure. The farmers try to have two harvests every year, one in the long rains in april-may, and one in the short rains in october-november. In the short rains it is usually not enough rains so the farmers do not put in too much effort because of the likelihood of a failed harvest. In addition the rain has become more and more unpredictable due to climate change, sometimes it is short rains when it is supposed to be long rains and vice versa.

On the other side of the river (from where?) there is a 5000 ha famine(farming?) area. Maize requires 5 acres and above in order for it to be profitable, while vegetables 1 and 1/2 acres could be enough. Thus the ministry of agriculture wants to focus on crops demanding less space.

PALWECO is an organization working on capacity building in Budalangi. Mainly sponsored by the Finnish government. They made a feasibility report on solar pumps in Budalangi. On the other hand they have later gone away from this idea, and would rather use hand or foot driven pumps.

There was plans on subsidizing the farmers for the capital cost of the solar pump, while the operational and maintenance cost would have to be carried by the farmers. The idea was that such a system would have to be purchased by a community of farmers.

One of the problems is that the inhabitants do not want to change their behavior. Six years ago a big irrigation scheme was made. It was called the Lower Nzoia irrigation scheme, but it involved that a lot of inhabitants had to move, which they did not want to do because they consider their land ancestral.

Sub-county business center

	Budalangi			
Year	2009	2012 (projected)	2015 (projected)	2017
Population	66723	72766	79356	84078

Density	354	386	421	447

Source: National Kenya

Interview with Sylvia at PALWECO 22/09-2014

Sylvia could tell that there was not really made a feasibility report regarding solar pumps for irrigation in Budalangi. They are however involved with some projects regarding the solar pumps, but PALWECO are strictly only funders not implementers. The implementers in this situation would be the Ministry of Agriculture and Irrigation of Bunyala.

The project can be divided into two phases, the infrastructure phase and the crop establishment phase. A project in Namonye has currently started, they have arrived to surveys and plans in the action plan. The full action plan is:

1. Community mobilization
    a. What are the needs?
    b. What is the community going to do?
    c. What is the donor going to do?
    d. What can be expected?
2. Formation of water user association
3. Surveys and plans
4. Environmental impact assessment
5. Train farmers on small-scale irrigation and water management
6. Expansion of water pond
7. Establishment of irrigation water
8. Installation of tanks and pumps

The intended way to distribute the water is with drip-irrigation. Water ponds are made/extended in order to gather runoff for it to be used for irrigation. Also shallow wells will be used.

In small-scale farming, they will recommend using mechanical pumps over solar pumps. They also have started a project in Mudembi. 150 households is expected to be affected. There are plans to upscale. PALWECO is funded by the government of Kenya and the Finnish ministry of foreign affairs.

Mudembi/Namonye 28/09

We walk along the pond and observe that it is dry. Before there were water there, but after the pond was made the water somehow has been redirected and is now gone. The first dike was made in 1970s. There are some shallow wells here, they think the ground water is far below. The borehole is not hard nor salty, it is 6-7 m deep. There are about 400 acres and 200-300 households in this community. In June the pond will be filled and we will see how it turns out.

The canals - rice irrigation scheme - 28/09

There are outgrowers and ingrowers. Ingrowers are farmers that are supported by the irrigation board. They are given fertilizers, the fields are plowed for free with a tractor, but they have to sell the rice to the board at a cheaper price. Outgrowers do it by themselves. The water is pumped from the river and distributed through canals, the outgrowers has to pay 4000 ksh per acre in one season for the water.

We talk to a farmer, she has 2.5 acres she says they harvest twice. One it takes 3 months from planting until harvest. The reason they only have two harvests a year is because the land has to stay unused and dry up for 3 months to kill diseases. The water has to be controlled at all times, if it is not controlled there is a risk of losing the seedlings.

She reckons that if you are the owner of the land and it is big enough you can earn a living. If you are working on the land for someone, it is very poorly paid. They are paid in contracts, so they get so and so for doing a certain thing. You get about 2500 kes per sack and you can get 20-25 sacks per acre. For Basmati it is considerably lower, only about 8 sacks per acre. The irrigation scheme is very large.

Lake Victoria - Port victoria P1 teacher - 28/09

Near the lake there is a farmer, he has about 1 acre of land where he tries to do horticulture. He says that they plant tomatoes, sukuma wiki, sim sim. There is a high demand for tomatoes, all year round. Sukuma wiki there is only a seasonal demand. Most people are fishing here though, there are not many serious farmers in this area. He reckons that with credit he would be able to afford a solar pump. On the side he is also a business-man, or he has a shop together with his wife.

Nicholas Otieno - Monani - 0711461995

There are about 10 farmers in this community, but many are not cultivating because they are afraid the flood will take the crops. Right now there is about 3-4 farmers in the area cultivating the land. There is demand to increase the food production. He has never heard of Solar pumps. He says he can afford a solar pump. He is willing to bear the costs of maintenance and operation. He is very interested in the technology and it sounds like a good solution.

George Gare - Ministry of Agriculture

We inform that we are planning a demonstration and we invite him to join us. He gives us the contact information of Nekesa, he is the procurement officer of PALWECO. He says we should make sure that we write an official invitation to him.

George informs us that there are two groups that there should be conducted a demonstration at. The Nandikinya group in Busagua and the Namonye group. The Nandikinya group has river as its water source, while Namonye has shallow well as its water source. He gave us the contact information to the leader of those two groups.

Nanikinya - John - 0724957551

Namonye - 0727700447

According to George there are no subsidies for farmers to apply for from PALWECO.

When asked about the salinity, George says he thinks the shallow wells are saline while the bore hole are not saline, but he says it all depends on the geological composition and that it varies from area to area. All in all he is not at all certain on any of this. He suggests that we go and talk to the ward administrator and the ward manager, since they are good in mobilizing the community.

Ward manager - Christoph Maloba - 0721548222

After the introductions I say that we were sent here by George Gare because he said that they could help us with community mobilization. They are very helpful and identify two communities where we can have demonstrations. They say that the area is very good for agriculture, but that the farmers has to rely on seasonal rain. When asked about funding they say that there is quite some possibility of getting funding for subsidizing the capital cost from the county assembly.

Bokomoa - meeting with the chief, asst. chief and some of the farmers

There are more than 50 farmers in this community. They mainly do horticulture, where they sell the produce. There is definitely a demand for higher food production. No one has ever heard of solar pumps before though. They are willing to invest in this technology and the average income of a family is 2-3000 shillings a month. They grow sukuma wiki, cow peas, tomatoes, chilies, maize and millet. Tomatoes are harvested 3 times a year, while the maize is harvested once. Irrigation is mostly done by hand, but some people has petrol pumps which they use to pump water from the swamp. The community is also doing some small-scale fishing.

After walking around a bit we meet the chairman of the Sionga Self help group. They are about25 people. They are very keen on seeing the demonstration.

Appendix 7 - Inventory of wells in Budalangi

Inventory of Boreholes in Bunyala Sub-County							
S/No.	Code No.	Name of water point	Village	Sub-Location	Location	Status	Remarks
1	C-5307	Mudembi Pri. Sch.	Mudembi	Mudembi	Bunyala East	Hand pump working	Serving school
2	C-9120	Namonye	Namonye	Mudembi	Bunyala East	Hand pump working	Needs rehabilitation
3	C-10143	Syakule	Syakule	Budalangi	Bunyala East	Hand pump working	Serving 160 people
4	C-10147	Sifugwe	Sifugwe	Budalangi	Bunyala East	Hand pump working	Serving 180 people
5	C-9127	Sifugwe	Sifugwe	Rwambwa	Bunyala East	Hand pump working	Needs rehabilitation
6	C-5196	Budebu	Budebu	Rwambwa	Bunyala East	Hand pump working	Serving 130 people
7	C-5194	Bukhoba	Bukhoba	Rwambwa	Bunyala East	Hand pump working	Serving 280 people
8	C-6156	Nayera	Nayera	Rwambwa	Bunyala East	Hand pump working	Serving 150 people
9	C-6153	Lwahanga	Lwahanga	Rwambwa	Bunyala East	Hand pump working	Serving 120 people
10	C-5192	Namalo	Namalo	Rwambwa	Bunyala East	Hand pump working	Serving 175 people
11	C-9184	Namalo Akulu	Namalo	Rwambwa	Bunyala East	Hand pump working	Serving 200 people
12	C-10144	Namakoli	Namalo	Rwambwa	Bunyala East	Hand pump working	Serving 130 people
13	C-5308	Sirimba Mission	Sirimba	Rwambwa	Bunyala East	Hand pump **NOT** working	Serving 140 people
14	C-8352	Dande	Dande	Sisenye	Bunyala North	Hand pump working	Saline water
15	C-10150	Mundere	Mundere	Mundere	Bunyala North	Hand pump working	Saline water
16	C-10151	Nabutswi	Nabutswi	Mundere	Bunyala North	Hand pump working	Under implementation
17	C-5306	Bwohola (kwa Omala)	Bwohola	Bulemia	Bunyala North	Hand pump working	Serving 250 people
18	C-10153	Rudacho	Rudacho	Bulemia	Bunyala North	Hand pump working	Boe hole casings damaged
19	C-10154	Rudacho Magoye	Rudacho	Bulemia	Bunyala North	Hand pump working	Bore hole filled with storm mud
20	C-5305	Masaka	Masaka	Bulemia	Bunyala North	Hand pump working	Needs rehabilitation
21	C-8799	Mukhobola	Mukhobola	Magombe West	Bunyala Central	Motorized submersible pump	5m^3/hr capacity s/ pump
22	-	Siamungu	Siamungu	Magombe East	Bunyala Central	Capped	Under implementation
23	C-10152	Nandekere	Nandekere	Bulemia	Bunyala North	Damaged by storm	Damaged
Inventory of Shallow Wells in Bunyala Sub-County							

S/No.	Code No.	Name of water point	Village	Sub-Location	Location	Status	Remarks
1	UN/DW/31	Busweti	Busweti	Mudembi	Bunyala east	Working	Serving 260 people
2	BS 532	Mumoni	Mumoni	Mudembi	Bunyala east	Working	Serving 250 people
3	BS 539	Nandekwe	Nandekwe	Mudembi	Bunyala east	Working	Serving 265 people
4	BUCODEV	Nandekwe	Nandekwe	Mudembi	Bunyala east	Working	Serving 235 people
5	UN/DW/31	Namonye	Namonye	Mudembi	Bunyala east	Working	Serving 255 people
6	BS 644	Bujwanga 'A'	Bujwanga 'A'	Mudembi	Bunyala east	Working	Serving 220 people
7	BS 28	Bujwanga 'B'	Bujwanga 'B'	Mudembi	Bunyala east	Working	Serving 280 people
8	BS 646	Mangongo	Mangongo	Mudembi	Bunyala east	Working	Serving 245 people
9	UN/DW/32	Busidia	Busidia	Mudembi	Bunyala east	Working	Serving 170 people
10	BS 540	Budunyi	Budunyi 'A'	Mudembi	Bunyala east	Working	Serving 160 people
11	BUCODEV	Budunyi	Budunyi 'B'	Mudembi	Bunyala east	Working	Serving 180 people
12	BS 533	Namuyama	Namuyama	Mudembi	Bunyala east	Working	Serving 145 people
13	BS 29	Mulua	Mulua	Mudembi	Bunyala east	Working	Serving 150 people
14	BS 518	Khulwano	Khulwano	Mudembi	Bunyala east	Working	Serving 175 people
15	UN/DW	Sikohe	Sikohe	Mudembi	Bunyala east	Working	Serving 170 people
16	BS 534	Mumbaya	Mumbaya	Budalangi	Bunyala east	Working	Serving 165 people
17	UN/DW	Ikhula	Ikhula	Budalangi	Bunyala east	Working	Serving 190 people
18	UN/DW	Kwa Ass. Chief	Mudembi	Mudembi	Bunyala east	Working	Serving 130 people
19	UN/DW	Mudembi Market	Mudembi	Mudembi	Bunyala east	Working	Serving 255 people
20	BS 23	Sibuka Pri. School	Sibuka	Mudembi	Bunyala east	Working	Serving 150 people + school
21	BS 836	Khulwano 'A'	Khulwano 'A'	Mudembi	Bunyala east	Working	Serving 130 people
22	UN/DW/30	Wekhonye	Wekhonye	Mudembi	Bunyala east	Working	Serving 175 people
23	BS 549	Makina	Makina	Budalangi	Bunyala east	Working	Serving 150 people
24	UN/DW	Lwarimba	Lwarimba	Budalangi	Bunyala east	Working	Serving 120 people
25	BS 537	Sipala	Sipala	Budalangi	Bunyala east	Working	Serving 245 people
26	BS 541	Makina	Makina	Budalangi	Bunyala east	Working	Serving 135 people

27	BS 538	Namagulu	Namagulu	Budalangi	Bunyala east	Not working	-
28	BS 16	Bulagu	Bulagu	Budalangi	Bunyala east	Working	Serving 145 people
29	BS 544	Nagoba	Nagoba	Budalangi	Bunyala east	Working	Serving 135 people
30	BS 550	Nangoba 'C'	Nangoba	Budalangi	Bunyala east	Working	Serving 150 people
31	BS 543	Bulagu Mukhuyu	Bulagu	Budalangi	Bunyala east	Working	Serving 120 people
32	BS 545	Khuluhindu 'A'	Khuluhindu	Budalangi	Bunyala east	Working	Serving 145 people
33	BS 546	Igigo Primary Sch	Igigo	Budalangi	Bunyala east	Not working	N/A
34	UN/DW	Igigo village	Igigo	Budalangi	Bunyala east	Working	Serving 125
35	UN/DW	Mumbira	Mumbira	Budalangi	Bunyala east	Working	Serving 140 people
36	UN/DW	Budalangi dispensary	Budalangi	Budalangi	Bunyala east	Working	Serving 300 people
37	UNICEF-WASH	Bujonjori	Bujonjori	Budalangi	Bunyala east	Working	Serving 165 people
38	UNICEF-WASH	Khuluhindu 'B'	Khuluhindu	Budalangi	Bunyala east	Working	Serving 140 people
39	BS 548	Namuningie	Namuningie	Mundere	Bunyala north	Working	Serving 150 people
40	UN/DW	Mundekwe	Mundekwe	Bulemia	Bunyala north	Working	Serving 140 people
41	BS 17	Idokho	Idokho	Bulemia	Bunyala north	Working	Serving 155 people
42	UNICEF-WASH	Bukalama	Bukalama 'A'	Bulemia	Bunyala north	Working	Serving 150 people
43	UNICEF-WASH	Bukalama	Bukalama 'B'	Bulemia	Bunyala north	Working	Serving 150 people
44	BS 554	Bumadeya	Bumadeya	Bukani	Bunyala west	Working	Serving 135 people
45	BS 556	Budiera	Budiera	Bukani	Bunyala west	Working	Serving 120 people
46	BS/DW/146	Ebutaru	Ebutaru	Bukani	Bunyala west	Working	Serving 140 people
47	BS 593	Bumadeya	Bumadeya	Bukani	Bunyala west	Working	Serving 150 people
48	BS 594	Nalugulu	Nalugulu	Siginga	Bunyala west	Not working	Needs rehab.
49	BS 555	Muhunga	Muhunga	Siginga	Bunyala west	Working	Serving 130 people
50	BS -	Ebukoyo	Ebukoyo	Siginga	Bunyala west	Working	Serious land dispute
51	BS 553	Siginga market	Siginga	Siginga	Bunyala west	Working	Serving 150 people
52	BS 9	Siginga	Siginga	Siginga	Bunyala west	Working	Serving 130 people
53	BS 836	Lunyafu pri. Sch	Lunyufu	Siginga	Bunyala west	Working	Serving 130 people

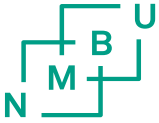
54	UNICEF-WASH	Bukonangwe	Bukonangwe	Bukoma	Bunyala west	Working	Serving 155 people
55	UNICEF-WASH	Mwangolalo	Mwangolalo	Siginga	Bunyala west	Working	Serving 120 people
56	UNICEF-WASH	Busweti	Busweti	Mudembi	Bunyala east	Working	Serving 150 people
57	BS 535	Munani	Munani	Rwambwa	Bunyala east	Working	Serving 145 people
58	BS 622	Lureko	Lureko	Rwambwa	Bunyala east	Working	Serving 130 people
59	BS 531	Bujumba	Bujumba	Rwambwa	Bunyala east	Working	Serving 150 people
60	BUGODEV	Bukhoba	Bukhoba	Rwambwa	Bunyala east	Working	Serving 140 people
61	BS 621	Mukhweso	Mukhweso	Rwambwa	Bunyala east	Working	Serving 155 people
62	BS 613	Buhuhiro store	Buhuhiro store	Rwambwa	Bunyala east	Working	Serving 250 people
63	BS 528	Bumwake	Bumwake	Rwambwa	Bunyala east	Working	Serving 140 people
64	BUGODEV	Lwahanga	Lwahanga	Rwambwa	Bunyala east	Working	Serving 155 people
65	BS 610	Pangara	Pangara	Rwambwa	Bunyala east	Working	Serving 100 people
66	BS -	Bukhwaya	Bukhwaya	Rwambwa	Bunyala east	Working	Serving 120 people
67	UNICEF-WASH	Mumoni	Mumoni	Mudembi	Bunyala east	Working	Serving 150 people
68	BS -	Mangongo	Mangongo	Mudembi	Bunyala east	Working	Serving 150 people
69	BS	Ruambwa	Ruambwa	Rwambwa	Bunyala east	Working	Serving 130 people
70	UNICEF-WASH	Nayera 'A'	Nayera 'A'	Rwambwa	Bunyala east	Working	Needs deepening - dries up
71	UNICEF-WASH	Emukhweso	Emukhweso	Rwambwa	Bunyala east	Working	Serving 156 people
72	BS -	Mulua	Mulua	Magombe east	Bunyala central	Working	Serving 145 people
73	BS 511	Buyuku	Buyuku 'A'	Magombe east	Bunyala central	Working	Serving 155 people
74	UN/DW	Buyuku	Buyuku 'B'	Magombe east	Bunyala central	Working	Serving 150 people
75	DW/BS/1/1/51	Habanga	Habanga	Magombe east	Bunyala central	Working	Serving 160 people
76	UN/DW	Odoke	Huluchi	Magombe east	Bunyala central	Working	Serving 125 people
77	UN/DW	Busagwa	Busagwa 'A'	Magombe east	Bunyala central	Working	Serving 140 people
78	BS -	Bubimbi	Bubimbi	Magombe east	Bunyala central	Working	Serving 165 people
79	BS 516	Busagwa	Busagwa 'B'	Magombe east	Bunyala central	Working	Serving 125 people
80	BS 515	Busagwa	Busagwa 'A'	Magombe east	Bunyala central	Working	Serving 115 people

81	BS 520	Busagwa pri. Sch	Busagwa	Magombe east	Bunyala central	Working	Serving 100 people + school
82	UN/DW	Busagwa village	Busagwa	Magombe east	Bunyala central	Working	Serving 155 people
83	BS 512	Magombe muhondo	Muhondo	Magombe east	Bunyala central	Working	Serving 140 people
84	BS -	Makombe market	Makombe	Magombe east	Bunyala central	Working	Serving 170 people
85	BS -	Hulugingo	Hulugingo	Magombe east	Bunyala central	Working	Serving 160 people
86	BS 19	Mubwayo sch.	Mubwayo	Magombe central	Bunyala central	Working	Serving 150 people
87	BS 20	Mundika/hu muhuka	Humuhuka	Magombe central	Bunyala central	Working	Serving 180 people
88	BS/DW/137	Mundika	Mundika	Magombe central	Bunyala central	Working	Serving 135 people
89	BS 526	Khubwira	Khubwira	Magombe central	Bunyala central	Working	Serving 200 people
90	BS 21	Nanjomi/burangasi	Burangasi	Magombe central	Bunyala central	Working	Serving 120 people
91	BS/DW/17	Bumalirani	Bumalirani	Magombe central	Bunyala central	Working	Serving 150 people
92	UNICEF-WASH	Khulusanye	Khulusanye	Magombe central	Bunyala central	Working	Serving 130 people
93	BS 519	Mundika Doho	Mundika	Magombe central	Bunyala central	Working	Serving 140 people
94	BS 140	Mubwayo	Mubwayo	Magombe central	Bunyala central	Working	Serving 165 people
95	UNICEF-WASH	Mungoma	Mungoma	Magombe central	Bunyala central	Working	Serving 115 people
96	BS 525	Khudenge	Khudenge	Magombe central	Bunyala central	Working	Serving 145 people
97	BS 16	Bubongo	Bubongo	Magombe west	Bunyala central	Working	Serving 110 people
98	BS 546	Makunda	Makunda	Magombe west	Bunyala central	Working	Serving 125 people
99	BS 524	Siduhumi	Siduhumi	Magombe west	Bunyala central	Working	Serving 145 people
100	BS 542	Buguguru	Buguguru	Magombe west	Bunyala central	Not working	Needs rehab.
101	UN/DW	Buguguru	Buguguru	Magombe west	Bunyala central	Working	Serving 125 people
102	BS 517	Khulugingo	Khulugingo	Magombe west	Bunyala central	Working	Serving 135 people
103	BS 518	Makunda school	Makunda	Magombe west	Bunyala central	Working	Serving school
104	UN/DW	Makunda church	Makunda	Magombe west	Bunyala central	Not working	Needs rehab.
105	UN/DW	Buhuyi	Buhuyi	Magombe west	Bunyala central	Working	Serving 130 people
106	UNICEF-WASH	Munaka	Munaka	Magombe west	Bunyala central	Working	Serving 110 people
107	UNICEF-WASH	Hakati	Hakati	Magombe west	Bunyala central	Working	Serving 155 people
108	BS 547	Magabira	Magabira	Lugale	Khajola	Working	Serving 175

							people
109	UNICEF-WASH	Galalaini	Galalaini	Lugale	Khajola	Working	Serving 140 people
110	BS 12	Hainga	Hainga	Lugale	Khajola	Not working	Needs rehab.
111	BS 11	Rugunga Primary School	Idokho	Rugunga	Khajola	Working	Serving school
112	UNICEF-WASH	Bukhwanga	Bukhwanga	Rugunga	Khajola	Working	Serving 105 people
113	BS 13	Lugale Primary School	Lugale 'B'	Lugale	Khajola	Working	Serving school only
114	BS 548	Sigomere	Sigomere	Rugunga	Khajula	Working	Serving 150 people
115	UNICEF-WASH	Lugale	Lugale 'A'	Lugale	Khajula	Working	Serving 150 people
116	UNICEF-WASH	Lugale	Lugale 'B'	Lugale	Khajula	Working	Serving 125 people
117	UNICEF-WASH	Lwakoko	Lwakoko	Mabinju	Khajula	Working	Serving 105 people
118	UNICEF-WASH	Khumwanda	Khumwanda	Mabinju	Khajula	Working	Serving 115 people
119	UNICEF-WASH	Malomba	Malomba	Mabinju	Khajula	Working	Very saline
120	BS 558	Kholohongo	Kholohongo	Mabinju	Khajula	Working	Serving 120 people
121	BS 523	Namabusi	Namabusi	Mabinju	Khajula	Working	Serving 129 people
122	UNICEF-WASH	Khuvali	Khuvali	Rugunga	Khajula	Working	Serving 95 people
123	UNICEF-WASH	Bukhalulu	Bukhalulu	Rugunga	Khajula	Working	Serving 300 people
124	UNICEF-WASH	Bucawrua	Emaloba	Mabinju	Khajula	Working	Serving 110 people
125	UNICEF-WASH	Khuluchi	Khuluchi	Mabinju	Khajula	Working	Serving 120 people
126	UNICEF-WASH	Buyanga	Buyanga	Rugunga	Khajula	Working	Serving 98 people
127	UNICEF-WASH	Bukhwanja	Bukhwanja	Rugunga	Khajula	Working	Serving 140 people
128	UNICEF-WASH	Bukodia	Bukodia	Lugale	Khajula	Working	Serving 150 people
129	UNICEF-WASH	Khareka	Khareka	Lugale	Khajula	Working	Serving 120 people
130	UNICEF-WASH	Bukeki	Bukeki	Mabinju	Khajula	Working	Serving 140 people
131	BS 30	Bulwani	Bulwani	Bulwani	Bunyala south	Working	Serving 130 people
132	BS 31	Bulwani	Bulwani	Bulwani	Bunyala south	Working	Serving 140 people
133	BS 32	Bulwani	Bulwani	Bulwani	Bunyala south	Working	Serving 117 people
134	UNICEF-WASH	Khadundu	Khadundu	Rukala	Bunyala south	Working	Serving 120 people
135	UNICEF-WASH	Budala village	Budala	Rukala	Bunyala south	Not working	Needs rehab.
136	BS 562	Rukala dispensary	Rukala	Rukala	Bunyala south	Working	Serving dispensary
137	UN/DW	Budala primary school	Budala	Rukala	Bunyala south	Working	Serving school
138	BS 563	Runyu Primary school	Runyu	Rukala	Bunyala south	Working	Serving school

139	UNICEF-WASH	Buduongi	Buduongi	Lugale	Khajula	Working	Serving 120 people
140	UNICEF-WASH	Idokho	Idokho	Rukala	Bunyala south	Working	Water very saline
141	UNICEF-WASH	MauMau	MauMau	Mabinju	Khajula	Working	Serving 110 people
142	UNICEF-WASH	Mabinju-Beach	Mabinju	Mabinju	Khajula	Working	Saline
143	UNICEF-WASH	Nadero	Nadero 'A'	Ruabwa	Bunyala east	Working	Serving 200 people
144	UNICEF-WASH	Bujumba-Munami	Munami	Ruabwa	Bunyala east	Working	Serving 115 people
145	UNICEF-WASH	Namonye	Namonye	Mudembi	Bunyala east	Working	Serving 150 people
146	UNICEF-WASH	Namakot-Sirimba	Namakot	Ruabwa	Bunyala east	Working	Serving 150 people
147	UNICEF-WASH	Idokho	Idokho	Bulemia	Bunyala north	Working	Serving 180 people
148	UNICEF-WASH	Huluchi	Huluchi	Magombe east	Bunyala central	Working	Serving 160 people
149	UNICEF-WASH	Munana	Munana	Magombe east	Bunyala central	Working	Serving 180 people
150	UNICEF-WASH	Bukwon i	Bukwon i	Magombe east	Bunyala central	Working	Serving 200 people
151	UNICEF-WASH	Khulukhongo	Khulukhongo	Magombe east	Bunyala central	Working	Serving 180 people
152	UNICEF-WASH	Khulugingo	Khulugingo	Magombe east	Bunyala central	Working	Serving 120 people
153	UNICEF-WASH	Bujwanga	Bujwanga	Magombe central	Bunyala central	Working	Serving 150 people
154	UNICEF-WASH	Bukhwanga	Bukhwanga	Magombe central	Bunyala central	Working	Serving 130 people
155	UNICEF-WASH	Khumurambi	Khumurambi	Magombe central	Bunyala central	Working	Serving ?? People
156	UNICEF-WASH	Sikurwe	Sikurwe	Magombe central	Bunyala central	Working	Serving 150 people
157	UNICEF-WASH	Sidokho	Sidokho	Rukala	Bunyala south	Working	Serving 130 people
158	UNICEF-WASH	Ikobo	Ikobo	Rukala	Bunyala south	Working	Serving 145 people
159	UNICEF-WASH	Buchiriba	Buchiriba	Budalangi	Bunyala east	Working	Serving 120 people
160	UNICEF-WASH	Nabonga	Namabua	Bukoma	Bunyala west	Working	Serving 250 people
161	UNICEF-WASH	Munginia	Munginia	Mudemai	Bunyala east	Working	Serving 150 people
162	UNICEF-WASH	Namabua	Namabua	Budalangi	Bunyala east	Working	Serving 160 people
163	UNICEF-WASH	Khugimini	Khugimini	Mudembi	Bunyala east	Working	Serving 120 people
164	UNICEF-WASH	Budunyi	Budunyi	Mudembi	Bunyala east	Working	Serving 180 people
165	UNICEF-WASH	Busidia	Busidia	Mudembi	Bunyala east	Working	Serving 120 people
166	UNICEF-WASH	Sidusia	Sidusia	Mudembi	Bunyala east	Working	Serving 140 people

167	UNICEF-WASH	Nandyuli	Nandyuli	Mudembi	Bunyala east	Working	Serving 160 people



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