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Final Report:

Project Title:

Retrofit for converting hand pumps into solar pumping systems with tap stations

Exploring the feasibility of “solarizing” existing manual pumps with a retrofit

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Authors:
Urs Heierli, SoPAS
Alois Müller, SoPAS
Karin Imoberdorf, SoPAS
Carlo Vassella, SoPAS

SoPAS
Solar Pump Association Switzerland

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Prepared by:
Urs Heierli, Karin Imoberdorf and Alois Müller
SoPAS
c/o msd GmbH, Mühlemattstrasse 45
3007 Bern
031 372 68 30
alois.mueller@ennos.ch
urs.heierli@msdconsult.ch

SoPAS
Solar Pump Association Switzerland

With the Support of:
REPIC Platform
c/o NET Nowak Energy & Technology Ltd.
Waldweg 8, CH-1717 St. Ursen
Tel: +41(0)26 494 00 30, Fax: +41(0)26 494 00 34, info@repic.ch / www.repic.ch

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Contents

1. Summary

The Solar Pump Association Switzerland (SoPAS) implemented a project to develop, test and pilot a retrofit solution for converting existing manual pumps into solar pumping systems with tap stations. The project was designed in response to an unmet need that was identified: reliable and easy access to water for consumption and household use. While there are thousands of hand pumps installed in Africa, many of them do not work well or are completely out of use. In those communities where the manual pump works, it is mostly women and children that are in charge of the time-consuming and physically demanding task of manual pumping. Against this backdrop, SoPAS designed a project to provide reliable access to water through a solar-powered tap station. During previous projects, SoPAS had learned that people prefer automated pumping systems and are willing to pay and maintain solarised systems if they are more reliable and more convenient than manual pumps (foot or hand pumps).

SoPAS engineers developed a "retrofit" device which allows to solarize existing hand- or foot pumps. The main component of the system is the sunlight pump - a highly efficient, small-scale solar water pump that was designed by the Swiss company ennos. The advantages of the retrofit are threefold: firstly, it gives a second life to the existing material. Secondly, the original manual operation of the pump can be maintained for times of increased water requirements and cloudy weather. Thirdly, it was anticipated that the retrofit would be considerably less costly (around 3'000 US $ with tanks and tap stations) compared to conventional solar drinking water installations which cost roughly 8'000 US $ without and over 20'000 US $ with a newly built suitable water well.

In the course of this project, three retrofit installations with water tanks and taps were realized in collaboration with Helvetas in the area of their project Qualieau in Northern Benin. During the first months, the pump systems ran smoothly and the feedback from the community members about the reliability and convenience was positive. However, the field tests revealed severe quality issues with the foot pumps (leaks, friction) which led to a reduced performance and even system failures. Even though a training was provided during the commissioning of the retrofits, it also became clear that the necessary technical know-how to operate, maintain and repair the systems in the long run was not available with the local technicians. The initial hypothesis of being able to solarize existing hand or foot pumps to guarantee a reliable water supply at low cost did not materialise. Furthermore, due to a change in government policies, Benin became an unsuitable country for a next phase and scaling of the project.

SoPAS has therefore decided not to plan a second project phase in Benin. The field testing of the retrofit has still been very important and insightful and SoPAS would like to propose a second phase with a new technology and a new partnership setup in Ghana, building on the lessons learned from this project.

2. Starting Point

There are several hundred thousand hand pumps installed in Africa, but only a fraction is still in operation. Recent experiences show that people prefer solar pumping systems and are willing to pay and maintain solarised systems if they provide a better service with overhead tanks and tap stations. However, solar drinking water installations are costly (roughly 8'000 US$ without and over 20'000 US$ with a newly built suitable water well).

An evaluation that was performed by SoPAS showed deficiencies in the maintenance of manual pumps and a very low willingness to pay: people paid in average 0.5 US$ per month for the maintenance of their water supply system, but easily 10 to 15 US$ per month for their mobile phones. The reason is that mobile phones are aspirational and something people care for. Manual pumps, on the other hand, are considered a public good with low local ownership. When the pump breaks down, it can cost some 50 US$ and there is very often not enough cash available to repair it.

3. Objectives

"The main objective is to have a field-tested prototype with the corresponding feedback to design a large-scale marketing strategy for retrofitted solar water supply systems."

This main objective was to be achieved through the following four steps:

1. Developing a functional prototype in Switzerland
2. Testing the prototype in the lab
3. Field testing the prototypes in the field in Benin in cooperation with Helvetas
4. Developing a strategy for the future dissemination based on the lessons learned

4. Project Review

4.1 Project Implementation

The development and testing of the retrofit prototype were performed at the lab of Bern University for Applied Sciences (Prof. Andrea Vezzini) where already the sunlight pump (an innovative solar pump, see: www.ennos.ch) was developed. The prototype was designed by Alois Müller, mechanical engineer and President of SoPAS. Both steps were successful and in time and in November 2018 the prototypes could be dispatched for field testing (for more details see the technical report).

A cooperation with Helvetas for the field testing in Benin was planned and executed. Carlo Vassella, field engineer of SoPAS, visited the three sites in Northern Benin in December 2018 for a first time to explore the local materials available, and a first retrofit could be installed with an existing manual pump. In the context of this project those were pumps operated by foot with a pedal. In April 2019, Carlo Vassella visited the site again accompanied by Hubert Bagnaba, solar engineer from Burkina Faso and they could finalize two more retrofit installations. This second visit revealed, to our surprise, that the quality of the foot pumps were deplorably low and leaks were common. This put our original hypothesis in doubt that retrofitting a manual pump for solar use was a suitable and highly efficient solution. The quality of the foot pumps was insufficient, even though we chose a model which was relatively expensive and had the reputation of being of high quality. With the leakages of the pumps, we realized that the overall efficiency of the water supply system is not satisfactory, although the retrofit device itself was highly efficient. The inefficiencies of the pumps were not so visible when operated by foot: women and children simply had to pump harder and longer – and nobody really cares for that. In response to the technical challenges, SoPAS decided to get high quality pump pistons manufactured in Switzerland to replace the low-quality ones in use. They were shipped to Benin and installed by Hubert Bagnaba in November 2019. All the retrofits were checked again and were functioning well. However, if each manual pump has to be equipped with parts made in Switzerland, a viable business model is not possible with the original concept. In consequence, modifications were made to the technical solution and the dissemination concept:

1) Modification of the technical solution

Illustration 1 shows the concept of the retrofit with the existing hand pump at the core of the design. The field testing revealed that our original concept had to be modified: the hypothesis that an efficient and low-cost retrofit device could solarize existing manual pumps was not anymore viable.

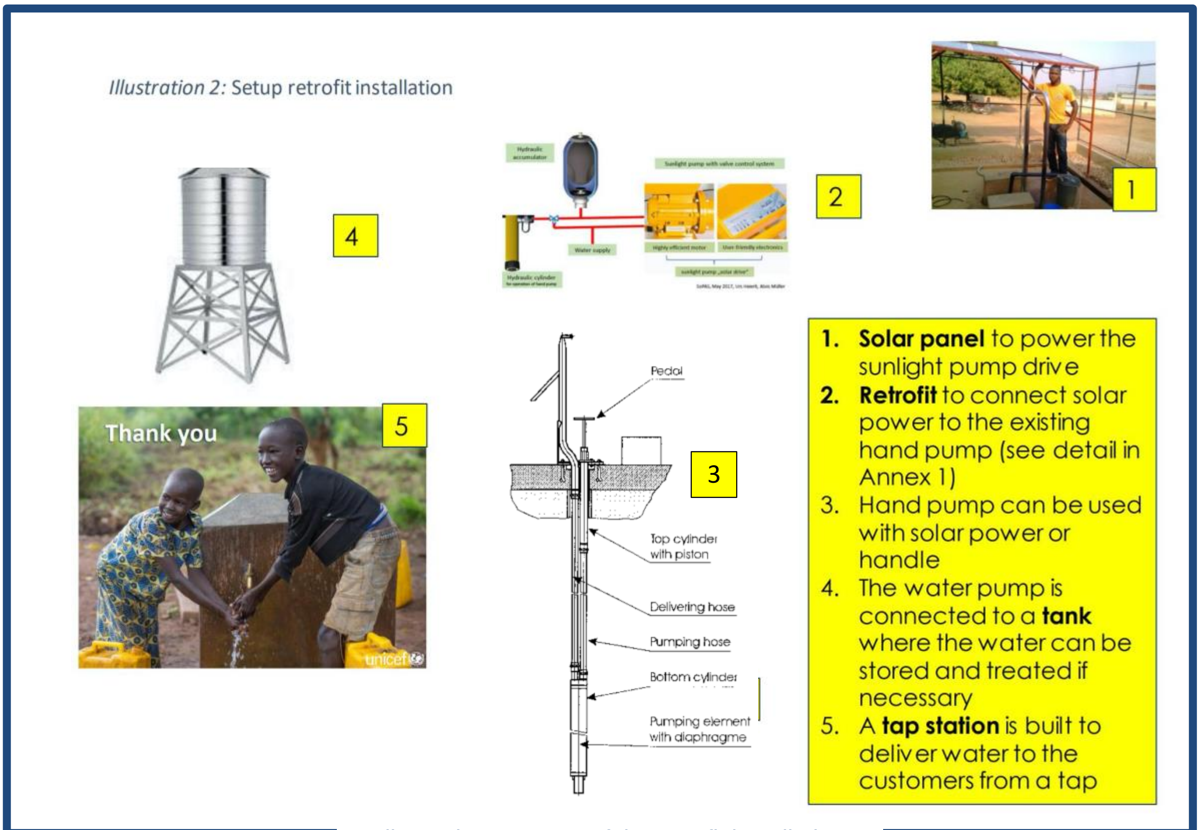

Illustration 1: Setup of the retrofit installation

The discovery that already installed manual pumps are inefficient due to low quality pistons leading to high friction undermined our original hypothesis. This leads to a lower-than-expected overall efficiency of a retrofitted pump and we concluded that it is not as promising as anticipated to go for a large-scale dissemination of the retrofit as it was developed.

2) Modification of the dissemination concept

Another modification was necessary regarding the original dissemination concept. An additional hurdle had come up because the Government of Benin had issued a new policy promising to the people to install fully automated tap water systems and to abandon hand pumps. This is a promise of the Government it has not yet – and will probably never be – fulfilled. Nevertheless it cooled the interest for our low-cost, small-scale solution and also our field partner, Helvetas, had to modify their WASH strategy.

Another mission was planned to design the dissemination concept a few months after the field tests were completed. However, the COVID-19 pandemic did not allow travelling anymore after March 2020. Based on the technical challenges encountered, the realisation that the necessary technical capacity was not available in the project area and that the policy environment was not favourable to decentralized water supply systems, SoPAS decided not to continue the project in Benin in a second phase. Instead, SoPAS has been working on a modified concept for solarized water tap stations with a planned field test in Ghana with a new partner setup.

4.2 Achievements of Objectives and Results

We could achieve the three key objectives of 1.) developing a prototype, 2.) testing it in the lab and 3.) testing it under real-life conditions in the North of Benin. It was only during this field testing that we discovered that the existing manual pumps on which we built the retrofit suffer from high friction and low efficiency. We learned that the retrofit as such was not suitable for large scale replication. However, in the meantime, we had tested another promising technology: the **impact pump** which consists of a hydraulic ram type pump and is operated by a sunlight pump (see: www.impactpumps.com). This combination would be much more promising and could still use an existing borehole, replacing the hand pump through the impact pump and thus guarantee a high operational efficiency at lower cost than a submersible pump.

What we also learned from the field tests is that the population has reacted **very positively** and was satisfied to have a solar-driven hand pump with an overhead tank and a tap station. They saw the benefit of such a system which supplied water quickly and conveniently. During the installation and commissioning of the retrofits, the local communities showed great interest and supported the work.

During the first three months, the retrofits operated without a problem. However, as described above, the quality issues caused the systems to leak to an extent that it made more sense for the communities to go back to the manual operation of the pumps. What we also learned is that the required **technical know-how** to maintain and repair the retrofits was not available locally. Even though the local technicians were trained during the commissioning of the retrofits, they could not put the systems back into use. For future projects, even more emphasis needs to be put on working with the right technical partners and selecting sites that are easily accessible.

4.3 Multiplication / Replication Preparation

Under these circumstances it would not have been wise to disseminate the prototypes on a larger scale and we realized that we should re-design the strategy if we want to take the lessons learned into consideration. Such a new strategy will be sketched out in the next chapter “Outlook”.

4.4 Impact / Sustainability

As the purpose of the project was to design, test and finally field-test a prototype, the quantitative impact is negligible.

The qualitative impact was however significant. People were happy with the solar-driven water systems: “During the field visits, SoPAS had a chance to interact with the community members. Their response was very positive: the community members were interested to learn about the retrofit and supported the installation team during their work. The community has a trustful relationship with the project partner Helvetas. The installed foot pump was used frequently by the community and people welcomed the idea to solarise the pumping process, to store water and to be able to get water “from the tap” without physical effort which was described as a big relieve especially for the women who are mostly in charge of fetching water. The solarisation of the foot pump was therefore seen as beneficial for the community." See also the technical report for pictures and more details.

Ecological	**Unit**	**At the REPIC Project's Completion**
Installed renewable energy capacity	[kW]	1 – 2 kW
Renewable energy produced	[kWh]/year	300 – 500 kWh
Amount of fossil fuel energy saved	[kWh]/year	negligible
Greenhouse gas reduction	[t CO_2-eq]/year	negligible
Newly collected and separated waste	[t]	na
Newly recycled waste	[t]	na
Economic		
Energy costs (LCOE)	[ct/kWh]	na
Triggered third-party funding/investments	[CHF]	na
Local private income generated	[CHF]	na
Social		
Number of beneficiaries	[Number]	Around 100 people fetching water for their families every day at each site
Number of new jobs	[Number]	
Number of trained personnel		

Table 1: Ecological, economic and social impact of the project

5. Figure Outlook / Further Actions

5.1 Multiplication / Replication

We learned through the field tests that our original hypothesis that a retrofit for existing hand pumps is not the right solution, given the fact that many hand pumps are of inferior quality, are badly maintained and have thus a low performance. However, SoPAS and ennos have in the meantime tested a **combination of the sunlight pumps with the impact pump** – a low-cost submersible

Picture 1: Testing of the sunlight pump and impact pump combination in Bangladesh, Source: https://www.impactpumps.com/2019/04/prototype-impact-pump-proves-impressive-efficiency/

pump driven by a surface pump[2] with very good results. This technology can also use an existing borehole, but the difference is that the hand pump is not used as piston but is replaced with the impact pump.

We also learned that a highly efficient and low-cost solar pump is not yet the full answer. The trend of the future market goes towards solarised tap stations with cashless automated payment systems. Such solutions are now tested and implemented under a WASH project in Ghana from which SoPAS can learn and potentially be part of. Under this project, people can pay for the water that they consume with cashless payment tokens and the money is collected in the villages through intermediaries (for example shop owners) who sell the tokens to the clients. The main operator uses fully automated systems (for example from SUSTEC, http://www.susteq.nl), where each system can be monitored remotely on a dashboard and where the money flows can be managed without handling any cash.

There are two types of clients with specific needs:

1. **End users**: the villagers who would like to have a convenient solution to pay with small amounts for each bucket of water and
2. **The operators**: the WASH organizations who work as operators and need an easy and transparent management system

The right solution for the future is thus a combination of different technologies and putting them together to a fully automated management system.

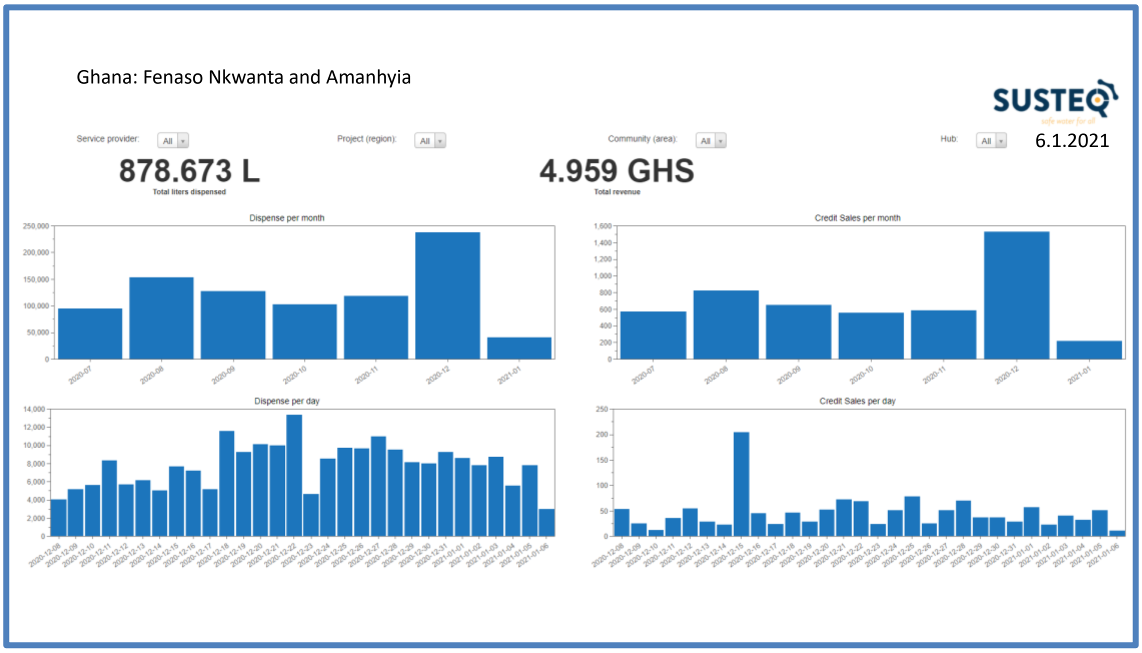

Illustration 2: Dashboard of a SUSTEQ cashless payment system in Ghana allowing remote monitoring

A new solution of a **combined sunlight/impact pump (SIP)** could become an interesting puzzle part in such a system and be an attractive alternative to submersible pumps. In the case of submersible pumps, the pump and motor are sunk to the bottom of the tubewell, which makes the installation, repair and maintenance difficult. The impact pump, on the other hand, can pump from deep water tables driven by a surface pump – for example the sunlight pump – which is easily accessible during operation, maintenance and repair. Existing submersible pumps from Lorentz or Grundfos are widely available but are considerably more expensive. SoPAS therefore would like to enter into a second phase of this project which will allow us to field test this combination in the context of Ghana and in cooperation with two new partners. One partner is the Don Bosco Vocational Training School in Accra as the technical partner and a Ghana WASH project as

[2] Normally, submersible pumps have the electric motor and pump at the bottom of the well whereas the impact pump works like a hydraulic ram and can be driven with a surface pump like the sunlight pump and achieve high lifts of deep water tables.

implementation partner. A separate note for such a second phase will be prepared and submitted to REPIC soon.

5.2 Impact / Sustainability

What are the sustainable effects (environmental, socio-economic aspects, CO_2 relevance, resource efficiency, etc.) expected during the multiplication phase, in the medium term?

There is a paradigm shift from community managed hand pump installations towards solarised tap stations with automated cashless payment systems. People are not able to maintain their systems unless they can pay in small quantities for the water they consume, and an efficient operator is required to install, run and maintain the water supply systems. The proposed sunlight/impact pump (SIP) can have a major impact in converting old-fashioned hand pump installations into solar tap station systems. If field testing shows – in a next phase – a reliable and cost-effective performance, the SIP systems can be a major part of the puzzle towards cashless automated systems.

6 Lessons Learned / Conclusions

The main findings are threefold:

1) **Technical solution for the solarisation of hand pumps**: the field tests have revealed that the original hypothesis was wrong that a prototype for retrofitting existing manual pumps with the sunlight pump would be a cheap and highly efficient technical solution. The field tests revealed severe quality issues with the manual pumps (leaks, friction) on which the retrofit was built. We could only achieve satisfactory overall performance by manufacturing high-quality pump pistons in Switzerland – which is not a sustainable solution if we are to use the retrofit in large numbers. Also, the necessary technical know-how to operate, maintain and repair the systems in the long run was not available with the local technicians. We have therefore abandoned the idea to solarize manual pumps with retrofits. In conclusion, the idea of cost savings through solarizing existing manual pumps did not materialise.
2) **New technical solutions**: a technical alternative was tested simultaneously (under a separate non-REPIC project) and has revealed an impressive field performance in form of a combination of a sunlight pump with an impact pump. SoPAS has had a research partnership with the team of the impact pump in Oxford for several years and has supported the field testing that has already been done in Bangladesh and in Kenya. This solution is slightly more costly than the original concept but instead of using an existing hand pump it can still use an existing borewell and is thus still considerably cheaper than a conventional submersible pump.
3) **Systems and not technologies**: in order to make solar solutions attractive to the two major customer groups, the end- users and the operators, reliability and ease of operation is key. It is therefore important to develop solutions that can be embedded in cashless payment systems to monitor the performance and cash payments remotely.

We have learned through the field tests and parallel continuous research that we can design an attractive technical and management solution. SoPAS is interested to enter into a second phase of field testing with a new partnership setup in Ghana:

1) **Don Bosco Vocational Training School as technical partner**: this school, supported by Don Bosco Switzerland, has set up a school and technical test centre for solar technicians in Ghana and have already integrated the sunlight pump in their curriculum. Don Bosco could become a competence centre for installing and maintaining solar water pumps and also for cashless payment systems.
2) **WASH Ghana project partner**: SoPAS can build on the experience of a WASH project in Ghana which tests automated cashless water supply systems. The SIP could be a suitable technology for their applications.

The importance of convenience and reliability

The lessons learned from this REPIC project and from parallel experiences in Ghana are extremely useful and have led to considerable insights. We could again confirm that people in Africa are highly interested in solarized water supplies and that the hand pump technology is outdated.

We learned also from other experiences in Ghana and DR Congo that people are highly interested in reliable access to safe water, but that the main driver is **convenience,** as a master thesis of a student in Ghana has shown.[4] People will be willing to contribute to the maintenance of their water supply systems, provided the water is available when needed, easy to operate, use and easy to pay. We need to take into consideration the different dimensions of convenience, as Vera Zimmerli has shown in her Master Thesis on “Creating Shared Value in the Cocoa Value Chain: Convenience as a Driver for Sustainable Water Supply and Sanitation – A Case Study in Ghana”:

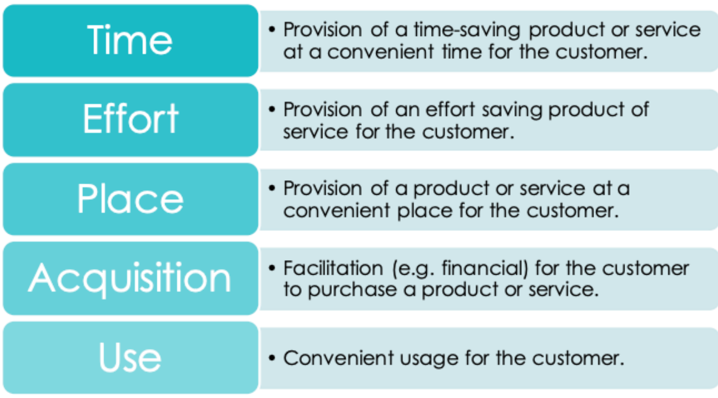

Illustration 3: Dimensions of convenience, Source: Vera Zimmerli

In addition, solutions should also be convenient for the operators of WASH systems and allow easy monitoring of the operation and of cashless payment systems.

7. Annex

1. Technical Report

[4] As part of a consultancy to a WASH project for cocoa farmers in Ghana by Andreas Koestler and Urs Heierli – both lecturers at University of St. Gallen – we commissioned a master thesis in combination with an extended field study. This study has given additional insights into the willingness to pay and the aspirations of water users in West Africa. See Vera Zimmerli: “Creating Shared Value in the Cocoa Value Chain: Convenience as a Driver for Sustainable Water Supply and Sanitation – A Case Study in Ghana” February 2019, master thesis University of St. Gallen.

Retrofit for converting hand pumps into solar pumping systems with tap stations

Technical Report

SoPAS, October 2020

Starting point

There are several hundred thousand hand pumps in operation in Africa. Recent experiences show that people prefer solar pumping systems and are willing to pay and maintain solarised systems if they provide a better service with overhead tanks and tap stations. However, solar drinking water installations are costly (roughly 8’000 US $ without and over 20’000 US $ with a newly built suitable water well).

An evaluation that was performed by SoPAS showed deficiencies in the maintenance of manual pumps and a very low willingness to pay: people paid in average 0.5 US $ per month for the maintenance of their water supply system, but easily 10 to 15 US $ per month for their mobile phones. The reason is that mobile phones are aspirational and something people care for. Manual pumps, on the other hand, are considered a public good with low local ownership. When the pump breaks down, it costs some 50 US $ and there is very often not enough cash available to repair it.

Pictures 1 and 2: Foot pumps used in the project area

Project idea

Assumption:

In the case of manual pumps, people will revert to more traditional means such as the old well or even search water from ponds when the pump breaks down. They will not do this with a tap station: they will repair it, pay a service provider to make it work again - just as they do when the mobile phone breaks down: nobody will stop calling, if the mobile phone has a problem but they will get it repaired.

Pourtant lorsque le robinet est à la maison, l'usager est prêt à payer pour garder le service !

Value proposition:

<u>Most common solution</u>: solarized drinking water systems, where mostly submersible pumps are used in addition to the hand or foot pump (not as retrofit). Cost from USD 8’000 up to USD 20’000 with water tank.

<u>Our retrofit solution:</u> Retrofitting hand pumps which remain functional. We estimate that the cost of our retrofit device would be in the order of USD 1’000 and the total investment for a solarisation would be in the order of USD 2’000-5’000.

→ A solarised water supply becomes more affordable and accessible for communities.

Technology:

SOPAS is promoting the sunlight pump – a highly efficient, small-scale solar water pump - in close cooperation with ennos. Through this project, the sunlight pump “solar drive” (= motor and electronics) can be made suitable for drinking water with a simple and universal retrofit device that could be applied to several types of existing hand pumps. See the following pages for illustrations.

Illustration 1: Main components retrofit

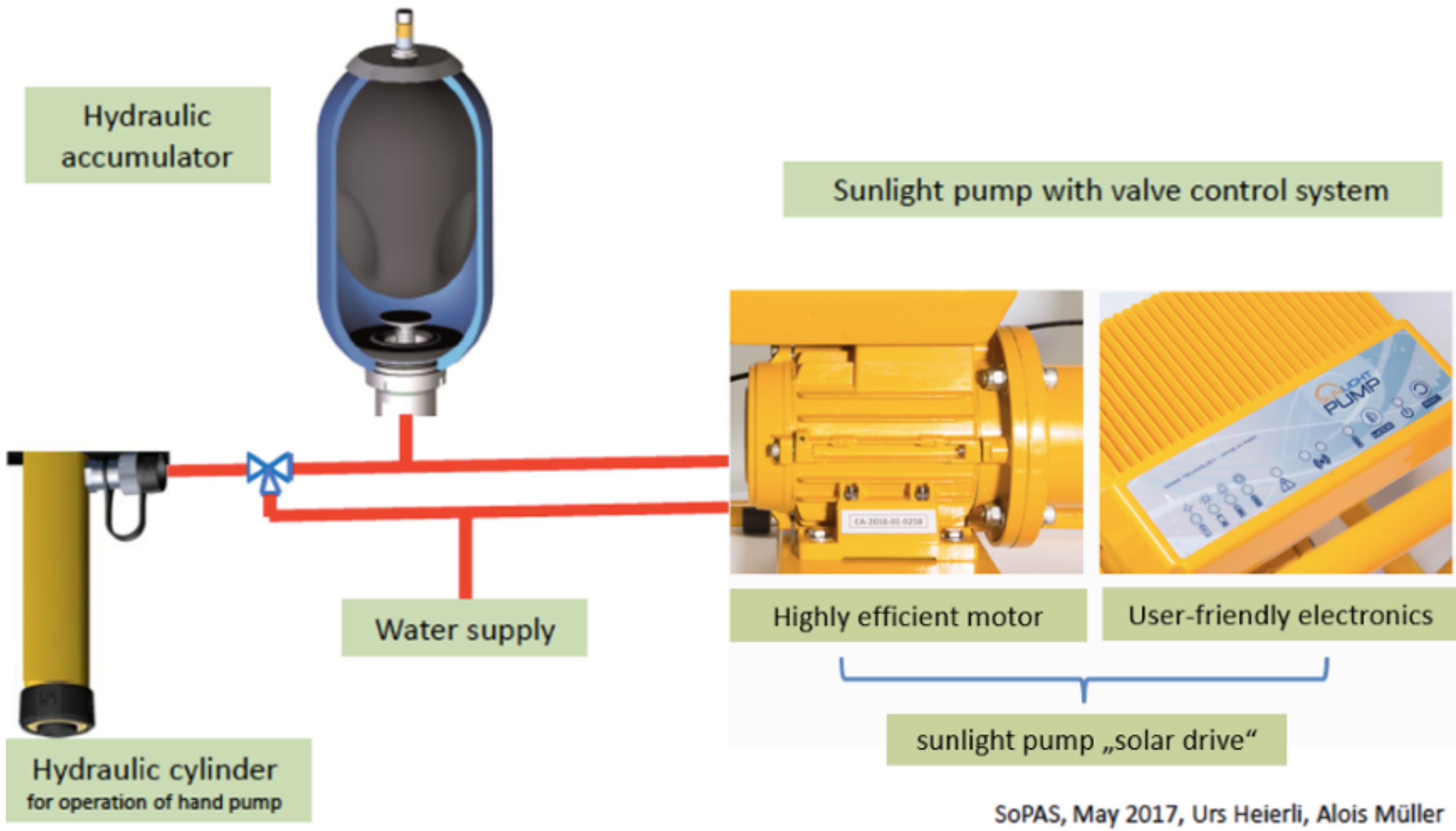

Illustration 2: Setup retrofit installation

1

2

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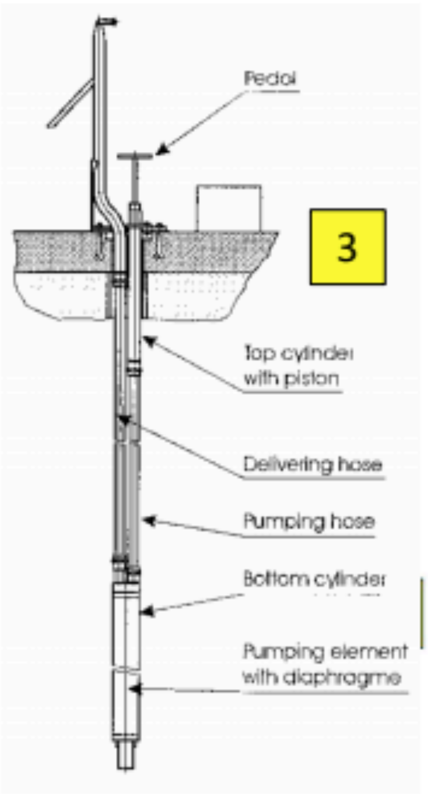


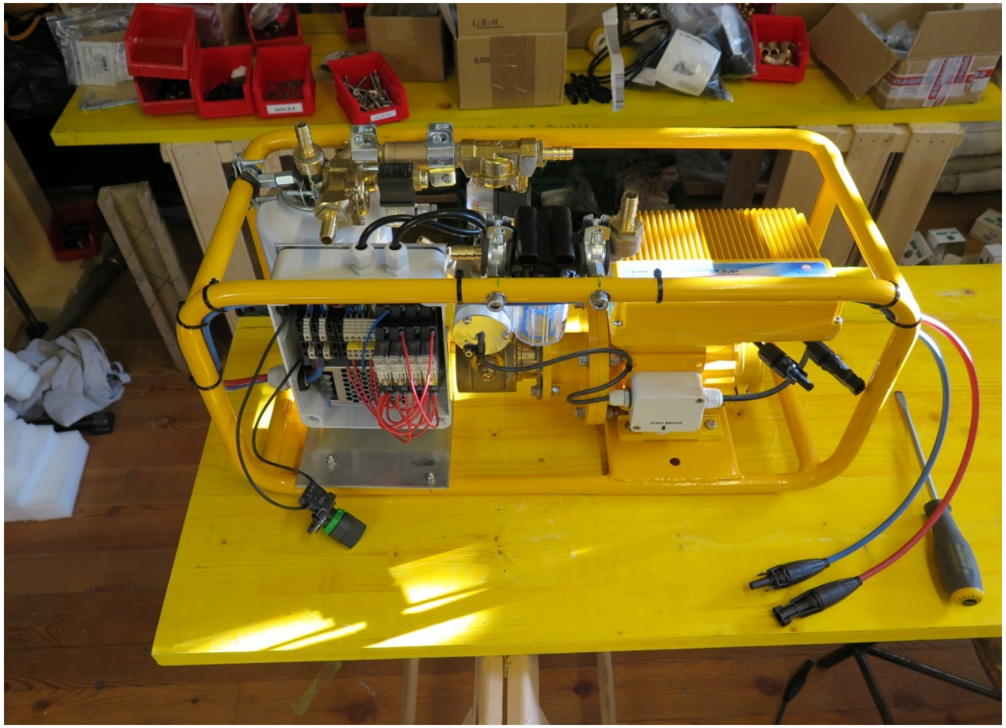
3

5

1. **Solar panel** to power the sunlight pump drive
2. **Retrofit** to connect solar power to the existing hand pump (see detail in Annex 1)
3. Hand pump can be used with solar power or handle
4. The water pump is connected to a **tank** where the water can be stored and treated if necessary
5. A **tap station** is built to deliver water to the customers from a tap

Development and testing of retrofit prototype in Switzerland

- The prototype of the solar retrofit device was designed by the SoPAS senior engineers and put to an endurance test at Berne University of Applied Sciences. Several months of testing on the facility specifically designed for the solar retrofit (see picture 3), allowed us to monitor the performance and fine-tune the prototype.
- The SoPAS field engineer and solar expert Carlo Vassella then finalized the prototypes and prepared them for the dispatch to Benin. Six prototypes were sent to Benin together with the necessary hoses and accessories in November 2018 (see picture 4).
- In parallel, the team of Helvetas Benin selected the sites for the retrofit installations in the North of Benin. The Helvetas team received detailed instructions from SoPAS about the necessary preparations and material that had to be purchased locally.



Picture 3: sunlight pump adapted for the solar retrofit

Picture 4: Prototypes ready for the dispatch to Benin

Field installations and training

SoPAS made three field missions to Bénin. Together with the Helvetas Bénin team, three installations were finished. The field missions took place:

- *December 2018*: The SoPAS field engineer Carlo Vassella visited Bénin to inspect the three sites selected in Banikoara, North of Bénin. One retrofit installation was realized and tested in Gbessara, Banikoara. This first installation provided the opportunity to test the retrofit with an existing foot pump in the field and to train the local technicians of Helvetas and the operators on the installation and use of the retrofit. This first visit also allowed Carlo Vassella to get an understanding of the local conditions, the sites and the material that is locally available in order to plan the next field visit and remaining installations.
- *April 2019*: Field mission by Carlo Vassella and Hubert Bagnaba. Hubert Bagnaba is an experienced solar (pumping) engineer who has realized a number of sunlight pump installations in Burkina Faso. Together, they finished two more retrofit installations.
- *November 2019*: Technical problems (water leaks) appeared due to the poor quality of the foot pumps (see also lessons learned). SoPAS decided to get high quality pump pistons manufactured in Switzerland to replace the low quality ones in the field. They were shipped to Bénin and installed by Hubert Bagnaba in November 2019. All the retrofits were checked again and were functioning well.

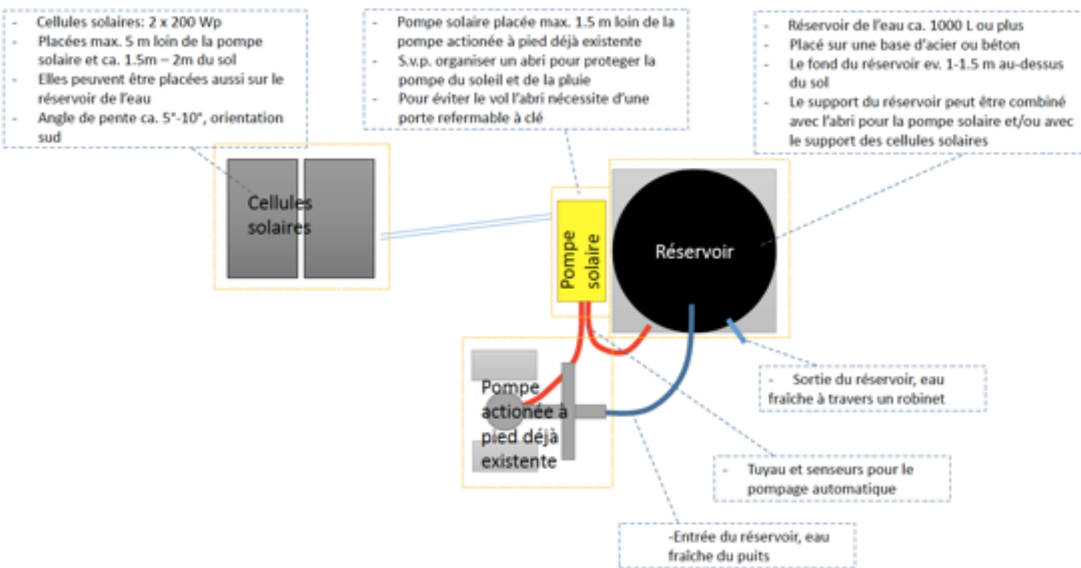


Illustration 3: Setup retrofit installation

Picture 5: Installation area Qualieau project Helvetas Banikoara Bénin

Field installations and training

Picture 6: Situation before the retrofit, foot pump with pedal

Picture 7: First pumping trial

Picture 8: Manufacturing of tank and panel structure

Picture 9: Mounting of 2’000 liters water tank

Field installations and training

Picture 10: Cleaning of solar panels

Picture 11: Training of retrofit operators

Picture 12: Commissioning of the retrofit together with operators

Picture 13: Handing over of the retrofit to the community

Feedback from users

During the field visits, SoPAS had a chance to interact with the community members. Their response was very positive: the community members were interested to learn about the retrofit and supported the installation team during their work. The community has a trustful relationship with the project partner Helvetas. The installed foot pump was used frequently by the community and people welcomed the idea to solarise the pumping process, to store water and to be able to get water "from the tap" without physical effort – which was described as a big relieve especially for the women who are mostly in charge of fetching water. The solarisation of the foot pump was therefore seen as beneficial for the community.

Picture 14: Community members are conveniently fetching water at the retrofit tap station

Lessons learned

- **Quality of foot pumps**: The foot pumps on which the retrofits were installed were not - as anticipated - of high quality and high efficiency. Even though it is an expensive pump that is manufactured in Europe, it was bad structurally (lot of friction). Another learning was that the foot pumps in the field were badly maintained. Even after a revision of the pumps was requested by SoPAS, they were not in a sufficient condition and had to be revised again. After water leakages were discovered on the retrofits, SoPAS decided to get high quality pump pistons manufactured in Switzerland to replace the original ones in the field. This solution worked and all the retrofits could be put back to use.
- **Storage of replacement parts:** The replacement parts that SoPAS delivered were stored far away from the installation sites. Even a simple defect such as a melted fuse therefore took time to be repaired.
- **Technical capacity:** SoPAS instructed the local operators on the use, maintenance and basic repair of the retrofit system. However, the local technical capacity was very limited and the operators had difficulties performing very simple technical work (e.g. changing a fuse). In view of a second project phase, the learning is that a stronger technical partnership must be in place to guarantee the functioning of the tap stations.
- **New legal framework**: After the project start, the Government of Bénin introduced a new directive proposing and promising pipe connections to all households in the country. This has discouraged the use of off-grid solutions and NGOs – such as the project partner Helvetas – have largely lost interested in off-grid water tap stations.

Outlook:

- Building on the experience from Bénin and after discussion with REPIC, SoPAS is working on a Phase 2 Outline with a new technology and more favorable conditions and partnerships in Ghana.