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Final Report:

Micro-Business and Female Small-Scale Farmers in Rural India

Innovation through Sustainable Energy Technology

Author(s):
Eva Schuepbach, Andrea Vezzini and Urs Muntwyler
Bern University of Applied Sciences, Institute for Energy and Mobility (IEM)
Burgdorf/Biel, Switzerland

Co-Author:
Tharun Anto
Thitali Low Carbon Solutions Pvt Ltd.
Kochi, India

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Prepared by:
PD Dr. Eva Schuepbach
Bern University of Applied Sciences BFH
Department of Engineering and Information Technology (BFH-TI)
Institute for Energy and Mobility (IEM)
Photovoltaic Laboratory (PV LAB)
Jlcoweg 1, CH-3400 Burgdorf / Switzerland
Tel: +41 (0)34 426 68 29, Fax: +41 (0)34 426 68 13
eva.schuepbach@bfh.ch / www.ti.bfh.ch/elektro / www.pvtest.ch

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

With the support of:
REPIC Platform
c/o NET Nowak Energy & Technology AG
Waldweg 8, CH-1717 St. Ursen / Switzerland
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

One billion people worldwide have access only to unreliable electricity networks and 1.2 billion have no access to electricity. In such under-electrified or even non-electrified regions, renewable energy and especially solar technology offer a particularly great potential. In agriculture, harnessing solar energy to drive photovoltaic water pumps can facilitate irrigation and crop production during the dry season, open the door for additional sources of income and thus contribute to rural development.

In India, around 300 million people lack access to electricity, and there is currently an under-served demand for solar water pumps. This pilot project hence addressed the deployment of solar water pumps in India. The solar water pump introduced was a photovoltaic water pump system ("sunlight pump") developed at the Institute for Energy and Mobility Research (IEM), Bern University of Applied Sciences BFH in Switzerland and now locally manufactured in India. Collaboration partners were both local non-profit organisations and local businesses in southern India.

Female farmers were targeted as deployment partners, as Indian women play a predominant role in earning a livelihood for their families, and to avoid the old trap of widening the gaps in a class system. In order to minimize the costs for installation, monitoring and service line set up during the "sunlight pump" field tests, female farmers close to the manufacturer (Bangalore, Karnataka) were selected. The main implementation partner was the female farmers' association of Kudumbashree in Kerala, where "sunlight pumps" were installed as part of an extended irrigation system with water tanks, drip irrigation kits and sprinkler systems. The female farmers of Kudumbashree can take advantage of a relatively high grid-connectivity in Kerala, in addition to subsidised electricity and hence, there was stiff competition for the "sunlight pump" from electric water pumps in this pilot project.

Nevertheless, training of the female farmers by Swiss engineers, jointly with the elected bodies of the local self-government in rural India (Panchayats) and in association with local village offices and the local project manager of this pilot project in India created considerable awareness for operations and maintenance of the "sunlight pump". Preliminary business models established with Kudumbashree show that using the "sunlight pump" for irrigation might be attractive to the association, when additional applications are adopted (e.g., the use of the "sunlight pump" for domestic water supply as demonstrated in this pilot project). Multiplication includes the deployment of the "sunlight pump" to urban farming, which currently is an explosive trend in the nearby city of Kochi, Kerala.

As a replication, the Solar Pump Association Switzerland (SoPAS) will, jointly with Caritas, install ten "sunlight pumps" in Bihar (northern India) in September 2015, where supplemental irrigation is needed over a longer period than in the state of Kerala. In regions with lower or no grid-connectivity, the "sunlight pump" could even be attached to a battery to offer additional advantages like powering solar lights or charging cell phones.

In conclusion, deployment of solar irrigation technology like the "sunlight pump", combined with an efficient use of water in irrigation (through water tanks and drip irrigation kits/sprinkler systems), can potentially offer new perspectives to female farmers and enhance the safety of farming village women (avoid overnight irrigation).

It is recommended that the female farmers of Kudumbashree install and use the deployed irrigation system again during the next dry seasons to gain a better understanding of all technologies. The local project manager in India and some experts of the Swiss project team could then follow up with the association to ensure that the "sunlight pumps", drip irrigation kits and sprinkler systems are to the full benefit of Kudumbashree in the future.

In this way, this pilot project conducted by Bern University of Applied Sciences BFH, Switzerland, will continue paving the way towards women empowerment in modern solar irrigation technology among female farmers in Kerala, India.

2. Starting Point: "To make it work, make it a business"

The United Nations declared 2012 as the «International Year of Sustainable Energy for All» [1]. However, about 1.2 billion people worldwide have no access to electricity and the development benefits it brings, and 1 billion more have access only to unreliable electricity networks [2]. In such under-electrified or even non-electrified regions, renewable energy and especially solar technology offer a particularly great potential. In agriculture, harnessing solar energy to drive photovoltaic water pumps can facilitate irrigation and crop production during the dry season, open the door for additional sources of income and thus contribute to rural development [3].

Aiming to meet these needs, a photovoltaic water pump system was developed by Professor Dr. Andrea Vezzini, Institute for Energy and Mobility Research (IEM), Department of Engineering and Information Technology at Bern University of Applied Sciences BFH in Biel, Switzerland. The so-called "sunlight pump" consists of a photovoltaic panel, an electronic controller including a maximum power point tracker and a human interface, a highly efficient permanent magnet motor and a rotary vane pump (Fig. 1). A detailed description of the development history and technology of the pump can be found in [4].

The pump motor, mechanical components and electronics of the "sunlight pump" are today produced at the ISO 9001-2008 certified solar module company Amro Technology Pvt. Ltd. in Bangalore, India. In this way, local technology and manufacturing capabilities are used and jobs created in the region.

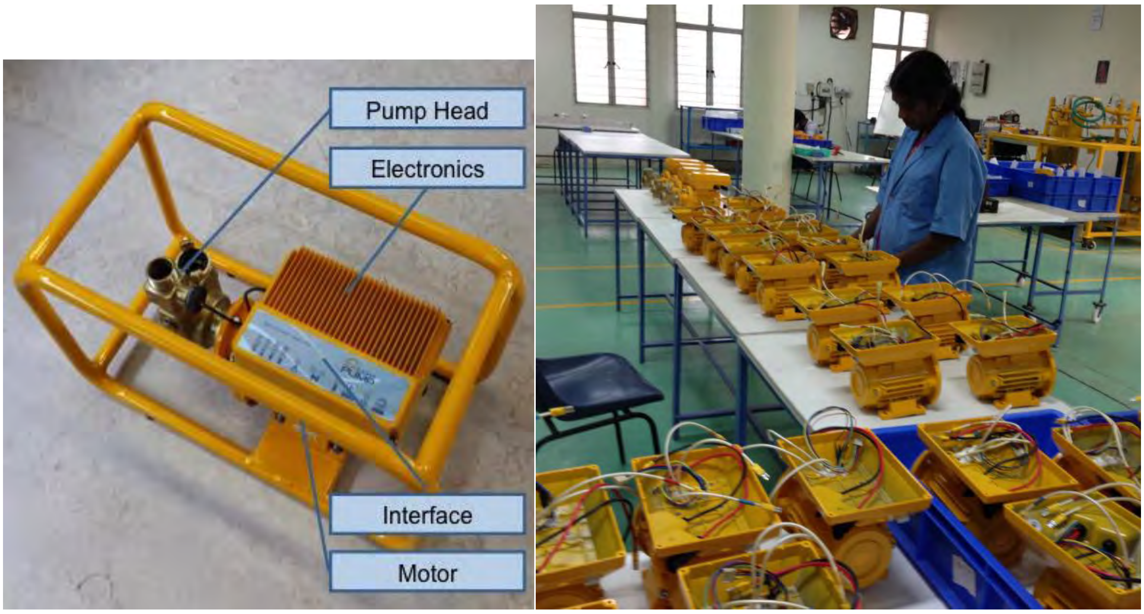


Fig. 1: The "sunlight pump" (left) was developed at Bern University of Applied Sciences BFH in Switzerland and brought from prototype level to production stage by ennos gmbh, a spin-off at BFH in Switzerland. Today, manufacturing of the "sunlight pump" is at Amro Technology Pvt. Ltd. In Bangalore, India (right). Source of photos: SoPAS.

3. Objectives

After improvements on the prototype, an initial small series of 150 pumps was produced for field testing in operational small-scale farming. The objective of this pilot project was thus to field test a small sample of the "sunlight pumps" near the local manufacturer. Through research conducted [5] it was found that the major obstacles in successful implementation of sustainable energy technology in developing countries are (a) traditional power structures and (b) the lack of participation. As Indian women play a predominant role in earning a livelihood for their families but are only ranked 114 in the "Global Gender Gap Index" [6], field testing concentrated on female farmers. In view of building up the service line for the "sunlight pump" and evaluating potential distribution partners, female farmers' associations with clear organization structures were aimed at.

The <u>overall objectives of this pilot project were</u>:

(i) To enhance productivity in the dry season;

iii) To raise awareness for sustainable energy solutions in India through education, and

(iii) To promote and bring new perspectives to female small-scale farmers in rural India.

The <u>specific objectives of this pilot project were</u>:

(iv) Evaluation of a possible distribution channel for the “sunlight pump” in rural India;

(v) Evaluation of a business model for the market introduction of the “sunlight pump” with the female farmers’ association at Kudumbashree, Kerala, India.

4. Project Review

4.1 Project Implementation

4.1.1 Implementation Partners

This pilot project was directed by PD Dr. Eva Schuepbach [7], Institute for Energy and Mobility Research (IEM), Department of Engineering and Information Technology at Bern University of Applied Sciences BFH. The local project coordinator in India was Mr. Tharun Anto [8] from Thitali Low Carbon Solutions Pvt. Ltd. Kochi (Kerala). The “sunlight pumps” were delivered by the local manufacturer, Amro Technology Pvt. Ltd. in Bangalore (Karnataka). Local implementation partners were the female farmers’ association Mulanthuruthy [8] in project phase I and the female farmers’ association of Kudumbashree in project phase II [9], both located in the state of Kerala (ca. 1 hour drive from Kochi). The main field testing was conducted with Kudumbashree, where the “sunlight pumps” were deployed as part of an extended irrigation system including the “sunlight pumps”, water tanks, drip irrigation kits and sprinkler systems. Other local collaboration partners in India contributing to the success of this pilot project are ACTS Education Group with its Rayasandra Campus near Bangalore, Karnataka [10] and the Synthite Group, Headquarter Kolenchery, Kerala [11]. As the project was nested within the three critical pillars “micro credit”, “entrepreneurship” and “women empowerment”, additional Swiss experts were involved in this pilot project, namely the solar expert and engineer Professor Urs Muntwyler, Head of the Photovoltaic Laboratory at BFH, Burgdorf, Switzerland [12] in project phase I+II, and SoPAS (the Solar Pump Association Switzerland) with Dr. Urs Heierli, Karin Imoberdorf and Alois Müller [13] in project phase II.

4.1.2 Project Phase I (Field Tests 2012-13)

A) Pump installation with the educational partner

In order to promote training and education on the “sunlight pump”, ACTS Rayasandra Campus near Bangalore and their network of school teachers working in the villages surrounding the Campus (ca. 500 acres, ca. 1000 families) was targeted as a field testing partner.

Fig. 2: Amro CEO (Ashok Mattoo) demonstrating the “sunlight pump” installation to the project leader (PD Dr. Eva Schuepbach), the local project manager in India, Mr. Tharun Anto (Thitali Low Carbon Solutions Pvt. Ltd., Kochi, Kerala) and an engineer of ACTS Education Group (left), and supervising the production of solar panels (right). Kick-off Meeting in Bangalore in February 2012. Source of photos: BFH-TI / IEM.

However, a kick-off meeting held from 6-8 February 2012 in Bangalore (Fig. 2) revealed that the water sources on the Campus and surrounding villages had been dried out. ACTS Rayasandra Campus was maintained as a pump installation site for educational and training purposes (students, teachers, local village women and girls), but the originally targeted “sunlight pump” installation sites in three villages surrounding the Campus were not found suitable any more.

B) Pump installation with the business partner

In view of the market introduction of the “sunlight pump”, collaboration was also established with an industry partner. The Synthite group operates a large number of farms all over South India including the states of Karnataka, Tamil Nadu and Andhra Pradesh and expressed interest in collaboration. Farmers in four villages (one in the Karnataka state (Handpost) and three in the Tamil Nadu state (Thalavady, Veerasikamani, and Chekkur) were selected for field testing. Synthite offered to have five “sunlight pumps” installed in these villages for the purpose of drip and water well irrigation. Each “sunlight pump” was sold to Synthite for $300 what was (in 2012) about the price of a competitor product (Chinese pump) on the local market in India. Synthite subsidized each “sunlight pump” with $150; consequently, each farmer had to invest $150 in this technology. After a technical meeting (March 2012) between BFH and Amro Technology Pvt. Ltd. in Bangalore, five “sunlight pumps” were installed with the interested Synthite farmers in June 2012 (Fig. 3) under the leadership of a Swiss engineer from BFH. He also instructed the local manager of this pilot project (Mr. Tharun Anto, Thitali Low Carbon Solutions Pvt. Ltd., Kochi, Kerala) in pump installation.

FARMTECH

Pumping solar power

Farmers in Tamil Nadu are a depressed lot now: power cuts that extend up to 12 hours are eating into their hopes. In areas which depend on bore wells or irrigation water, the situation is acute; and there is no immediate sign of a respite.

Synthite Industries Ltd, which is working with the chilli farmers in the Sankarankovil and Tenkassi area of the State, is implementing a pilot project for using solar power to mitigate their woes. Farmtech, the agriculture extension wing of the company, in association with Bern University, Switzerland, is distributing solar-powered water pumps for the farmers. This is for the first time that solar pumps are being used in India for irrigation.

Under the pilot project, five farmers have been given the complete system comprising solar panels and pumps. The total cost of a pump would be about ₹50,000. The university makes it available at ₹15,000 of which half the amount is borne by Farmtech. Each pump can irrigate up to one-and-a-half acres of land and the experiment has been successful, said Mr. Jainendran G, Lead-Farmtech. The company has already extended this project to Tamilnadu-Karnataka border also, he said.

Solar panel

Getting the panel ready

Fixing the foot valve

Here's water

The team that made it happen

Fig. 3: Pump installation with Synthite farmers in June 2012 (by BFH engineer Lukas Menzi, left in the bottom-right picture), as documented in the Synthite company magazine “Farmtech”.

Following installation and demonstration of the “sunlight pump” to the Synthite farmers, a monitoring system was developed by BFH and the local project manager to gather information relevant to pump operations. The results of the telephone interviews and face-to-face meetings revealed that especially the flexible use of the “sunlight pump” was appreciated. As the system is mobile, it can be moved from one borehole to another and can be taken home overnight to avoid stealing. Some Synthite farmers, however, also reported that they cannot fully satisfy their irrigation needs due to considerable evaporation losses.

C) Pump installation with the female farmers of the Mulanthuruthy agriculture cooperative
In search for female farmers’ association close to the local manufacturer in Bangalore, an only women's University in Kochi was contacted who had collaborated with a rural vegetable farming project for years. The University suggested to contact the Fruit and Vegetable Council of Kerala, the Residents’ Association of Kochi and the Cooperation of Kochi (Panchayats, elected local self-governing body in rural India). The Fruit and Vegetable Council of Kerala and the Residents Association of Cochin jointly promote a scheme of terrace farming of fruit and vegetable in participating houses in Kochi, which is mostly done by women. In the associated female farmers’ agriculture cooperative in Mulanthuruthy, the women farmers cultivate paddy (rice) in the wet season and vegetables during the dry season. In this area, a canal-based irrigation is prevalent where paddy (rice) was cultivated in December 2012. After the paddy season, the female farmers wanted to install overhead tanks to which the water was to be pumped with the “sunlight pump” during the day and vegetables irrigated overnight.

Mulanthuruthy was interested in exploring the possibility of being included as a field testing partner in this pilot project. On 29 December 2012, a 120W “sunlight pump” was hence installed for demonstration purposes by the local project manager in India and demonstrated to the female farmers at Mulanthuruthy, the Panchayat of Mulanthuruthy and the Local Village Office. A shed for the “sunlight pump” and solar panel (see Fig. 4) was financed and constructed by the husbands of the female farmers living near the pump installation site.

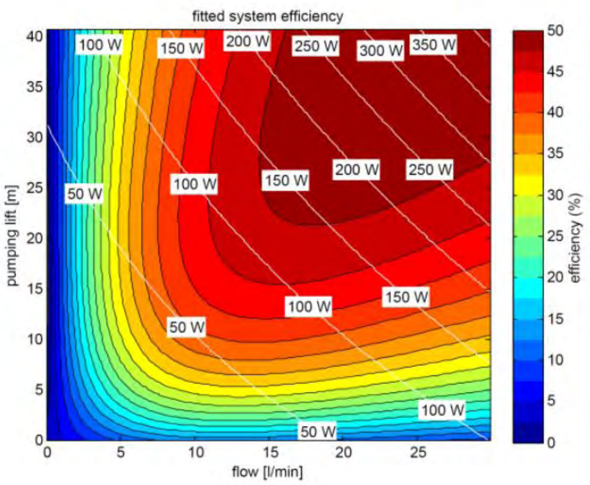
Fig. 4: Female farmers of the Mulanthuruthy agriculture cooperative demonstrate the installed “sunlight pump” to a representative of the Swiss Embassy in India during the January 2013 Workshop. Source of photo: BFH-TI / IEM.

In the subsequent monitoring, the female farmers positively reported on the “sunlight pump”, especially on the pump requiring minimal attention as it is self-starting. They, however, also expressed a need for additional infrastructure like a financed shed to safely store the pump, overhead tanks and drip irrigation kits for overnight irrigation (reduce evaporation losses). This need was confirmed by an expert from the Swiss Embassy in Delhi [14] visiting the pilot project and the female farmers at Mulanthuruthy. The investment for future sheds and any additional irrigation infrastructure stretched, however, the financial capabilities of the families interested in field testing the "sunlight pump". The female farmers' association in Mulanthuruthy was hence reluctant to fully commit itself as a field testing partner.

4.1.3 Technical Improvements and Laboratory Tests on the "Sunlight Pump"

After completion of Project Phase I, the results of the pilot project were presented at an international Conference (EU PVSEC Amsterdam, 2014; [15]). The feed-backs of all end-users in the operational field tests were compiled and integrated into further technical pump development to better satisfy the farmer's needs. Extensive laboratory simulations (Fig. 5a) on the "sunlight pump" were complemented with measurements in a new "test bench for solar water pumps" (Fig. 5b) established by Professor Urs Muntwyler at the Photovoltaic Laboratory at BFH in Burgdorf, Switzerland [16]. In this test bench, the pumps are measured according to Swiss standard EN 62253 [17], of particular interest are the power as a function of flow rate at a constant pump height and the start-up power.

The "sunlight pump" was also upgraded with an infrared communication interface in view of "pay per liter" and microfinance options. Every "sunlight pump" now goes through a one hour quality test routine at the local manufacturer in India (Amro Technology Pvt. Ltd.) before it is cleared to be delivered. The test protocols are uploaded on a server that the BFH engineers in Switzerland can access to supervise the production process and to provide input.



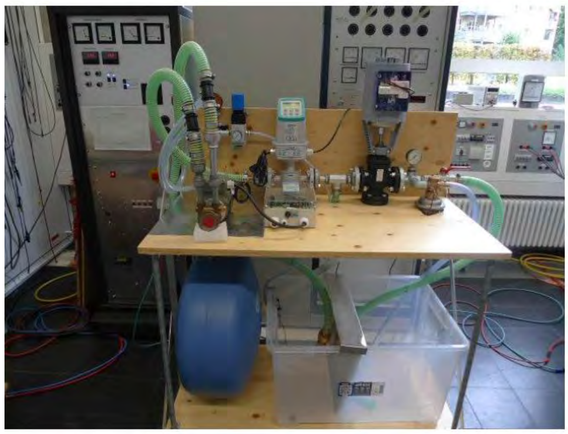


Fig. 5a-b: Test bench for solar water pumps (left) at BFH-TI / IEM in Burgdorf and results of laboratory simulations (right) at BFH-TI / IEM in Biel, showing the system's efficiency of "sunlight pump" and links between pumping height, water flow rate and solar module power [15]. Source of graph and photo: BFH-TI / IEM.

Following the field-testing, technical improvements, laboratory examinations and test bench measurements, the key features of the improved "sunlight pump" are:

Capacity: The maximum capacity of the pump model used in Kudumbashree is 28 liters/minute. At 6 full load hours on a sunny day, this corresponds to a daily water output of around 10'440 liters. If the total water lift is increased, the panel size has to be increased proportionally.

Flexibility: The pump system (pump and panel) can be tailor-made to the needs of the users. Depending on their water requirements per day and the total water lift, the system can be adjusted by adding standard solar panels between 80 and 320 Watt. The required solar panel surface increases proportionally with the required water lift. Another interesting feature is that the pump can be connected to the solar panel directly or to a battery (charged by the panel).

Efficiency: The pump is characterized by a very high system efficiency to make the system affordable (because higher efficiency translates into lesser solar panel surface required).

Portability: The weight of around 11 kg, the measures of 24 x 29 x 49 cm and the metal frame (Fig. 1) allows the farmer to carry the sunlight pump around easily to protect it from stealing or to move it between scattered plots and from borehole to borehole. This also creates a business opportunity because a pumping service provider could move around with the device (ideally connected to a battery) to pump water at his neighbours' plots.

User-friendliness: The electronic interface with LED indicators informs the user about the operational state of the pump and indicates possible errors. The so-called "flow switch" is a sensor that stops the pump in case the water source has run dry. This prevents the pump from running dry and getting damaged. The so-called "overflow switch" sensor stops the pump when the water reservoir is full. The pump will automatically restart if the water flow is sufficient again or if the water tank is emptied.

4.1.4 Towards Field Testing the "Sunlight Pump" in an Extended Irrigation System

As suggested by [14], field testing the improved "sunlight pump" was planned in the context of the added value offered by an extended irrigation infrastructure including water tanks and drip irrigation kits / sprinkler systems (Project Phase II: 2014-15). Given this complexity, the logistics in this pilot project were to be managed in an even more efficient way. Existing local field testing partners in India were hence contacted and collaboration interests re-discussed.

The Synthite farmers' drawback as field testing partners in project phase II was that their fields spread over a very large geographical region encompassing the states of Karnataka, Kerala and Tamil Nadu. Field testing of the improved "sunlight pumps" and extended irrigation infrastructure with Synthite was hence perceived as too costly. Moreover, Synthite did not collaborate with female farmers. Synthite was hence kindly invited to postpone business collaboration with this pilot project. As with the female farmers of the Mulanthuruthy agriculture cooperative, they were reluctant to fully become committed.

Other female farmers' associations were hence contacted and evaluated. Over a period of several months from late 2013 to spring 2014, and under the lead of the local project manager in India (Mr. Tharun Anto), interests and irrigation needs were discussed in detail with the female farmers' association in Kudumbashree, Kerala.

The literal meaning of Kudumbashree is prosperity (shree) of family (Kudumbam). Launched by the Government of Kerala in 1998 for wiping out absolute poverty from the state through concerted community action under the leadership of local self-governments, Kudumbashree is today one of the largest women-empowering projects in the country. The programme has more than 4 million female farmers participating, covers more than 50% of the households in Kerala and is today a well-known and well-renowned women-empowering organization, aiming to provide access to micro-credits and to support female entrepreneurs. The Kudumbashree initiative has today succeeded in addressing the basic needs of the less privileged women, thus providing them a more dignified life and a better future, and is also involved in responsible and sustainable tourism [18].

While the Kudumbashree association of female farmers expressed a general interest in working with new technology, they were not interested in an abrupt change in their irrigation technology. Kudumbashree was keen, however, to promoting new technologies and innovations, especially in drip irrigation for vegetable cultivation, and to deploy the "sunlight pump" and associated irrigation infrastructure on parts of their fields. This <u>partial irrigation</u> (of ca. 1/5 – 1/3 of a plot of ca. 2000-3000 m^2) was going to offer the opportunity for comparison of different irrigation technologies in the future.

The mode of cooperation with Kudumbashree as a field testing partner in this pilot project was defined in a "Memorandum of Understanding" [18] signed jointly between BFH and Kudumbashree in spring 2014 and submitted to REPIC. It was agreed that so-called "Farmer's Facilitation Centres" (FFC), represented by employed, dedicated female farmers, will have the overall responsibility of the improved "sunlight pump" and associated irrigation infrastructure.

All five participating villages identified by Kudumbashree were in one hour driving distance from Kochi, Kerala (villages Edakattuvayal, Vadakkekara, Thiriumarady, Chendamagalam, and Mazhavanoor). Most female farmers in these villages do not possess their own land but lease land for agriculture from Kudumbashree. The organisation assigns a master farmer to a group of four female farmers, organised under the umbrella of so-called Joint Liability Groups (JLGs).

4.1.5 Project Phase II (Field Tests 2014-15)

Deployment of the improved "sunlight pump" and associated irrigation infrastructure was supported by SoPAS, the local project manager of this pilot project in India (Mr. Tharun Anto) and realised jointly with the Kudumbashree management, especially the District Manager (Mrs. Thanie Thomas). First assessments of potential installation sites were carried out in April 2014 by a Swiss engineer from SoPAS (Alois Müller; [19]) resulting in recommendations and instructions to Kudumbashree on how to prepare the installation sites. During this first field visit, the female farmers of the Kudumbashree association mentioned that they were going to plant pineapples (and not vegetables) and that the pineapples need to be irrigated from the top. It was hence decided to install micro sprinkler systems (2 x 500m^2) at these specific plots.

In June 2014, another Swiss engineer of SoPAS (Josef Roos) visited Kudumbashree to support the evaluation and purchase of large 5’000 litre rigid water tanks on the local market and additional material (like water hose, etc.). It turned out that the female farmers were, however, reluctant to place large, heavy water tanks on the roof of their houses to create the requested pressure for the micro sprinklers. The farmers were hence advised to consult with a structural engineer before they install the tanks. Additional instructions on the preparation of the “sunlight pump” installation site were also provided. Four drip irrigation kits (2 x 500m^2, 2x 200m^2) were sourced in India. The low-pressure inline drip kits operate between 1.5-3 meters head (0.15 to 0.3 bar). Drip irrigation systems bring the water efficiently and uniformly to the roots of the plants. Micro sprinklers require a slightly higher pressure of 5-8 meters.

After all installation sites were evaluated and further instructions for the preparation of the sites were given, the drip irrigation kits, sprinkler systems and ten “sunlight pumps” (equipped with the tank overflow sensor) were shipped from the local manufacturer in Bangalore to Kudumbashree. The material arrived in and was received in Kochi in the end of June 2014 and then transported to Kudumbashree under the supervision of both the local project manager (Mr. Tharun Anto) and Prof. Dr. Andrea Vezzini. All material was checked and listed by Prof. Dr. Andrea Vezzini and then stored at the local Kudumbashree office, alongside the water tanks purchased on the local markets. Prof. Vezzini also conducted an “opening the box” training event for both the participating female farmers, the Kudumbashree district office and regional policy makers on 28 June 2014 (Fig. 6).

Fig. 6: Prof. Dr. Andrea Vezzini (left) listing the shipped irrigation material and introducing the “sunlight pump” to the female farmers (right), the local Kudumbashree office and regional policy makers in an “Opening the Box” Workshop held on 28 June 2014 with Kudumbashree, Kerala, India. Source of photos: BFH-TI / IEM.

In September 2014, six “sunlight pumps” were installed by a SoPAS engineer in Ernakulam, one hour drive from Kochi. Four “sunlight pumps” were installed under the lead of Mrs. Achamma Alias, who is a very dynamic master farmer that has been trained by Kudumbashree. One pump was installed at the house of Mrs. Alley Jos, the present Group Coordinator of the Kudumbashree Panchayat Office in Vengala. Installation site no. 6 was at another female farmers’ house. Four spare “sunlight pumps” were kept at the local Kudumbashree office with other material (solar panels, water hose, etc.). Training and installation demonstrations and workshops on the “sunlight pumps” were carried out for the participating female farmers (Fig. 7) and with the support of the local project manager in India (Mr. Tharun Anto).

Fig. 7: Installation of the “sunlight pump” by SoPAS engineer Alois Müller (taking the pictures), assisted by the local project manager, Mr. Tharun Anto (black T-shirt), and demonstration to the female farmers of the Kudumbashree association of female farmers in September 2014. Source of photos: SoPAS.

As for the water tanks, the installation sites had not fully been prepared by the female farmers at Kudumbashree before the SoPAS installation visit in September 2014. Hence, the tanks could not be placed to their final positions and the relevant connections could not be made by the SoPAS engineer. SoPAS hence contracted the local project manager, Mr. Tharun Anto, to supervise the final installation of the water tanks and connections to the tanks.

Due to the unusual long rainy season, the drip irrigation kits and sprinkler systems were not installed either in September 2014. The SoPAS engineer laid out an example of the system and explained it to the local project manager in India (Mr. Tharun Anto), who was contracted by SoPAS to finalise the installation of the drip irrigation kits and sprinkler systems based on the instructions. Mr. Tharun Anto was also contracted to transfer the data (on the amount of water pump with the “sunlight pump”) to the drop-box, and to supervise the finalisation of the physical protection for the “sunlight pumps” and solar panels. The plan was to have all six units fully installed, commissioned, finalised and transferred to the involved female farmers of the Kudumbashree association within two weeks. In the meantime, SoPAS was also going to send a differential pressure valve for the sprinkler kits to Kudumbashree at its own costs.

Because of unusual heavy rainfall in Kerala up to December 2014, finalisation of the infrastructure installation (water tanks, drip irrigation kits / sprinkler systems) could, however, only be achieved in late December 2014. Following the installation, all “sunlight pumps” and water tanks installed with Kudumbashree female farmers were in use. The drip irrigation kits and sprinkler systems were, however, not used as the female farmers were not convinced that the amount of water supplied is sufficient. When Dr. Urs Heierli (SoPAS) visited Kerala in February 2015, the drip irrigation kits and sprinkler systems were still installed but were still not used. When Karin Imoberdorf (SoPAS) visited Kudumbashree in April 2015, all drip irrigation kits and sprinkler systems had been removed by the female farmers.

4.2 Achievement of Objectives and Results

4.2.1 Objective (i): To enhance productivity in the dry season

Although Kudumbashree was keen to promoting especially drip irrigation for vegetable cultivation, no vegetables were finally planted by the female farmers selected for testing the “sunlight pump”. The underlying reason (information given by Kudumbashree in April 2014) was that the price of the vegetables had dropped and hence banana and pineapple were cultivated because market sale was expected to be more promising. Whereas vegetable has a growth cycle of 3 months, banana and pineapple have a cycle of about 12-18 months. Given this sudden shift in cultivation, objective (i) could not be achieved as no full growth cycle for banana and pineapple could be completed.

4.2.2 Objective (ii):
To raise awareness for sustainable energy solutions in India through education

The **"sunlight pump"** was a new technology (solar technology) to all farmers involved in the field testing in this pilot project. The beneficiaries of the "sunlight pump" like the technology because of (a) the inexhaustible, cost free energy of the sun allows them to become independent of the electricity grid or expensive diesel and because (b) the sunlight pump is a very compact and portable system. Hence, there was overall a high level of acceptance for the pump.

The "sunlight pump" installed at ACTS Rayasandra Campus near Bangalore in June 2012 aimed at on-site training and education of students, teachers, local village women and girls on the Campus. Supported by BFH, ACTS also started a course on sustainability in which they trained more than 100 students in pump operations and demonstrated the pump to a couple of foreign visitors. ACTS has hence been very good at bringing the educational aspects to this pilot project.

Synthite, who purchased five "sunlight pumps", published an article in their company magazine about the pump installations in June 2012, to disseminate their engagement in solar low-cost technology for irrigation. The Synthite CEO said the article was well received by his company professionals. In addition, the Synthite farmers involved in this pilot project later demonstrated the pump to their neighbours and relatives or even leased them the "sunlight pump".

The female farmers of the Mulanthuruthy association have learned how to operate the "sunlight pump" since December 2012. In order to create awareness about the "sunlight pump", sustainability and low-cost sustainable technologies, the local Panchayat and the Agriculture Office conducted an event to introduce and demonstrate pump operations to other female farmers in the association.

The female farmers of the Kudumbashree association were very motivated and interested and also proud they got the chance to test the "sunlight pump", and demonstrated considerable confidence and skills in handling the "sunlight pump" and associated water tanks. Following the installation, all "sunlight pumps" were operated by the female farmers who, in general, seem to have understood how to use the pump after some initial insecurities regarding the pump handling. For example, one female farmer reported that the pump was not running. When the SoPAS engineer checked, the pump was set on "battery mode". The difference between battery mode and solar panel mode was explained again, and it was demonstrated how to switch between the two modes.

The local manufacturer in India (Amro Technology Pvt. Ltd. in Bangalore) has learned a lot from this pilot project, especially from their field visit. One of the Amro electricians participated in the field visit in April 2015 to fix some of the technical problems that had appeared on a pump installation with the female farmers of the Kudumbashree organisation. The Amro electrician not only demonstrated a very good understanding of the technology and technical skills, but was also thrilled to finally see the product in operations that Amro had been working on for many months.

The local project manager in India (Mr. Tharun Anto, Thitali Low Carbon Solutions Pvt. Ltd. in Kochi), was instructed in pump installation in project phase I (ACTS Rayasandra Campus Bangalore, Synthite farmers) and was then capable of installing the "sunlight pump" with the female farmers at Mulanthuruthy on his own. He was efficient in raising awareness of solar energy technology in general and the "sunlight pump" in particular, and especially among the target groups in this pilot project (female farmers).

While the **water tanks** were considered useful (the technology has been known to some of the female farmers at Kudumbashree before) and are in operation at all installation sites at the Kudumbashree association, the **drip irrigation kits and sprinkler systems** were new to the female farmers and haven't been used so far. At this moment, the female farmers at Kudumbashree are not convinced that irrigation kits and sprinkler systems provide a sufficient water supply for their crops.

4.2.3 Objective (iii):
To promote and bring new perspectives to female small-scale farmers in rural India

The land leased to female farmers by Kudumbashree is, similarly to Burgdorf (Switzerland), characterised by an extended canal system. The largest canals are filled with water most of the time, while the smaller canals are flooded ca. 1-2x a week. In these smaller canals, the irrigation water then either floods the fields or needs to be brought to the fields by hand, as electricity grid to drive electric pumps is not fully reliable (or only available overnight), and renting electric pumps / running diesel pumps may be too costly.

Compared to a powerful diesel pump or the electric pumps that are predominant in Kerala, the “sunlight pump” has a small discharge rate per hour. The “sunlight pump” can, therefore, not be a one-to-one replacement of conventional, existing irrigation technology like a diesel or an electric pump. Yet, while these over-dimensioned diesel or electric pumps are only used for about half an hour a day, the “sunlight pump” runs throughout the day and pumps considerable amounts of water - sufficient to cover the needs of smallholder farmers (the currently available “sunlight pump” models have maximum capacities of 10, 15 and 30 m^3/day). This, however, implies that the water has to be used as productively and efficiently as possible.

Hand-irrigation requires additional staff to be employed and, in addition, can cause considerable safety issues for the female farmer. One of the female farmers’ group of the Kudumbashree association involved in this pilot project spent two days on irrigating the whole field (of approximately 1.2 ha) and paid four people 400 Rp each per day for this work (which cost the group a total of 3’200 Rp per week). Additional money is spent for renting the equipment (pumps and hoses) [19]. With sprinkler systems, a need identified by the Kudumbashree association to irrigate their pineapple plants, irrigation was estimated 1x/week by the female farmers. Sprinkler systems are also an added value as they are automatic and beneficial in terms of safety. Nevertheless, the installed sprinkler systems were not used, rather the female farmers reported that the outlets were not sufficiently high.

4.2.4 Objective (iv):
Evaluation of a possible distribution channel for the “sunlight pump” in rural India

As Kudumbashree generally supports the introduction of innovative technologies and encourages the entrepreneurial spirit of their members, the potential for the female farmer groups to become the service providers (repair and maintenance) for the “sunlight pump” in Kerala has been discussed. Even more so, as - according to the Kudumbashree management (Mrs. Thomas) - the Joint Liability Groups of Kudumbashree already execute similar activities with other technologies such as power tillers. In view of moving towards this avenue, a “trouble-shooting” system was established jointly with Kudumbashree during the field tests as follows:

- Amro provided a 12 month warranty on all defects in material and workmanship of the “sunlight pumps”, starting from the date of installation. If a pump was damaged because of improper use, the repair or replacement costs were supposed to be covered by this pilot project;

- In order to minimise the risk of damage on crops for Kudumbashree because of failure of one of the “sunlight pumps”, four out of ten pumps were stored at the District Office (Panchayat Office Vengola; https://en.wikipedia.org/wiki/Vengola). These spare “sunlight pumps” served as immediate replacement pumps to avoid any damage on the crops, or to replace faulty parts of the „sunlight pump”, either by the female farmers themselves or aided by the local project manager;

- If the problem could not be solved locally, the faulty pump was supposed to be sent back to the manufacturer in Bangalore, replaced and brought back to Kudumbashree. In this case, the transport costs were to be covered by this pilot project.

During the field test with the female farmers at Kudumbashree, there were only a few problems with the “sunlight pump” (related to the electronics, e.g., short circuits in the electronics, water entering through a sticker that came loose). The problems were fixed on-site in a concerted effort between Kudumbashree, Amro, BFH and SoPAS.

Currently, the Kudumbashree association has no clear vision on how a specific distribution network for the “sunlight pump” could be set up. There is some vague understanding of Kudumbashree that the organisation could become the distributor for the “sunlight pump” with some female farmers acting as solar pump experts who can also guarantee the repair and maintenance of the systems.

4.2.5 Objective (v):
Evaluation of a business model for the market introduction of the "sunlight pump" with the female farmers' association at Kudumbashree, Kerala, India

Data on a possible business model for the market introduction of the "sunlight pumps" by the female farmers of the Kudumbashree association were collected. One of the lead farmers of Kudumbashree suggested a rental-purchase scheme but no clear ideas and indications do exist on figures and how such a scheme could work. Fact is that Kudumbashree offers its members access to favourable loans. Hence, based on all information gathered in Kerala and collected from the female farmers of the Kudumbashree association, a rough calculation on a potential financing scheme was established (see Options 1-4 below and [20]). The results show that the monthly fee in Options 3 and 4 comes very close to the Rs. 1'000 / month that are currently paid for electricity by the female farmers of Kudumbashree. The calculations don't, however, include any retail/service margin for the Joint Liability Groups, which will service and rent the pumps.

Option 1: Kudumbashree buys the "sunlight pump" from the Indian distributor (pump and panel only):

Investment cost for pump an panel only	Rs. 85'000
Down payment by the user	Rs. 10'000
Loan amount @ 3 % (with subsidised interest rate)	Rs. 75'000
Amortisation in 4 years:	
Loan amount	Rs. 75'000
Interest (Rs. 2'250 per year)	Rs. 9'000
Total amount to be paid in 48 months	Rs. 84'000
Monthly rental purchase fee (48 months)	**Rs. 1'750**

Option 2: Kudumbashree buys the "sunlight pumps" from the Indian distributor (including drip kit):

Investment cost for a complete system including drip kit	Rs. 100'000
Down payment by the user	Rs. 10'000
Loan amount @ 3 % (with subsidised interest rate)	Rs. 90'000
Amortisation in 4 years:	
Loan amount	Rs. 90'000
Interest (Rs. 2'700 per year)	Rs. 10'800
Total amount to be paid in 48 months	Rs. 100'800
Monthly rental purchase fee (48 months)	**Rs. 2'100**

Option 3: Kudumbashree becomes the distributor of the "sunlight pump" in the region (pump and panel only):

Investment cost for pump and panel only (wholesale price)	Rs. 50'000
Down payment by the user	Rs. 10'000
Loan amount @ 3 % (with subsidised interest rate)	Rs. 40'000
Amortisation in 4 years:	
Loan amount	Rs. 40'000
Interest (Rs. 1'200 per year)	Rs. 4'800
Total amount to be paid in 48 months	Rs. 48'800
Monthly rental purchase fee (48 months)	**Rs. 1'016**

Option 4: Kudumbashree becomes the distributor of the “sunlight pump” in the region (complete system):

Investment cost for a complete system including drip kit (wholesale price)	Rs. 63’000
Down payment by the user	Rs. 10’000
Loan amount @ 3 % (with subsidised interest rate)	Rs. 53’000
Amortisation in 4 years:	
Loan amount	Rs. 53’000
Interest (Rs. 1’590 per year)	Rs. 6’360
Total amount to be paid in 48 months	Rs. 59’360
Monthly rental purchase fee (48 months)	**Rs. 1’236**

4.3 Multiplication / Replication Preparation

4.3.1 The private sector in India

Initial multiplication avenues were explored with the Synthite group in project phase I. Synthite purchased each sunlight pump for $300 in 2012 (this was then about the price of a competitor product, e.g., Chinese pump, on the local market in India) and asked $150 from their farmers, hence subsidized each pump with $150. The $1500 from the pump sales to Synthite served as “own funding” for the local project manager in India, Mr. Tharun Anto (Thitali Low Carbon Solutions Pvt. Ltd.).

4.3.2 The government sector in India

In February 2015, a meeting was scheduled between Dr. Urs Heierli (SoPAS), Daniel Ziegerer (Head of Cooperation) and Anand Shukla (Senior Thematic Advisor Energy) at SDC in Delhi, India, to present the “sunlight pump” pilot project in Kudumbashree, Kerala [21]. While SDC has currently no specific activities in the field of solar pumps, they were very interested to hear more about this project and to establish contacts with their colleagues from GIZ which have a solar pump project in the state of Bihar under the Indo-German Energy Program (IGEN). During a follow-up visit in Delhi in April 2015, Karin Imoberdorf (SoPAS) met with Anand Shukla again to attend a meeting at GIZ and discuss the potential of solar pumps in India in general and of the “sunlight pump” in particular. Both, SDC and GIZ expressed their interest in supporting SoPAS in introducing the “sunlight pump” in India.

4.3.3 The urban market in India

There is an increasing trend towards urban farming in Kochi, and hence a big potential for the “sunlight pump” in the urban context in Kerala. One of the female famers of the Kudumbashree association is very active selling seedlings to urban farmers in Kochi. While she herself does not own a garden she has good links with a demonstration farm nearby that is frequently visited by urban farmers from Kochi. One of the spare “sunlight pumps” stored at the Kudumbashree office is likely installed at this demo farm (together with a drip irrigation kit) in the near future. In this way, the many visitors to the farm can be demonstrated the operations of both the “sunlight pump” and the drip irrigation kits in view of multiplication.

4.4 Impact / Sustainability

After having received training on the installation and operations of the “sunlight pump” by Swiss engineers, the female farmers involved in this pilot project have proven that they are able to translate what they have learned into practice. Examples are the female farmers of the Kudumbashree association (a) moving the “sunlight pump” from one plot to another for irrigation or (b) moving the “sunlight pump” to their house and thus using it to generate a continuous domestic water supply.

As for the local manufacturer (Amro) in Bangalore, he already made several changes to the production process based on the feed-back received from the main implementation partner "Kudumbashree" in Kerala.

The local project manager in India, Mr. Tharun Anto, coordinated the pilot project among various agencies like educational institutions (BFH, ACTS), private companies (AMRO, Synthite), local agricultural cooperatives (Mulanthuruthy, Kudumbashree) and their female farmers, and local self-governments (Panchayats). He decoded both the technology and the Swiss engineering language on behalf of the Indian farmers, and was able to create awareness and develop a sustainable excitement among the Indian target groups to use the deployed irrigation technology. Due to the constant monitoring process and the careful, stepwise implementation of this pilot project by BFH, Mr. Tharun Anto has been able to deal with all practical hassles, to acquire the technical knowhow of installation and replacement of the "sunlight pump", which resulted in an enhanced practical knowledge about the dynamics of the logistics and eventually led to the success of this pilot project.

Awareness was raised among the implementation partner as described in Section 4.2.

5 Outlook / Further Actions

5.1 Multiplication / Replication

Today, Kochi considerably depends on the import of vegetables from the Tamil Nadu state. Concerns over quality issues have been raised due to missing declarations on pesticides and fertilizers in this imported vegetable (pers. comm. Dr. Urs Heierli, SoPAS, 12.6.2015). This may (partly) explain the explosive rise in urban farming activities in Kochi. One of the Kudumbashree female farmers has started her own urban farming business selling seedlings to urban farmers. She also collaborates with a demonstration farm on which the "sunlight pump" and drip irrigation kits will be installed in the near future to demonstrate the installations to the frequent visitors from Kochi. Discussions with Kudumbashree have been pointed into this direction and the organization is currently in the process of decision-making.

With regard to drip irrigation kits and sprinkler systems, the female farmers of the Kudumbashree association still need to be convinced (by demonstration) that these technologies save water and have other benefits like a reduced need for fertilizers and pesticides and an increased productivity. Also, it will have to be evaluated, jointly with the female farmers in Kudumbashree, why pineapple plants need to be irrigated from the top or whether this (traditional) mode of irrigation perhaps leads to increased evaporation losses. Other potentially ineffective irrigation practices (e.g., watering of the brown (dead) banana leaves) identified in this pilot project during awareness-raising events with the female farmers of Kudumbashree also will have to be addressed.

Reflecting on these traditional irrigation practices takes a considerable amount of time and is a longer-term awareness raising effort beyond the scope of this pilot project. Information on, e.g., water needs of different crops should ideally be provided by an expert and person that the female farmers trust (for example an agronomist collaborating with a master farmer of Kudumbashree). The female farmers also would need additional support in installing the drip irrigation kits and sprinkler systems by a trained (local) engineer who ensures that this technology functions properly before the female farmers use it.

SoPAS currently has on-going projects in several developing countries with the goal to not only to make the technology available at the local market. But SoPAS also aims at offering extensive after sales services through collaborations with local distribution partners. Apart from getting access to the new technology ("sunlight pump"), interested farmers (even in remote areas) need to get advice on how to design and install irrigations systems (including water tanks, drip irrigation kits / sprinkler systems) and need to be able to contact a local technical person in case they need maintenance and repair services.

5.2 Impact / Sustainability

Thanks to this pilot project directed by BFH (PD Dr. Eva Schuepbach), the "sunlight pump" was promoted in India for the first time. In the future, the "sunlight pump" will also be implemented in countries like Bangladesh, Kenya, Burkina Faso and Honduras, where SoPAS aims to give potential end users and distribution partners a better idea of the technology ("people only believe it when they see it").

The “sunlight pump” will be commercialised by ennos gmbh who is convinced that, after several years of extensive field testing, research and development activities, the avenues are now prepared for the “sunlight pump” to be ready for mass production and mass marketing. ennos gmbh will hence steadily scale-up the production and the marketing of the “sunlight pump” in the years to come.
Implementation in India initially concentrates on states in the north where ennos gmbh will build a project in Bihar starting in September 2015. With regard to distribution, ennos gmbh is able to build on a contact network in India and has, e.g., established good contacts with a distribution network for solar equipment that can guarantee support services and access to micro-credits, and has a roll-out strategy for 50 districts. Building on the experiences from this pilot project, ennos gmbh will - together with NGOs, private sector companies, micro-finance institutions and distribution partners - build up a sustainable supply chain, including extensive before and after sales services and financing options for the end users in India.

6 Conclusions / Lessons Learned / Recommendations

6.1. Conclusions

<u>Objective (i):</u> To enhance productivity in the dry season. Originally, the female farmers of the Kudumbashree association involved in this pilot project indicated that they were going to grow vegetables, an ideal short-term (3-month cycle) and high value crop in the context of field-testing the “sunlight pump” and associated evaluation of a potential business model. However, later in the collaboration process, the plantation of banana and pineapple crops with a 12 and 18 month cycle, respectively, was preferred by the Kudumbashree organisation (due to higher market prices). Hence, no full crop cycle could be completed in the frame of this pilot project. Measuring a full cycle would, however, also have been hindered by the long unusual rainy period in late 2014. The irrigation practices adopted by the female farmers of Kudumbashree are still the same, only the way the water is pumped today has changed (using solar energy to drive the “sunlight pump”). This has, however, no influence on the productivity or will not reduce the amount of fertilizers/pesticides (as might be expected when adopting drip irrigation practices).

<u>Objective (ii):</u> To raise awareness for sustainable energy solutions in India through education. Through the joint efforts of the local collaboration and implementation partners (ACTS Rayasandra Campus, Synthite, local project manager (Thitali Low Carbon Solutions Pvt. Ltd., Kochi), local manufacturer (Amro Technologies Pvt. Ltd., Bangalore), and the female farmers’ associations of Mulanthuruthy and Kudumbashree) and the project leaders at BFH in Switzerland with its collaboration partner SoPAS.

<u>Objective (iii):</u> To promote and bring new perspectives to female small-scale farmers in rural India. For now, it is impossible to quantify such perspectives for the female farmers at Kudumbashree. The reason is that they themselves have no good understanding of their own economics yet. Also, they currently do not see yet the full benefits of the extended irrigation system with the drip irrigation kits and sprinkler systems, as these haven’t been operated.

<u>Objective (iv):</u> Evaluation of a possible distribution channel for the “sunlight pump” in rural India. This pilot project suggests that there may be a business case for Kudumbashree acting as a distributor, both for the “sunlight pump” / solar panels and for the extended irrigation infrastructure (drip irrigation kits / sprinkler systems). While the organisation itself has no clear vision on how this could be set up today, its female farmers involved in the field tests clearly gained expertise in operating and maintaining the “sunlight pump” and may successfully move along the avenue of becoming solar water pump experts in the future.

<u>Objective (v):</u> Evaluation of a business model for the market introduction of the “sunlight pump” with the female farmers’ association at Kudumbashree, Kerala. Whether or not the business model established in this pilot project is a real option and acceptable for Kudumbashree needs to be decided by the organisation itself. Governing factors will certainly include the figures obtained from the completed full crop cycle as well as the retail and service margins for the Joint Liability Group, which will service and rent the pumps in the Kudumbashree association.

6.2 Lessons Learned / Recommendations

6.2.1 Implementation Partner

Kudumbashree is a highly interesting partner as the organization is very well structured and is very big (more than 4 million members). In the limited timeframe of this pilot project (one dry season), some of their female farmers had a chance to get familiar with the “sunlight pump” and associated water tanks and see the benefits. They have, however, not accepted the drip irrigation kits and sprinkler systems yet. For these modern irrigation technologies, the female farmers clearly need more information to develop trust. Ideally, this information could be provided by a master farmer from Kudumbashree. Also, in order for Kudumbashree to be able to make full use of the advantages of deployed modern (renewable) irrigation technology and to become a model for other farmers, a solid local support structure to provide technical assistance in operating, servicing and repairing is needed.

It is hence recommended to let the female farmers of the Kudumbashree association install and use the irrigation system again during the next dry seasons so that they can gain more experience and Kudumbashree as an organization gets a better understanding of the technologies. SoPAS will then follow-up with the Kudumbashree management to see what support they can provide to their female farmers in the long-term (e.g. support by technical person, agronomist etc.) and to ensure that the “sunlight pumps” and the drip irrigation kits and sprinkler systems are to the full benefit of the farmers.

The lessons learned are that new perspectives for female farmers in associations like Kudumbashree include both the use of (new) solar energy technology (i.e., the “sunlight pump”) and the efficient use of water in irrigation.

6.2.2 Installations

Sunlight pump. All farmers involved in this pilot project were instructed to build some sort of permanent structure from locally available material (bamboo, wood, bricks etc.) to attach the pump and protect it from rain and stealing. Most farmers, however, insufficiently protected the pumps against the heavy rain (which is common in Kerala). As with the female farmers of the Mulanthuruthy agriculture cooperative, a stable shed was financed and constructed by the husbands of the female farmers to protect the “sunlight pump” (and to mount the solar panels). This was perceived as too expensive by the local farmers, however, and the construction of such a shed was included in the project costs in project phase II. As with the female farmers of the Kudumbashree association, one farmer covered the “sunlight pump” with a plastic bag, while another farmer protected the pump with a corrugated metal sheet, which increases the heat of the system and may damage the electronics. In this case, SoPAS recommended to put a piece of wood or bamboo between the pump and the metal sheet to increase the air circulation and to cool the system.

Solar panels. With the female farmers of the Kudumbashree association, the solar panels were fixed on a stable wooden structure at only one installation site but leaned against the well or some other structure at all other sites. This is not an ideal situation because the panels can easily be damaged by strong winds (which is not unusual in this region) or easily be stolen. It is thus recommended to fix the solar panels on a stable, permanent wooden or metal structure or on the roof of the house.

Water tanks. The female farmers of the Kudumbashree association were understandably reluctant to mount large water tanks on the roof of their houses because they fear this could cause damage to the structure. It is recommended to consult with a structural engineer before any such installations in the future.

Drip irrigation kits/sprinkler systems. The sprinkler irrigation kits were supplied to the female farmers of the Kudumbashree association because they informed the project that pineapples have to be irrigated from the top. The feed-back received after the installation was, however, that the sprinklers are not high enough. When evaluating the farmers’ needs in the future, information should be offered to the farmers on trustworthy and likely more productive and water saving irrigation practices. In the case of this pilot project, Kudumbashree could have provided this information to the participating female farmers directly, or could have engaged an agronomist (paid by the project) to carry out an awareness workshop on irrigation practices with the female farmers. In this way, it might perhaps have been possible to incentivize the female farmers to transition to a more productive and water saving irrigation practice on parts of their fields during this pilot test.

Shed / Infrastructure. Farmers without an already existing pump house or a shed to safely store the pump and solar panels installed on the roof top are not motivated to create a new infrastructure as this is too costly for them.

6.2.3 Economics

The female farmers involved in this pilot project can take advantage of a relatively high grid-connectivity in Kerala, in addition to subsidised electricity and hence, there is stiff competition for the “sunlight pump” from electric pumps in this state. Nevertheless, female farmers’ associations (Mulanthuruthy, Kudumbashree) in Kerala were selected for field testing in this pilot project because they operate in the back-country of Kochi (Kerala) where the local project manager is located. This considerably reduced the installation, monitoring and data collection costs and also facilitated the interaction with the local manufacturer in Bangalore (Karnataka) in view of setting up a full service line for the “sunlight pump”.

If a leasing-rental system were applied in Kudumbashree for the “sunlight pump”, it would cost Rs 1’200 per month as compared to the fee for monthly grid electricity of Rs 1’000 (see Section 4.2). This fee of Rs 1’200 per month would have to be paid during the months when the “sunlight pump” is used for irrigation (4 months in the case of Kerala), but also in the other months when no irrigation is needed. By operating the “sunlight pump”, the female farmers can potentially save the cost for electrical pump rent. Additional savings can be achieved when the system including the “sunlight pump”, solar panels and water tanks is also used in the context of domestic water supply as successfully demonstrated by the female farmers of Kudumbashree in this pilot project. Another interesting aspect is that the “sunlight pump” could be supplemented with a battery to store the energy that is not needed for pumping during the day. This extra energy stored in the battery could then be used to extend the pumping hours (for example during the peak dry season when a lot of water is needed) or to even power other appliances (e.g. light or cell phone charging).

Kudumbashree has created a local market where the female farmers can sell their products. The product is collected by the local Kudumbashree officers and sold at the local markets (e.g., the city of Kochi). The organic fruit and vegetables produced by the Kudumbashree female farmers are in high demand. By taking out the intermediary agent, Kudumbashree can offer the products below the usual market price, which even increases the demand. Given the high demand in Kochi for high-quality, organic vegetables, it is expected that there is an increasing potential and need to cultivate additional vegetables at Kudumbashree fields in the future, which may convince Kudumbashree to pursue the “sunlight pump” avenue. What may also be very attractive in the cultural perception of the female farmers in Kudumbashree is the fact that the sun provides electricity free of cost once the system is paid off.

The financial model established in this pilot project for Kudumbashree (Section 4.2) might be different for other states as irrigation durations are comparatively short in the Kerala state where the “sunlight pumps” were field tested. Table 1 shows that supplemental irrigation for banana and pineapple is only needed during 4 months (from December to March) in Kerala. When comparing the precipitation chart for Kochi (Kerala) with other states in India [22], it becomes evident that some regions in India, e.g., Rajasthan (10 months) or Bihar (8 months), need supplemental irrigation over a much longer period than four months (Kochi, Kerala).

Table 1: Precipitation and water needs for banana and pineapple in Kochi, Kerala
(Data resulting from the FAO water tool CROPWAT run by Simon Spöhel, BFH-HAFL).

		Water needs mm	
Month	Precipitation	Banana	Pineapple
March 2014	22	95	60
April 2014	61	95	60
May 2014	314	95	60
June 2014	425	95	60
July 2014	538	95	60
August 2014	878	95	60
September 2014	260	95	60
October 2014	424	95	60
November 2014	123	95	60
December 2014	28	95	60
January 2015	0	95	60
February 2015	3	95	60

6.2.4 Final Remarks

On the Indian subcontinent - an emerging economy with over 1.271 billion people (2015), the second most populous country in the world and more than a sixth of the world's population [23], 70% of the population live in rural areas [24]. Agriculture is one of the pillars of the Indian economy and the largest livelihood provider in India, as most village people earn their living either through agriculture or handicrafts [25]. Affordable water availability and control for crop production is critical for the development of rural India, even more so as supporting all family members through agriculture has become increasingly difficult and people move to towns and cities in search of jobs [26]. Hence, there is undeniably a huge potential and under-served demand for solar water pumps in India - especially for systems like the "sunlight pump", as around 300 million people in India lack access to electricity, almost the size of the entire population of the United States.

Mr. Tarun Kapoor, the Joint Secretary of India's Ministry of New and Renewable Energy, goes as far as saying that [27], "Irrigation pumps may be the single largest application for solar in the country." It is hoped that this pilot project, conducted by BFH in Switzerland and directed by PD Dr. Eva Schuepbach and Mr. Tharun Anto, may help paving the way towards women empowerment in modern solar irrigation technology among female farmers in Kerala, India.

6.2.5 Communication / Presentation of the Results

The results of this pilot project were disseminated to the international scientific community at the 29th EU PVSEC 2014 in Amsterdam, The Netherlands [15]. In Switzerland, the pilot project was presented in 2011, 2012 and 2013 (see [7], [8], [5]) in hitech, the newsletter of the Department of Engineering and Information Technology at BFH, and in an online article following the REPIC event in 2013 on: "REPIC: Erfolgsfaktoren für Projekte in Entwicklungsländern", see:

http://www.ee-news.ch/de/article/27266/repic-erfolgsfaktoren-fuer-wirkungsvolle-projekte-in-entwicklungslaendern

Debriefing and exchange with Kobü/ the Swiss Embassy in Delhi, India is documented in [14] and [21].

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Sunlight pumps in Kerala: matching solar and women power

Notes on visit to Kudumbashri in Cochin / Kerala

by Urs Heierli

with Tharun Anto and Mathew Antony,

February 9 to 11, 2015

M S + D
Urs Heierli, Ph.D.
Muehlenmattstrasse 45
CH-3007 Bern
Switzerland

T +41 031 372 68 30
F +41 031 372 68 32
E urs.heierli@msdconsult.ch
www.msdconsult.ch
www.poverty.ch

Present Situation

In February 2015, the actual situation presents itself in a summary as follows:

1. **Overall result**: Five of six pumps are used and, overall, people like them a lot and act with enthusiasm. This is a promising result and a good achievement for a first phase, despite the fact that Kerala and especially the Cochin area may not be an optimal area for the introduction of solar pumps (see last chapter).
2. **Kudumbashri women**: are organized in JLGs, Joint Liability Groups, and 4 of the pumps are installed with the group of Achamma Alias, a very dynamic lady who is also officially trained as a master farmer by Kudumbashri. One more pump is installed with Mrs. Alley Jos, the present Group Coordinator of Kudumbashri Panchayat office in Vengala. The former Group Coordinator, Mrs. Shiji Anil was not re-elected. One lady, Shanta Thamphan, has not installed nor used the system, mainly because she wanted to have sprinkler irrigation systems, but there was no place to put the tank at the appropriate level (6 to 10 m elevation).
3. **Technical issues**: The operational downtime of the pumps is still unacceptably high and 4 of the 10 pumps are under repair. This has to do that these pumps still have the first series of electronics and this flaw will soon be corrected.
   When people see the pumps running, they are interested to also get one.
4. **Irrigation systems**: However, the second element of the watering system, drip and sprinkler irrigation is not yet implemented. Although the drip systems are installed, the women are not familiar with its use and think the water that comes out of the drippers is not enough. They are used to irrigate their plantations – banana and pineapple – with hoses and using a more powerful pump (3 hp or 5 hp) connected to the electric grid. They are interested in drip, but the introduction of drip is a significant behaviour change process and needs a lot of understanding and special efforts to make the water flows visible. I have recommended them to put a glass of water under the dripper and see with their own eyes how much water has come out after one hour. We will also provide them with precise instructions how much water they need to give.
5. **Irrigation knowledge**: It seems that the women have no idea how much water their plants need and also have probably wrong perceptions – e.g. that the dead banana leafs also need to be washed and that pineapple irrigation needs to be done from above, pouring water onto the fruits. They follow just some traditions, but without a scientific base. To change this, they would need some proper advice and conviction. Also, as their crops are at risk, they will not be innovative, before they are really sure.
6. **The sprinkler systems:** are not yet installed as it is quite challenging to find a good solution to get the required pressure. The families who offered that the tank could be installed on top of their house, withdrew their offer, when they saw that the tank was 5'000 litres. This means to find a way to increase the pressure with the use of a differential pressure valve. This is yet to be done, but there are two such valves available in the project and Tharun Anto will install them now, as he has got the full instructions.

Agricultural economics:

1. **Agriculture in Kerala:** is in a peculiar situation. Wages are high and for many people, there are other opportunities to earn their living than agriculture (migration to the Middle East or other States in India). For this reason, those left behind – the typical Kudumbashri members – do agriculture for lack of opportunities and they usually rent the land. Often, these land plots are spread out in very different locations. As wages are high, daily labourers would get 500 Rs. per day and the JLGs are only viable because they do not count their labour cost as costs but as income. A JLG group with 4 members would have to earn 4x500x30x12 Rs per year or Rs. 700'000 as opportunity income, but as this income is not available in cash, they do farming even

if revenues are lower. It is estimated that the 4 members of Achammas JLG make – altogether - around Rs. 400’000 per year only. However, to find out the precise income, a lot of interviews would be required as they do not keep any records.

2. **Achamma**: Achamma has around 3 acres of banana, 4.8 acres of paddy and 4.2 acres of pineapple. The leases are usually short term, but Achamma got some 3 years leases for pineapple. For paddy, they use some mechanization for tilling.
   Growing banana seems to be the most profitable: yields are around 10 tons per acre or 30 tons from 3 acres. Prices are around 25 Rs per kg leading to a gross income of Rs. 750’000. But the cost of rent and other cost – without labour – are in the order of certainly Rs. 200’000, so probably still a good crop to grow.
   With pineapple, the situation looks quite bleak: yields are in the order of 6 to 12 tons per acre and prices have fallen to 10 Rs per kg. So, gross income may be in the order of 4x6000x10 = Rs. 240’000, or Rs 480’000 if yields are 12 tons. However, already the plants cost 6 Rs per plant per acre, or 4x18’000x6 = Rs. 400’000. With 4 lacs as input cost plus land rent of Rs. 50’000, it is likely that – at this low price – pineapple growing is hardly breaking even or is not profitable.
3. **Summary of agricultural economics**: it is absolutely impossible to calculate returns at a short term. Not only should we observe several cropping cycles, but the women will only slowly get into new crops – for example vegetables – and the first step is to introduce an innovation step-by-step. With the present crops, the JLG members can increase their harvests by:
   a) extending irrigation to new areas of rented land because the pump is portable,
   b) gaining time with drip and sprinklers – once they are adopting the new irrigation systems – and once the women realize it takes less time for them to irrigate with drip.
   c) There is a good potential for growing – especially organic – vegetables as there is a proven demand for such vegetables in the city of Kochi.

General Findings and conclusions:

At this stage we can summarize the following finding and draw provisional conclusions.

1. **Usefulness of the pump**: Members of the JLGs like the pumps (5 out of 6) because they provide a good service to them and because the pumps are portable. Electricity of the grid is cheap but not free and presently the opportunity cost would be around 1’000 Rs per month. Having the solar pumps gives them more flexibility because the women rent land from other owners. Although Kerala has quite a well functioning grid, there will be power cuts ahead, when the heat increases and more irrigation and air conditioning is used. Then the solar pumps will be even more appreciated.
2. **Solar pump and drip**: a solar pump makes no sense for flood irrigation. The water that can be pumped is too precious to be applied in huge quantities as with diesel or grid-electric pumps. This means that introducing solar pumps must come as a package of innovations including more efficient ways to irrigate.
3. **Adoption of innovative irrigation systems**: introducing drip and sprinkler irrigation systems is for most farmers a revolution and require a significant behaviour change compared to their traditional irrigation practices. The adoption of such systems require
   a) quite a lot of awareness,
   b) trust that the system deliver sufficient water – and for the women it is hard to believe that these few drops are sufficient – and
   c) a change of behaviour shifting away from traditional practices.
   Clearly, the women have not yet come to that stage and do not see the benefits of drip and sprinklers
4. **Kudumbashris views**: we had at the end of the short visit a discussion with Mrs. Tanie Thomas, the district coordinator for Kochi. Her staff hat briefed her that 5 of 6 pumps were used and she found this encouraging. Kudumbashri is a large organization with over 4 million members and is very keen to introduce new technologies and innovations, especially promoting drip and vegetable growing. They have a pilot program with 40 farmers (male) in Male and organize a field

visit for "master farmers" such as Mrs. Achamma, shortly. Mrs. Thomas could also imagine that women's groups will one day take over service operations for solar pumps. JLGs do already similar activities with other technologies such as power tillers.

5. **Interesting example in urban terrace gardening:** the discussion with Mrs. Thomas revealed an interesting example with a high potential for cooperation. Mrs. Bina, a former master farmer, has started an enterprise providing drip irrigated gardening packages for terrace gardens. She offers a package of 400 bags for a terrace with drip irrigation and seedlings, inputs and even help for marketing services for 50'000 Rs. and Kudumbashri is subsiding this package for the urban poor with 35 %. It seems that there is a huge demand, because people are mistrusting vegetables coming from Tamil Nadu (poisoned with pesticides). Indeed, we could visit a Government owned nursery selling all kinds of seedlings, and even on a simple Wednesday morning, the nursery was full of clients. We could not meet Mrs. Bina during my trip, because she was in the field, but Tharun Anto will meet her and provide a report on how she has setup her business. We may even consider to give her a solar pump as well to explore whether there is an application for urban gardening.

Marketing Sunlight pumps at the base of the pyramid.

It is obviously too early to draw a solid business model at this stage. We are at the very early introduction of a very significant innovation and moreover targeting a market at the base of the pyramid. This process will require significantly more time until a full-fledged business model can emerge, but the first experiences are still encouraging. If we apply the theoretical framework of Anderson and Billou, the so-called 4 As of marketing, we can say today more or less the following (reversing the order slightly):

1. **Acceptability:** The JLGs are in the process of accepting the solar pump and do still require some more awareness, knowledge and trust to accept the innovative drip and sprinkler irrigation systems. However, it is amazing that almost all the women have fully accepted the solar pump despite the availability of more powerful grid-electricity pump. This is a surprising fact because our initial assessment was that solar pumping can most likely not compete with grid electricity. However, the fact that these women are renting small plots of land – scattered and not uniformly – implies that they do not always have electric pumps available. The portability of the pump is therefore a big advantage. This advantage may be increased in the summer when power cuts are becoming more frequent. Mrs. Alley Jos has installed the pump close to her house and is also using the pump for filling their water tank on the roof. She appreciates the pump also for this reason, as she can use it not only for irrigation but also for having running water in her house. The fact that the pump has an automatic flow switch when the tank is full is another feature that makes the pump attractive.
2. **Awareness:** Introducing completely new ways of irrigation requires much more awareness than just a simple demonstration. We have to ensure that both the drip as also the sprinkler systems are properly installed and will function well. We also must provide the women with more data on the watering needs of each plant, the watering habits now and prove that the drip and sprinkler systems can give enough water. All this needs to be done without putting their crops at risk.
3. **Affordability:** Solar pumps are not cheap especially compared to electric pumps connected to the grid. There are also some subsidies for grid electricity and Mrs. Achamma pays now only some Rs 1'000 per month for electricity for pumping, and small electric pumps do cost only between Rs. 5'000 to 10'000. However, a grid connection is required on top of the pump, and a large pump (5hp) needs a pump house. It is obvious that against this stiff competition, it is challenging to find an attractive financing scheme.
   At the moment, it is not possible to discuss financing options because the women have themselves not a good understanding of their own economics. Mrs Achamma was herself proposing a rental-purchase scheme, but was not able to give any figures how such a scheme could work, especially as the full benefits – from drip and sprinklers – are yet to be experienced. However, Kudumbashri gives favourable loans at very low interest rates.

A first calculation would show the following:

<u>Option 1: PfP has its own distributor and Kudumbashri is client:</u>

a) Investment costs for an entire system (pump, panel, drip) Rs. 100’000
b) Downpayment of 10 % by the user Rs 10’000
c) Loan amount @ 3 % (with subsidized interest rate) Rs. 90’000

Amortization in 4 Years:

Loan amount		Rs. 90’000
Interest (Rs. 2700 per year)		Rs. 10’800
Total amount to be paid in 48 months	Rs. 100’800	
Monthly rental purchase fee (48 months)		Rs. 2’100

This is roughly double the amount that Mrs. Achamma pays for electricity, but if one takes the advantages in account (portability), this is not anymore so far from imagination.

<u>Option 2: Kudumbashri as distributor:</u>

a) investment cost for an entire system (wholesale price)		Rs 63’000
b) downpayment Rs. 10’000		Rs 10’000
c) loan amount	Rs. 53’000	
Amortization in 4 years:		
Loan amount		Rs. 53’000
Interest Rs. Rs 1590 per year		Rs. 6’000
Total amount to be paid in 48 months	Rs. 59’000	
Monthly rental purchase fee (48 months)		Rs. 1’230

This is now very close to the Rs. 1’000 for electricity, especially if some other advantages could also be exploited such as charging phones or a battery. What is also very attractive is the fact that the solar system provides electricity free of cost, once the system is paid: and this seems to be an attractive option in Kerala’s cultural perceptions.

4. **<u>Availability:</u>** it is obviously much too early to think of a distribution network, but one option could be that JLGs of Kudumbashri could become retailers and perform activities of installation, servicing and rental operators. In this case, a cost-effective and efficient distribution network could be established providing new opportunities to JLGs. This is not just a dream: if Mrs. Bina has managed – on her own – to setup an enterprise for urban terrace gardening services, it could well be that similar things could happen with the Sunlight Pump and with drip and sprinkler irrigation.

<u>Lessons for the future – selection criteria</u>

There are quite a few interesting experiences and lessons to be learned. These are summarized in the following points:

1. **<u>Site selection – irrigation needs</u>**:
   We have asked HAFL (School of Agricultural, Forest and Food Sciences in Zollikofen) for advice on the irrigation needs of pineapple and banana in the area of Cochin. Simon Spöhel made a run with the FAO water tool CROPWAT and came to the first conclusion that neither pineapple nor banana would need a lot of irrigation, only some supplemental irrigation. This was a forecast and I did an effective rainwater analysis for the past 12 months. This looks roughly as follows: as the table in Annex 1 shows, supplemental irrigation would only be needed for 5 months, from

December to March. The precipitation chart for Cochin confirms this (Annex 2), but in the case of Rajasthan (Annex 3), this period would be extended to more than 10 months per year.

2. **Irrigation period and costing**: the duration of irrigation reverts the economics considerably and what is considered to be an advantage – that a solar pump provides “free” electricity once it is paid – becomes a disadvantage: if a leasing-rental system is applied, then it would cost 1200 Rs per month even for the months when it is not used (whereas the grid electricity would only cost the 1000 Rs during the 4 months).
3. **Selection of farmers**: it would be better to select farmers that grow vegetables as a short term and high value crop rather than banana and pineapple with 12 or 18 months cycles. It would also be recommendable to choose farmers with previous experience of drip and / or sprinkler systems. They could then make use of the full advantages of modern solar powered irrigation.
4. **Technical support**: it would be necessary to make further tests with a more solid technical support structure being able to provide solid technical assistance in servicing the solar pumps and installation and use of drip and sprinkler irrigation.
5. **Off-grid sites**: It is surprising that the sunlight pump is perceived as an interesting option despite the competition of a more or less functioning grid supply as it is the case in Kerala. In areas without a functioning grid – no grid or long power cuts – it would be better to exploit additional benefits of solar power such as light, charging of phones, batteries, fans and TV.

Despite these factors, Kudumbashri is a very attractive and interested partner because the women members are really dynamic, motivated and promising partners. Also, as a potential agency for distribution, Kudumbashri has enormous potential.

In February 2015, Urs Heierli had the opportunity to meet with Daniel Ziegerer (Head of Cooperation) and Anand Shukla (Senior Thematic Advisor- Energy) from SDC in Delhi to present the solar pump project in Kerala. While SDC has no specific activities in the field of solar pumps for now, they were very interested to hear more about this project and to establish contacts with their colleagues from GIZ which have a solar pump project in the state of Bihar under the Indo-German Energy Program (IGEN).

Berne, 6th March 2015 Urs Heierli

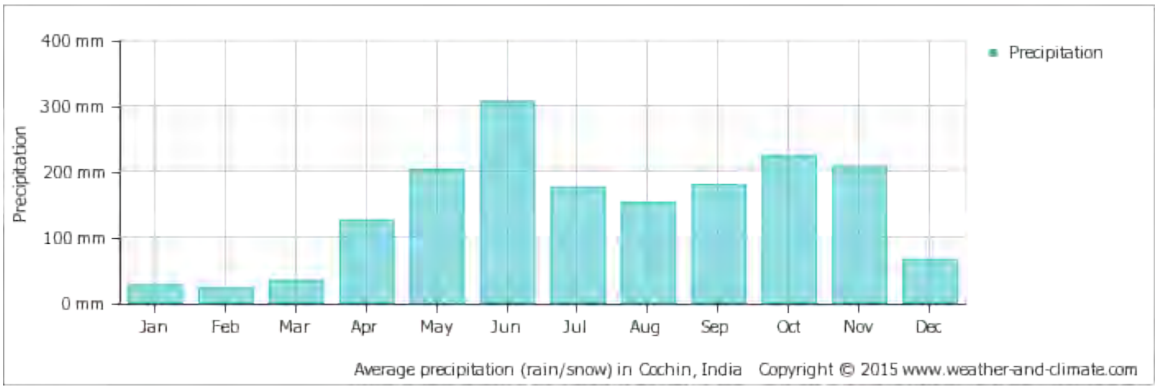
Annex: Statistics and Photos

Annex 1: Rain Cochin in mm

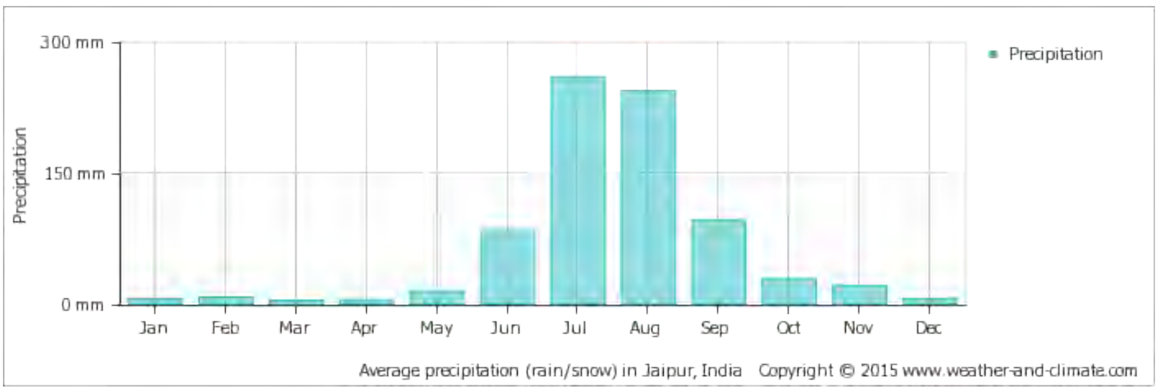
Month	Precipitation	Water needs Banana	Pineapple
March 2014	22	95	60
April 2014	61	95	60
May 2014	314	95	60
June 2014	425	95	60
July 2014	538	95	60
August 2014	878	95	60
September 2014	260	95	60
October 2014	424	95	60
November 2014	123	95	60
December 2014	28	95	60
January 2015	0	95	60
February 2015	3	95	60

Annex 2: precipitation in Cochin

This can also be seen in the following graph



Annex 3: Precipitation in Rajasthan



Mrs. Achamma, master farmer irrigation pineapple and banana

Struggling to understand drip irrigation (above)

Demonstration urban gardening with drip at Kudumbashri head office

<u>Selling saplings for urban gardening at Government nursery in Cochin</u>

INTRODUCING SOLAR WATER PUMPS TO FEMALE FARMERS IN INDIA

Eva Schuepbach[1], Urs Muntwyler[1], Andrea Vezzini[2], Alois Müller[2], Duglas Urena[1]
Bern University of Applied Sciences BFH, Engineering and Information Technology, Institute for Energy and Mobility
[1]Jlcoweg 1, CH-3400 Burgdorf, Switzerland / / Fax +41 344266813 / E-Mail:eva.schuepbach@bfh.ch
[2]Quellgasse 21, CH-2501 Biel, Switzerland

ABSTRACT: Today, over 20% of the global population lack access to electricity, most of them in rural areas. In such non-electrified and under-electrified regions, renewable energy and especially solar technology offer a particularly great potential. For the development of rural areas, the critical issue is affordable water availability for crop production. Small-scale farmers hence depend on rainwater and the wet season. In the dry season, crops can sell at a price up to three times higher if irrigation is possible. Harnessing solar energy for irrigation during the dry season can, therefore, open the door for additional sources of income. Aiming to meet these needs, Bern University of Applied Sciences (BFH) in Switzerland developed a small power (40W-120W) photovoltaic water pump ("SunLight Pump") that is now locally produced in Bangalore, India. As Indian women play a predominant role in earning a livelihood for their families, the pump was also tested with female farmers. Current deployment is with the female farmers' association in Kudumbashree; the association operates the Swiss "SunLight Pump" as part of an irrigation system with water tanks and micro sprinklers in view of validating a possible business model.
Keywords: Water-Pumping, Rural Electrification, Developing Countries, Dissemination, Education and Training

1 BACKGROUND

The United Nations declared 2012 as the «International Year of Sustainable Energy for All» [1]. To comply with this initiative, Bern University of Applied Sciences (BFH) in Switzerland aims at implementing small power (40W-120W) photovoltaic water pumps with female farmers in India [2].

The Indian subcontinent is an emerging economy with over 1.15 billion people of which about 700 million live in the countryside. Agriculture is one of the pillars of the Indian economy; affordable water availability and control for crop production is hence a critical issue for developing the rural areas.

Small-scale farmers mostly depend on rainwater and the wet season for crop production. In the dry season, crops can sell at a price up to three times higher than in the wet season, if irrigation is possible.

Fig. 1. Manually-operated pump (left) and treadle pump (right).

However, many small-scale farmers cannot afford irrigation. Also, large-scale irrigation systems often only cover certain regions but do not reach the fields of small-scale farmers.

In villages without electric power supply, manually-operated pumps and diesel pumps are vital for small-scale farmers (Fig. 1). While manually-operated and treadle pumps are extremely labour-intensive, diesel is expensive, and people in villages rapidly purchase electronic water pumps once they are connected to the electric grid. But grid electricity may go off after some hours while additional nine hours of irrigation would be needed for crop production. Harnessing solar energy to drive photovoltaic water pumps for irrigation and crop production can, therefore, open the door for additional sources of income during the dry season and thus contribute to rural development.

2 TO MAKE IT WORK, MAKE IT A BUSINESS

A photovoltaic water pump system was developed by Professor Dr. Andrea Vezzini at BFH in Biel, Switzerland [3]. The so-called "SunLight Pump" consists of a photovoltaic panel, an electronic controller including a maximum power point tracker and optimum water lift indicators, a highly efficient motor technology and a mechanical pump system (www.ti.bfh.ch).

The pump uses the same efficient electric motor as developed to win several world champion titles like the Australian World Solar challenge in 1990 ("Spirit of Biel/Bienne") and in the record breaking electric bike "Spirit of Bike" in 2001. A detailed description of the development history and technology of the pump can be found in [4].

The system was brought from prototype level to production stage by ennos gmbh, a spin-off at BFH in Switzerland. Manufacturing of the pump motor, mechanical components and electronics controller of the "SunLight Pump" (Fig. 2) is now by an ISO 9001-2008 certified solar module company in Bangalore, India. In this way, local technology and manufacturing capabilities are used and jobs are created in the region. After improvements on the prototype, an initial small series of 150 pumps were produced in India for field testing.

Fig. 2. Manufacturing by www.amrotechnology.com

3 FIELD-TESTING WITH FEMALE FARMERS

3.1 Introduction

Indian women play a predominant role in earning a livelihood for their families. Affordable solar water pump technology may hence offer new economic perspectives for female farmers and adolescent village girls. In the frame of a pilot project directed by PD Dr. Eva Schuepbach [5], some of the first (locally-produced) "SunLight Pump" systems were thus tested with a female farmer's association in southern India in 2012. The female farmers learned how to operate the pump during installation by a Swiss engineer (Fig. 3). In order to create awareness about low-cost sustainable technologies, other female farmers were demonstrated pump operations by the local Panchayat (elected body of the local self-government in rural India) and the Agricultural Office.

Fig. 3. Field tests with Mulanthuruthy female farmers' association, Kerala, India.

The feed-backs of the female farmers revealed that the "SunLight Pump" system is especially good for flexible use. As the system is mobile, it can be moved from one borehole to another, and can be taken home overnight to avoid stealing. The female farmers also positively reported on the pump requiring minimal attention as it is self-starting.

3.2 Technical Improvements and Laboratory Tests

The feed-backs of the end-users of all operational field tests were integrated into further technical pump development to better satisfy the farmer's needs. In view of "pay per litre" and microfinance options, the system was also upgraded with an infrared communication interface (www.ti.bfh.ch).

The extensive laboratory simulations (Fig. 4) on the "SunLight Pump" are now complemented with measurements in a new "test bench for solar water pumps". This test bench was established by Professor Urs Muntwyler at the Photovoltaic Laboratory at BFH in Burgdorf, Switzerland (Fig. 5), where the pumps are currently measured according to Swiss standard EN 62253 [6]. Of particular interest are the power as a function of flow rate at a constant pump height and the start-up power.

Following the field-testing, technical improvements, laboratory examinations and test bench measurements, field operations in 2014-15 will be nested within the three critical pillars "micro credit", "entrepreneurship" and "empowerment". In this context, a series of the "SunLight Pumps" are deployed with the female farmers' association in Kudumbashree. Kerala, southern India [5], see Fig. 6 and www.kudumbashree.org. Deployment is supported by msd consulting GmbH Switzerland.

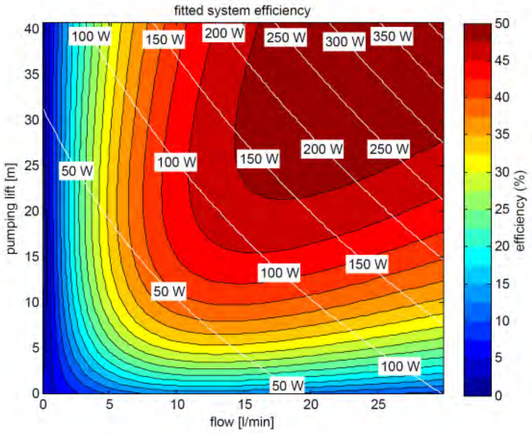


Fig. 4. System's efficiency of the "SunLight Pump" and links between pumping height, water flow rate and solar module power.

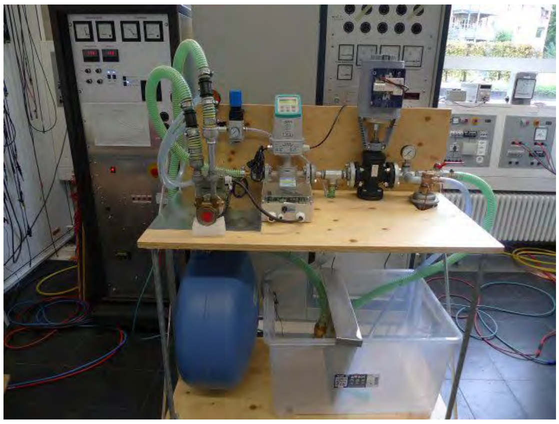


Fig. 5: Test bench for solar water pumps.

4 BUSINESS MODEL VALIDATION

The female farmers at Kudumbashree operate the "SunLight Pumps" as part of an integrated irrigation system with mobile water tanks and micro sprinklers (Fig. 7).

Fig. 6: Female farmers at Kudumbashree discussing operations of the "SunLight Pump" in summer 2014.

Jointly with Kudumbashree and the local project manager in India (thitali low carbon solutions pvt., Kochi, India), a business model will be validated on the quantity of pumped irrigation water, crop production (Fig. 7) and the income generated through sales of these agricultural products on the local (urban) market in the dry season (Fig. 8).

Fig. 7: Female farmer at Kudumbashree studying the manual on "SunLight Pump" operations (autumn 2014).

Fig. 8: A pine apple field included in the business model validation with Kudumbashree 2014-15. The field needs to be watered by four people for two days a week, once a week during the dry season. The female farmers at Kudumbashree thus look forward to the irrigation support as provided by the Swiss "SunLight Pump".

5 CONCLUSIONS

Solar energy is not only a sustainable energy solution for irrigation and crop production in the dry season. But local manufacturing of solar energy technology solutions creates new jobs in the region, and deployment allows control over energy availability.

The "SunLight Pump" uses sunlight as the major energy source. This energy can also drive home light systems and other infrastructure; research work on such extensions is underway at BFH in Switzerland [7].

In view of these developments, solar energy technology in rural areas may offer new economic perspectives for female farmers and adolescent village girls [8], [9], and thus help paving the way towards reducing gender-based disparities in rural communities [10].

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Sustainable energy concepts in developing and emerging countries

Energy and mobility are viewed as important drivers for economic and social development (World Business Council for Sustainable Development, www.wbcsd.org). One of the three pillars at the Institute for Energy and Mobility Research (IEM) hence aims to contribute to improved living conditions in developing countries and emerging economies. Here, we present an example of sustainable energy technology developed at Bern University of Applied Sciences (BUAS) and planned mass implementation in rural India.

Dr. Eva Schüpbach
Lecturer for Sustainable Mobility
Foto: www.arteplus.ch

Improve living conditions with sustainable energy

Renewable energy technologies have a great potential in providing energy services to developing countries. Today, over 20% of the global population lack access to electricity, most of them in rural areas. Scenarios indicate that this situation will not improve until 2030 and will be prevailing in sub-Saharan Africa, India and other developing Asian countries, excluding China (IEA, 2010). In his keynote address at the Delhi Sustainable Development Summit (2 - 4 February 2006), Claude Mandil, Executive Director at IEA, commented: «To meet the energy demand and stabilize carbon dioxide concentrations, unprecedented technology changes must occur in this century…No single technology or policy can do it all.»

Altering technologies is also of great importance for achieving a green economy and the Millennium Goals (UNEP, 2011). These were adopted at the United Nations General Assembly Millennium Summit in 2000, and aim to improve the living conditions of the world's poor, with an ambitious target of 2015 to realise these goals. Although there is no Millennium Development Goal related to energy, the availability of energy is a prerequisite for the realisation of many of these goals.

As an institution that adopts practices of corporate social responsibility, the Institute for Energy and Mobility Research (IEM) at Bern University of Applied Sciences (BUAS) aims to deploy sustainable energy concepts to developing and emerging countries.

From left to right: Diesel Pump, Hand Pump, Treadle Pum

To make it work, make it a business: Micro-entrepreneurs in India

For the development of rural areas, the critical issue is affordable water availability and control for crop production. Small-scale farmers mostly depend on rainwater and the wet season. During the rainy season, dumping prices on the market often don't cover the production costs while, in the dry season, these crops can sell at a price that is up to three times higher, if irrigation is available.

In villages without electric power supply, manually-operated pumps and diesel pumps are vital for small-scale farmers to provide the badly needed additional income during the dry season. However, manually-operated pumps and treadle pumps are extremely labour intensive. Many small-scale farmers hence cannot afford irrigation, and large-scale irrigation systems mostly cover certain areas only and do not reach the fields of small producers. When the villages are connected to the grid system, electric water pumps are preferred but then, grid electricity may go off after some hours while additional nine hours of irrigation would be needed for crop production.

Harnessing solar energy for irrigation to replace part of the exhausting manual labour, avoid tremendous cost in diesel or unreliable grids can drive agriculture in rural areas. Sustainable energy concepts may also open the door to additional sources of income for the rural population (e.g., agritourism, see Raghunandan et al., 2010). The above ideas are underlying a pilot project on introducing the «Swiss Solar Water Pump» in rural India after 2012 (Schuepbach et al., 2011).

The «Swiss Solar Water Pump»

A solar water pump (termed «Swiss Solar Water Pump») was developed at IEM, using similar efficient electric motor technology as in the (i) famous «Spirit of Biel/Bienne» solar vehicle to win the race in Australia in 1990 and (ii) record-breaking electric bike «Spirit of Bike» in 2001. It is a low cost 40-120W photovoltaic water pump system for irrigation aiming at mass distribution to individuals and personal use. The pump does not need a battery and operates at the optimum efficiency even if the solar radiation is changing or is very low.

The «Swiss Solar Water Pump» is so small that the expensive parts (including panel) are transportable to avoid stealing and allow micro-entrepreneurs to move from borehole to borehole. The power output of the system has been designed to cover the needs of small farmer families for production in developing and emerging countries and dissemination with local manufacturers. The concept of local production has a double impact on the economy as it both lowers the price and creates jobs in the renewable energy business. This visionary approach is important as the cost associated with ending global energy poverty by 2030 is estimated to about $36 billion per year (IEA, 2010). Currently, 150 «Swiss Solar Water Pumps» are installed - jointly with CARITAS Switzerland and IDE-Gates - in Bangladesh (see photographs) to test whether our sustainable energy concept holds for future mass implementation. ■

Swiss Solar Water Pump
Photos: Irene Kunz and David Tschanz

Kontakt:
> eva.schuepbach@bfh.ch
> Infos: www.ti.bfh.ch/iem

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Lifelong Learning and Sustainable Energy Technology

Engineers work in completely different environments today as compared to the time when they were educated at the University. Some of the new constraints are globalisation and new markets, or the shift to post-fossile energy systems. What can an institution of higher education like Bern University of Applied Sciences (BUAS) contribute to face the challenges associated with lifelong learning?

PD Dr. Eva Schüpbach
Guest Professor of Sustainability
Foto: www.arteplus.ch

Photo 2:
Prof. Dr. Eva Schüpbach discussing the installation of solar water pumps with women living in slums and assembling in a church at Rayasandra village

Lifelong Learning in Sustainability for Engineers

Lifelong learning is an education process that continues throughout life. Current conceptions focus around economic views and argue that lifelong learning provides adult learners with the skills which employers need to compete in the global market. The development of top employability skills such as problem-solving or application of ICT (Information and Communication Technology) serves to promote the knowledge-based society. The UN «Decade on Education for Sustainable Development» (2005-2014; www.desd.org/) has launched a debate on the inclusion of sustainability skills in lifelong learning. From an engineer's perspective, sustainability not only involves understanding the technology, but also the impact upon the environment, and how to make this technology socially acceptable and economically viable.

Developing Sustainable Energy Technology in the Context of Globalisation

Sustainability education for engineers also includes making the connections between local and global scales. The new Institute for Energy and Mobility Research (IEM) at BUAS aims at offering both a research and learning platform in the field and develops sustainable energy technology that is deployed to emerging and developing countries. BUAS hence complies with an initiative of the United Nations, designating 2012 as the «International Year of Sustainable Energy for All» (www.un.org).

Among the sustainable energy technology developed by BUAS in Biel is the «Swiss Solar Water Pump», a unique low cost 80-160 W photovoltaic system. It integrates the rich experience of BUAS in different areas (e.g., motor design, electronics) and has been developed, and brought from prototype level to production stage by Prof. Dr. Andrea Vezzini (BUAS) jointly with Amro Technology Ltd., India (Ashok Mattoo). This solar company in Bangalore manufactures the motor and electronics controller and hence creates jobs in the region (photo 1).

Photo 1:
Amro Technology CEO Ashok Mattoo demonstrating the installation of the «Swiss Solar Water Pump» to the leader of the implementation project (Prof. Dr. Eva Schüpbach) and her team in Bangalore (local managers: ACTS Education Group and Tharun Anto, thitali ltd.).
Photos: BFH-TI

Beyond Engineering Knowhow: Practical Implementation of Sustainable Technology in India

To build a sustainable energy future, application of engineering knowhow needs to follow the avenue of a combined economic, social and environmental approach. All three aspects of sustainability are addressed in a new course (sustainability in engineering) given by Prof. Dr. Eva Schüpbach in the summer semester 2012. The course draws on a collaboration with US colleagues on the theory of system's thinking for sustainability. It also involves the participants in a new research and education project with India. Research in this project concentrates on implementing the «Swiss Solar Water Pump» with village people in rural India, primarily women. Especially in regions where electricity is not available, the low-cost photovoltaic pump systems can provide affordable irrigation water to grow crops and have a source of income during the dry season. Education in this India project aims at engineers of all age, for example through a new Master course on renewable energy offered by Mumbai University. To foster capacity building and lifelong learning among stakeholders, policy makers and the lay people, and to enable exchange with engineers, outreach events are conducted both in urban centres and rural parts of India, including slums (photo 2). ■

Kontakt:
> eva.schuepbach@bfh.ch

Eva Schüpbach is an atmospheric scientist with a Doctorate from the University of East Anglia, Norwich, U.K. (www.uea.ac.uk) and a Habilitation from the University of Bern, Switzerland (www.unibe.ch). Being a BBT-fundet Guest Professor of Sustainability at Bern University of Applied Sciences (BUAS; www.bfh.ch), she contributes to the build-up of the new Institute for Energy and Mobility Research (IEM). Her research project in India on «Micro-Business and Female Small-Scale Farmers in Rural India: Innovation Through Sustainable Energy Technology» (2012-13) is funded by REPIC (www.repic.ch), BUAS and ACTS Education Group, Bangalore, India for whom Prof. Dr. Eva Schüpbach serves as a Distinguished Professor of Global Change (www.wcu.co.in/People.htm).

New Avenues in Renewable Energy Engineering Education (RE3)

As the global energy market is in a phase of transition, attention is increasingly focused towards renewable energy sources and energy efficiency. Expert knowhow on renewable energy engineering is now more important than ever before. New educational avenues offer professionals the possibility to re-gain the competences required for building a sustainable energy future.

Dr. habil Eva Schüpbach
Lecturer for Sustainability in Engineering Sciences
Foto: arteplus.ch

Visionary Research and Market Application

The Department of Engineering and Information Technology at Bern University of Applied Sciences (BUAS-EIT; www.ti.bfh.ch/en.html) in Switzerland has been open to new developments in sustainable energy technology since the early 1980s. Examples are the construction of light-weight electric vehicles that inspired Mr Hayek to launch the «SMART» car, which eventually went into production at Mercedes Benz. Or the invention of the first worldwide feed-in tariff system («Burgdorf Model») to feed in the electricity produced from photovoltaic installations into the grid and get a return on investment.

Education in Solar Energy Production

The newly founded Institute for Energy and Mobility Research (IEM) at BUAS-EIT concentrates this huge experience in an integrated learning environment on energy, mobility and deploying low-cost renewable energy technology. As a strong pillar of IEM, the Photovoltaic Laboratory (PV Lab; www.pvtest.ch), founded in 1993 and now directed by Prof. Urs Muntwyler, has developed a new suite of (continuing) education programmes. Among the offers is a short course in photovoltaic design and installation for worldwide professionals (engineers, electricians) with (ideally) at least a bachelor's degree. The 6-week course, directed by Dr. habil Eva Schüpbach, strongly combines theory and practice and attracts ambitious participants who seek to start or pursue their career in the field of renewable energy technology and engineering. After successful completion of the course, trainees will be able to plan and build own PV installations based on international standards.

Energy Transition: From Local to Global

The curriculum involves taught lessons, exercises and practical training towards understanding the technology and the impact upon the environment, and how to make renewable energy technology socially acceptable and economically viable. The new competences gained and lessons learnt are immediately applied in a special project. This supervised own research concentrates on a problem in the home country of the participant and ensures immediate knowhow transfer. Among the first trainees in 2012 is an engineer from the Indonesian Sumatran Orang-utan Conservation Programme, reintroducing ex-captive orang-utans into the wild. He received his Certificate in November 2012. ■

Trainees of the short course in photovoltaic for worldwide professionals can take full advantage of the knowhow, expertise and infrastructure of the Photovoltaic Laboratory at BUAS Burgdorf.
Photo: BUAS-EIT

Solar Energy Technology Empowers Women in Under-Electrified Regions

Renewable energy and especially solar technology offer a particularly great potential for the energy transition in non-electrified and under-electrified regions. As evidenced in a project in India directed by Dr. habil Eva Schüpbach, the combination of economic viability, service build-up, and social acceptance drives the successful market entrance of solar energy technology.

Women cooperating in the female farmers' association in Mulanthuruthy (Kerala, India) proudly demonstrate the solar water pump to a representative of the Swiss Embassy in India during the January 2013 Workshop.
Photo: BUAS-TI

Solar Technology and Development in Rural India

Today, over 20% of the global population lack access to electricity, most of them in rural areas (www.iea.org). Of the 1.15 billion people in India, about 700 million live in the countryside. For the development of rural areas, the critical issue is affordable water availability. Small-scale farmers mostly depend on rainwater and the wet season for crop production. In the dry season, crops can sell at a price up to three times higher than in the wet season, if irrigation is possible. Harnessing solar energy for irrigation during the dry season can, therefore, open the door for additional sources of income.

Avoid the Old Trap of Widening the Gender Gap

Although Indian women play a predominant role in earning a livelihood for their families, the Global Gender Gap Index 2012[1] places India on rank 105 out of 135 countries. This project hence seeks to empower female farmers and adolescent village girls through deployment of solar water pump technology for irrigation and crop production in the dry season. The solar water pump systems have been developed by Prof. Dr. Andrea Vezzini at BUAS-EIT and are locally manufactured in India by AMROSOLAR pvt. The pump installation is carried out with cooperating female farmers' associations, one of which is an hour's drive away from Cochin (Kerala). The twelve women farmers in this association jointly cultivate paddy (rice) in the wet season and vegetables during the dry season. They also cooperate with a Women-only University in Cochin access to the urban market where the harvest can be sold. With the first solar water pump installed in the village of Mulanthuruthy on 29 December 2012, the female farmers will pump water to an overhead tank during the day and irrigate vegetables through the night.

Energy Transition at the Grassroot Level

The introduction of the solar water pump technology in this female farmers' association is promoted by the Panchayat and the local village office. Panchayats are governing bodies at the lowest unit of the local self-government in rural India and consist of (elected) representatives of the rural people. Both the Panchayat and local village office of Mulanthuruthy perceive solar water pumps as beneficial to the female farmers and a self-aid rather than a technology stigmatized as «introduced by a foreign development aid agency». It is the collaborative network of women farmers, Panchayat, local village office and senior female faculty at the University in Cochin that paves the way towards reducing gender-based disparities through solar energy technology. ■

Contact
> eva.schuepbach@bfh.ch
> Infos: www.repic.ch >en
www.actsgroup.org

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