ELECTRIFYING THE POOR: HIGHLY ECONOMIC OFF-GRID PV SYSTEMS IN ETHIOPIA – A BASIS FOR SUSTAINABLE RURAL DEVELOPMENT

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ABSTRACT
Nearly all of the about 80% of Ethiopians living in rural areas have no access to electricity. Excellent solar conditions enable attractive small off-grid PV systems for rural population. Their today's energy budget allows short payback periods of only about 2 to 4 years. As a consequence of high oil prices, even larger PV systems are very competitive to diesel generators and village power supply, respectively. A solar electrification roadmap for rural Ethiopia is already started and includes model projects, professional solar training and initiating local solar businesses. Highly economic solar systems, available to rural population, generate additional purchasing power and open new financial capabilities for sustainable rural development.

Keywords
Rural Electrification, Dissemination, Education and Training, Developing Countries, Sustainable Development

1 INTRODUCTION

Installations of photovoltaic (PV) systems have shown high growth rates around the world [1]. Nevertheless, most PV markets need considerable governmental support to reach parity with prevailing electricity supply. On the other side, highly economic but still small PV markets exist like in Ethiopia, for instance. A sustainable market development of such markets often dominated by small off-grid PV solutions has to consider several key success factors for rural electrification. Similar success patterns have been observed around the world: adequate system design, training of installers and end-users, financing, service and institutional cooperation [2-5].

This paper presents a detailed analysis of economics for off-grid PV in Ethiopia, key factors for successful PV diffusion, a solar dissemination roadmap adapted to Ethiopian needs and the fundamental impact of rural electrification with PV on sustainable rural development.

2 BACKGROUND TO ETHIOPIA

Ethiopia is a landlocked country situated in the Horn of Africa with a population estimated at over 83 million by 2007. Its annual population growth rate of 2.5% ranks it 28th fastest growing of 229 countries in the world [6]. In terms of gross domestic product (GDP) per capita Ethiopia is rated 174th of 179 and in terms of human development index it is rated 169th of 177 [7]. These numbers indicate Ethiopia as one of the poorest countries in the world. More country specific data can be found elsewhere [8]. Most Ethiopians live in rural areas (84%) and only 1% of those have access to electricity. Nevertheless, solar irradiation is well above 2,000 kWh/m²/y, ranging from 1,950 – 2,600 kWh/m²/y, providing an excellent basis for PV (Figure 1). Due to its conditions, Ethiopia is an excellent example for most of the least developed countries in the sunbelt, hence several results achieved for Ethiopia might be transferred to countries comprising more than 500 million people around the world.

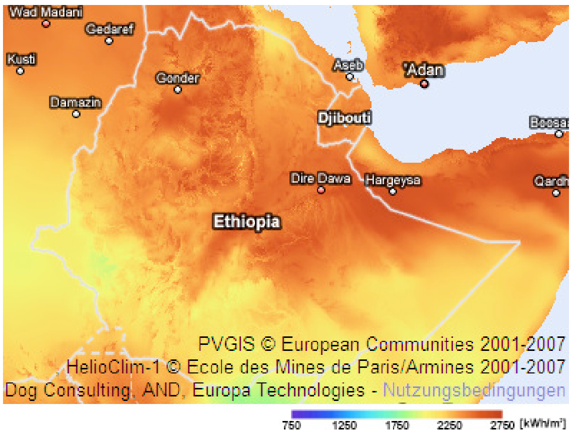

Figure 1: Global irradiation incident on optimally-inclined equator-oriented PV modules in Ethiopia [9].

Currently Ethiopia generates its power from its vast hydro power potential and supplemented diesel power plants. 647 MW or 89% of the installed grid connected capacity comes from hydro-electric power plants [10]. Economically feasible hydro-electric power potential would be up to 30 GW [11]. Due to seasonal rainfalls the generation capacity significantly depends on the amount of rain water during the raining season. This results in power shedding during periods with low water levels. Such periods regularly force the Ethiopian Electricity Power Company (EEPCo) to cut off customers from power supply, even in the capital. Ethiopia has launched construction of several new hydro-electric power plants to prevent power shortages and meet the demand growth [10].

Ethiopia exhibits excellent prerequisites for a nearly 100% renewable energy supply. Superb hydro and solar resources offer the chance of renewable energy supply in an economically, ecologically and socially sustainable way. Such PV-hydro potentials have been already analysed for Ethiopia [12] and might lead to utility-scale PV power plants [13]. These enormous renewable energy potentials might be connected to the DESERTEC plan in EU-MENA region [14] and further document the enormous energy supply potential of renewable energy sources.

Nevertheless, more than 80% of the Ethiopian population has no access to electricity, in particular in rural areas where more than 80% of the Ethiopians live. Overcoming this obstacle is a key for sustainable rural development.

3 ECONOMICS OF OFF-GRID PV IN ETHIOPIA

Like everywhere in the world, consumers in Ethiopia have a need for such as light, communication (e.g. radio, TV, cell phone) or mechanical energy (e.g. cooling, water pumping) but not electricity as an end in itself. In Ethiopia conventional rural energy usage is based on kerosene lamps for light and dry cell batteries for radios and tape recorders. Electric light is more easy and comfortable to handle, brighter, less expensive, cleaner and much safer than kerosene lamps.

3.1 SMALL OFF-GRID PV SOLAR HOME SYSTEMS vs CONVENTIONAL ENERGY USE

Typical off-grid PV solar home systems (SHS) in Ethiopia consist of a 10 Wp PV module, charge and remote controller, 18 Ah gel lead acid battery, two 50 lm/W LED lamps and one plug for a radio or tape recorder. Commonly two kerosene lamps are used by one family plus optionally one radio or tape recorder powered by dry cell batteries.

A simple financial tool for comparing alternative options is the calculation of payback periods [15]. Knowing all cash flows for investment, spare parts, service, financing cost and available budgets for energy needs, one can derive the payback period in which the investment pays off. If the lifetime of an investment is longer than the payback period, a financial benefit will be generated.

All necessary data are available in local currency, therefore the calculation is performed in Ethiopian Birr (ETB), as of March 2009, currency exchange rate was set to 14 ETB/€. Major assumptions are for the average energy budget of an Ethiopian family, cost of the SHS and its components, which have to be exchanged in regular intervals: complete 10 Wp PV system (3,200 ETB), fuel cost for one kerosene lamp (45 ETB/month), dry cell batteries for one radio (24 ETB/month), dry cell batteries for one tape recorder (48 ETB/month), new PV battery (440 ETB/every 4 years), new charge and remote controller (600 ETB/every 10 years), 4 new LED lamps (400 ETB/every 7 years), inflation 10% p.a. and credit cost 3% p.a. over inflation rate.

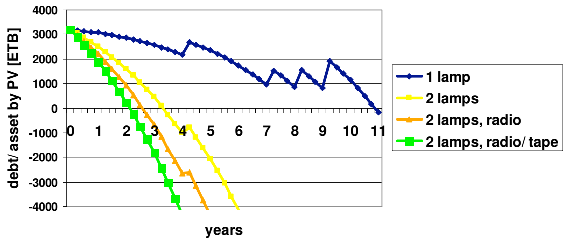

Figure 2: Payback period of small off-grid PV systems in Ethiopia. A today's 10 Wp PV system is compared to conventional energy consumption in rural areas. Replacement needs for battery, LED lamp and charge controller are the reason for the discontinuous shape of the graphs.

The payback period of a standard 10 Wp SHS is between 2 to 4 years, depending on energy consumptions habits of the users. Families using two kerosene lamps reach break-even of their investment in a 10 Wp SHS in about 3.5 years. After break-even there are only regular replacement costs of some components which add up to a significant monthly reduction of energy cost by about 80%. This 80% cost reduction is equivalent to a present value [15] in the year of break-even of about 8,500 and 20,000 ETB for assumed system lifetimes of 10 and 20 years, respectively. Families with larger energy budgets, for the given example of two lamps and dry cell batteries for radio and tape recorder, reach break-even in 2.2 years, benefit from a 90% cost reduction of their energy budget in the year of break-even and achieve a present value in the year of break-even of about 15,500 and 32,000 ETB for assumed system lifetimes of 10 and 20 years, respectively. Notably, these present values approximately equal 9 and 18 times the GDP/capita, respectively. Saved energy spending can be used for increasing the standards of living, e.g. better energy supply, education, medical aid, improved houses and much more.

Financial benefit for SHS owners is obvious, in particular in respect to an expected system lifetime of 20 years. Profitability of rural off-grid SHS is considerably higher than on-grid PV installations in most developed countries [16]. A comparable metric would be the internal rate of return (IRR), which indicates the profitability of an investment [15]. Inflation corrected IRR for on-grid PV installations are about 5 – 7%, whereas IRR for the two lamps and the two lamps plus dry cell batteries case reaches 28 and 45%, respectively. Main reasons for this remarkable economic outcome are: high energy prices for rural population, which correlate to world market prices for fossil fuels, and ineffective use of the energy.

3.2 OFF-GRID PV vs DIESEL GENERATORS

Despite low income in Ethiopia the desire to use electricity is very strong and Ethiopians are willing to pay high prices for electricity. In the past rural electrification was primarily realized by simply installing one diesel generator per village and connecting the houses to it. With focus on oil price development new options like PV came to mind. To replace the existing model of electrification PV has to fulfil some requirements: The consumer wants electricity to be reliable, affordable and available when he needs it.

For PV this obviously can only be achieved by installing a storage system like a lead acid battery, which is commonly used throughout the world, a reliable technology and a cheap way to store small amounts of electricity with focus on costs. This configuration of the PV system can provide a reliable supply of electricity whenever there is demand.

The major question is whether PV is affordable for rural population in Ethiopia? For the case of a 10 Wp SHS versus conventional energy use, the profitability calculation is shown in section 3.1. For the case of PV systems versus diesel generators [17], an appropriate financial tool for answering this question is the concept of levelized cost of electricity (LCOE) [15]. All cost categories, i.e. investment and capital cost, operation and maintenance and fuel cost, have to be put on an annual basis. LCOE are obtained by dividing annual costs by annual energy generation, this enables a direct comparison of alternatives in terms of cost per energy, in this section €/kWh.

Several assumptions have to be taken into account for the comparison. Major assumption is the supply of an entire village, i.e. a system size of at least 1 kWp. Costs for a low voltage distribution system are neglected, as it is required for both systems. Estimates for these costs are in the order of up to 0.60 €/kWh for comparable energy consumption profiles [18]. In case of one single electricity user, e.g. for small businesses, no distribution network would be needed and the following cost estimates can be used. Assumptions for the PV system are: investment cost PV system excluding storage 4,000 €/kWp, investment cost storage system 250 €/kW and 280 €/kWh, battery lifetime between 4 – 10 years, 6 hours of average daily battery usage, maximum usage of battery capacity 70%, weighted average cost of capital 6.4%, ratio of direct PV electricity consumption to stored PV electricity consumption 1:1. Assumptions for diesel generator system are: investment cost 250 €/kW, annual operation and maintenance 35 €/kW, lifetime 6 years, load factor 50%, energy conversion efficiency 33%, weighted average cost of capital 6.4%, fuel price diesel 0.89 $/l, currency exchange rate 1.4 $/€, effective premium of diesel price in Ethiopia compared to world market price of crude oil by 100%, increase of diesel fuel in rural areas far away from trade centers (distance to port factor, DtP) by 50% and energy density of diesel 10 kWh_{th}/l.[19, 20]

Main difference of PV system to diesel generator in LCOE calculations is the 90% portion of fuel cost of LCOE for diesel generators (Figure 3) and the nearly 100% portion of initial investment cost of LCOE for PV systems. It is a serious problem for the Ethiopian population to obtain financing for a PV system. However clever financing schemes and revolving fund schemes might minimize this disadvantage of PV (section 5.4).

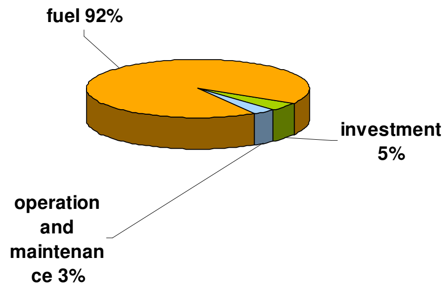

Figure 3: LCOE breakdown of diesel generators. Assumptions as mentioned in the text and average diesel price of 0.89 $/l.

During operation PV is much cheaper than a diesel generator. About 90% of the LCOE for the diesel generator is determined by the highly volatile cost of fuel (Figure 3). Contrary to this expenses for operation and maintenance of PV systems are much lower and have only a minor share of the LCOE.

In combination of these facts it is easy to understand why diesel generators are such an interesting option at the first sight. The problem of this solution is that the major part of cost will come later during operation and make it complicated to run a diesel generator continuously.

In rural areas it is rather difficult to maintain a diesel generator because of the lack of essential spare parts and fuel availability or for maintenance reasons. As a result of this some villages own a generator, but it is out of operation and cannot supply reliable electricity. Another problem is the low voltage connection of the houses. In some cases the villagers cannot afford to connect their house to the central generator. Energy loss in such low voltage distribution networks and low power demand of end-users are significant and worsen the financial performance. Furthermore air and noise pollution of a diesel generator is not negligible.

PV systems combined with an appropriate electricity storage system can minimize the operation cost and need only minor maintenance due to the absence of moving parts. Provides that batteries and PV are properly recycled at the end of their lifetime, there will be no pollution and a further positive environmental effect will be generated by a shorter energy payback time of the entire system [21]. Such a system can provide electricity to the customer during the lifetime estimated to 25 years for PV and 4 - 10 years for lead acid batteries [3]. Due to the modular characteristic, the system can be extended in case of growing electricity demand and according to needs of the users.

All these facts reveal PV as one of the most promising solutions for rural electrification. It is free of pollution and runs without fuel. But as the LCOE for diesel generators strongly depends on the oil price PV needs certain oil prices to be competitive (Figure 4).

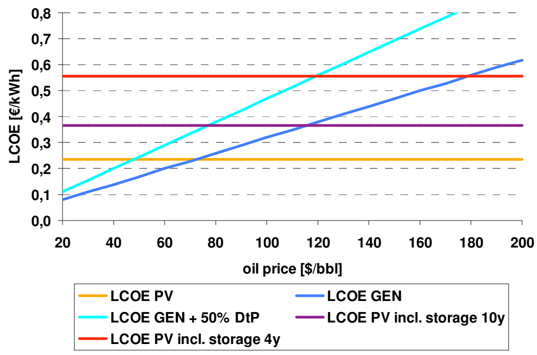

Figure 4: LCOE comparison of PV and diesel generators depending on different oil prices. Different systems are: stand-alone PV, diesel generators close to trade centers, diesel generators in rural areas, PV systems including battery storage with an assumed battery lifetime of 4 and 10 years, respectively. Assumptions of this section.

As depicted in Figure 4, LCOE of PV is independent on oil price variations, whereas LCOE of diesel generators escalates with rising oil prices. Due to the lack of proper infrastructure and supply the diesel price per litre in larger cities and trade centers cannot be applied in rural areas. An additional factor has to be added to quantify the transport costs and the trader margin, according to the aforementioned assumptions a conservative increase by about 50% is expected, as one can locally observe increases up to 70 – 100%.

Generation cost of PV electricity is dependent on the specific system design, the quality of components and optimised operation modes. LCOE of PV without storage can be expected to be slightly below 0.25 €/kWh, which equals an effective crude oil price of 50 $/bbl. Off-grid PV solutions including battery storage of 4 and 10 years battery lifetime can achieve LCOE of about 0.37 and 0.55 €/kWh, which equals an effective crude oil price of 80 and 120 $/bbl, respectively. In 2008 the spike of crude oil prices was above 140 $/bbl. Historically high crude oil prices are very likely in the years to come due to the fact of globally declining oil reserves [22].

An analysis of these estimates shows a clear indication. Only during a short transition period a combination of PV and diesel generators seems to be economic, in particular a combination of existing diesel generators with new PV systems without storage. Whenever the sun is shining, solar power is used and costly fuel is saved. Batteries with optimised lifetime are essential for an early diesel-parity of stand-alone off-grid PV solutions. High battery lifetimes can be achieved by providing a closed system to the user, which prevents misbehaviour like deep discharge and therefore increases lifetime. This means, in some regions and if other additional costs apply, PV is already competitive at current oil prices. Furthermore, there may be a significant upward potential in the favour of PV, due to increasing oil prices and further decreasing PV cost [16].

3.3 ADDRESSABLE MARKETS FOR OFF-GRID PV IN ETHIOPIA

The last two paragraphs showed that small off-grid SHS are highly beneficial for rural population in Ethiopia and village power supply by diesel generators is no real alternative. Based on this insight, together with Ethiopian energy experts we derived a rough estimate of today's addressable market for SHS in Ethiopia (Table 1) [23]. A good overview on current market trends in Ethiopia and evaluations of local strategies can be found elsewhere [24, 25].

Typical off-grid PV home systems in Ethiopia consist of a 10 Wp PV system. An estimate of Ethiopian PV experts led to PV system demand in power units of 2 Wp for light for one house 4 h/day, 10 Wp for light and music, 20 Wp, 50 Wp and 100 Wp which is sufficient for a little cinema or a health station with refrigerators. This estimate is close to similar analyses of other Ethiopian experts [25] and is based on today's GDP/capita. Optimised PV systems are expected to be sold at a significantly lower price than today, including scaling effects in distribution channels in Ethiopia. These effects are known from other markets and are reflected in local prices [26, 27]. Assumptions for the calculation below are: addressable rural households in Ethiopia (10 million), specific off-grid PV SHS price (150 ETB/Wp), currency exchange rate (14 ETB/€) and several years of market development. Markets for commercial off-grid and on-grid PV systems are not considered but would significantly increase the market potential.

PV systems	distri-bution	house-holds	PV demand	Market for optimised systems	
[Wp]	[%]	[mio]	[MWp]	[mETB]	[m€]
2	20%	2	4	600	43
10	20%	2	20	3,000	214
20	30%	3	60	9,000	643
50	20%	2	100	15,000	1,071
100	10%	1	100	15,000	1,071
total	100%	10	284	42,600	3,043

Table 1: Ethiopian cumulated off-grid PV addressable markets for solar home systems.

Remarkably, nearly all Ethiopians in rural areas could have access to electricity and they could afford it. These estimates show that 70% of rural population would significantly improve their standards of living and effectively save money for energy needs if they had access to SHS in the power range of not more than 20 Wp. The market segments for SHS larger than 20 Wp might offer an addressable volume of about 2,000 million €. As discussed in section 3.1 investments in SHS would pay off within 2 to 4 years and reduce energy budgets by 80 – 90% after this payback period. Imagine a fast and nationwide diffusion of privately financed SHS, an enormous boost in private financial capabilities in rural areas can be expected. Rural villagers can decide which needs they may cover first, e.g. enlargement of their SHS, education, investments in their houses, medical aid, communication technologies and much more. Besides the Solar-Center dissemination strategy by Solar Energy Foundation (section 5.3), a solar enlightenment programme for schools in Ethiopia could convince rural villagers how solar energy could improve their own lives. Similar programmes were started in other countries [28].

4 KEY SUCCESS FACTORS FOR RURAL ELECTRIFICATION WITH PV

In the last decades in several countries around the world local initiatives for diffusion of SHS have started [2-5]. Learnings in such markets are summarized in this section and build the basis for a unique approach of off-grid PV diffusion in Ethiopia in the next section.

More than 1.5 billion people around the world have no access to electricity [29]. Most of the families in such areas spend 5 – 10 $ every month to buy kerosene for light and dry cell batteries to power a small radio. A small PV system would allow them to have brighter light, more hours of use for radios and cell phones at lower cost.

The question is why do so little people have a PV power supply. What are the obstacles for them to buy such a system?

4.1 LOCAL AVAILABILITY

Main reason is the local availability of such solar systems. In only a few countries around the world close meshed networks exist, where PV systems are available. Such countries are Kenya and Bangladesh, both countries are success stories in terms of rural electrification with the help of small PV systems. In Kenya the local battery manufacturer built up a network of battery charging stations. These stations are also used to sell PV systems and all necessary components. More than 5% of the Kenyan population live in households with PV power supply. This might be the highest rate in the world. Another success story can be seen in Bangladesh, where a micro credit bank has more than 700 technical centres which sell, install and maintain small PV systems. In 2009 more than 100,000 such systems will be sold in Bangladesh. This is another record.

4.2 MISSING INFORMATION FLOW

One problem of a faster diffusion of PV systems is the missing information flow between the end-users and the manufacturers. PV manufacturers are mainly located in industrialized countries. Their main market are on-grid PV systems [1]. In most cases they have no information about the potential users. On the other hand the users and the potential distributors in the target countries of rural electrification have no experience about PV systems. Since customers and producers are located in different countries and have very different background it is hard to initialize the communication.

4.3 FINANCING

Financing is another obstacle which blocks fast growth of the off-grid PV markets. The use of kerosene needs small amounts of money every week and every month. For people supplied by an own small PV system it is necessary to invest a relative high amount of money at once. Nevertheless, the effect of financing is often overestimated. Even in Bangladesh, where excellent financing instruments are available, most of the users buy their system on cash.

4.4 SPECIAL APPLIANCES

Small PV systems need special appliances. Such systems are working on low voltage and the generator as well as the battery provide direct current (DC). Most of the loads in industrialized countries are working with alternating current (AC). Since the globally dominating market is the market for AC appliances, there is a certain pressure to use the same appliance for small PV systems as well. AC appliances are not well adopted for solar application. In most cases they are not energy efficient, since electricity in utility networks does not cost much money. To convert DC to AC is also expensive and a reasonable amount of energy is lost. Having access to well adopted DC appliances would significantly increase the market for SHS.

The business for cell phones shows the potential of small solar systems. In case of mobile communication there are large national networks selling big quantities of cellular phones. The amount of money, for the phone and the top up of the credit are over the time not lower than for a PV system. Very important in this case is the fact that the function of the cell phone is well proven. The network of vendors can also offer maintenance and service.

4.5 SOCIAL SUSTAINABILITY

Necessary prerequisite for successful rural electrification is the will for social sustainability. Considerable investments of scarce resources in long-term goods require the will for development. A key indicator for social sustainability of individuals and entire societies is the clear preference of better long-term results versus faster but less valuable short-term benefits. A good example would be significant higher investment cost in PV systems at low running cost versus low capital expenditures in diesel generators at high fuel cost

5 A NEW APPROACH FOR RURAL ELECTRIFICATION IN ETHIOPIA

Energy is an important prerequisite for prosperity and security. 550 million people in Africa have no access to light and modern forms of energy [29].

With donations alone it is not possible to eradicate the poverty in Ethiopia which largely results from the lack of power. This will only be achieved if the will and energy to alleviate the distress grow and ripen in Africa itself.

Solar projects financed with donations must therefore work according to the principle “help for self-help” if they want trigger developments of an enduring nature. Humanitarian development aid projects should encourage self-initiative and then play a supporting role. In the end, it is essential that a self-supporting solar economy develops in Ethiopia: from the solar worker to the manufacture of equipment such as solar modules, charge controller etc.

The Solar Energy Foundation – Stiftung Solarenergie – is dedicated to development aid. The aim is to alleviate poverty in developing countries by promoting the use of renewable sources of energy, above all solar power. Energy is vital because it is a prerequisite for education, healthcare and development. At present the foundation is only active in Africa, mainly in Ethiopia. The Solar Energy Foundation represents one of the largest PV projects in East Africa. The implementation of the detailed approach for rural electrification in Ethiopia shown in this section is the dedicated roadmap of the Solar Energy Foundation [8]. Final aim of the Solar Energy Foundation: “To make ourselves superfluous again as NGO by initiating and developing a local solar market” (Figure 5).

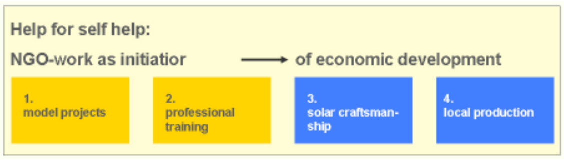

Figure 5: Steps for solar development in Ethiopia developed by Solar Energy Foundation.

Main principles of Solar Energy Foundation:

- Working close to the people and orientated towards their actual needs
- Solar products in best quality
- Working only with well trained solar technicians
- Focus on After-Sales-Service and maintenance - the biggest challenge in rural areas
- Providing a financing option for end-users

5.1 MODEL PROJECTS

The model projects display the possible applications for solar energy in an exemplary fashion. Here, people can experience the benefits of solar energy in everyday life at first-hand.

The model project area is Rema, a village 140 km north of Addis Ababa. The villagers of Rema chose to have solar power rather than a diesel generator, because of concern about the running costs of the generator (Figures 3 and 4). The Solar Energy Foundation installed more than 2,000 solar systems for free, but people have to pay for maintenance, service and have to deposit money for spare parts, e.g. battery. This money is collected in monthly rates since 2005 by the village community.

5.2 PROFESSIONAL SOLAR TRAINING: INTERNATIONAL SOLAR ENERGY SCHOOL

Trained professionals are required in Ethiopia in order to install and maintain the solar systems because detailed knowledge of this modern and environmentally-friendly technology is essential in order to be able to efficiently apply it. If PV is to be established as a widely accepted source of energy supply it will need a reputation of reliability. Designing small off-grid systems raises more challenges as compared to rather large systems for on-grid feed-in. Maintenance costs and reliability which are dominated by battery lifetime can be significantly influenced by component sizing and user behaviour. Therefore it is of utter importance that system installer and user are sufficiently familiar to the topic. The Solar Energy Foundation therefore set up the "International Solar Energy School" in autumn 2007.

The courses of the "International Solar Energy School" are held in the new Solar Valley in the west of Addis Ababa as well as in the Solar Energy Foundation’s Solar-Center in Rema.

The "International Solar Energy School" is the first professional solar training institution in Ethiopia. The core training course qualifies the student as a "Rural Solar Energy Manager". It lasts approximately six months and consists of three parts: solar technology, management of a small-scale business and practical applications. At the end of this time, the graduates are then in a position to manage their own solar businesses. With this education they will be able to introduce their customers into the details of the acquired solar home system and they will know how to choose and combine the different components of the system, install it at the ideal location and carry out any necessary maintenance. The training is done with combined efforts of local staff and lecturers from countries with an established PV industry. In this way, a network of independently operating Solar-Centers will come into being to spread PV knowledge throughout Ethiopia. As part of PV knowledge dissemination strategy, Solar Energy Foundation produced a reference book for education purposes and documentation of insights and experience gathered in rural electrification in Ethiopia [30]. Basis for widespread off-grid PV systems is dissemination of PV knowledge in Ethiopia.

A further task of the "International Solar Energy School" is to setup a test center for solar technology. The test center may be used by all organisations in East Africa.

5.3 INITIATING A LOCAL SOLAR BUSINESS

On the basis of the experience gathered in the course of the pilot projects of the Solar Energy Foundation, a network of Solar-Centers (Figure 6) will be set up spanning the whole of Ethiopia. These are small-scale businesses managed by people who were trained at the Solar Energy Foundation's "International Solar Energy School" in Rema.

The Solar-Centers have the following tasks:

- Advising and informing potential users
- Selling solar systems
- Technical operating management: providing maintenance and service work, carrying out repairs
- Management of Revolving Fund Financing System

In the end the Solar-Centers are independent Ethiopian small-scale businesses which are affiliated to the Solar Energy Foundation by a kind of franchise agreement. The Foundation offers them tried and tested high-quality products, professional further training, marketing support as well as its own financing system. The aim is to establish 50 Solar-Centers in various areas of Ethiopia within the next 5 years.

Figure 6: Map of the current Solar-Centers. Solar-Center: Humeara, Woliso, Abusaja, Yirgalem, Minjar. Solar-Village and International Solar Energy School: Rema. Headquarter of Solar Energy Foundation: Addis Ababa.

5.4 REVOLVING FUND FINANCING SYSTEM

Solar Energy Foundation has partnered with Arc Finance, a US-based non-profit organization, to structure and implement an end-user finance program in Ethiopia to offer customers the opportunity to purchase solar products on an instalment basis. Arc Finance focuses on linking energy and water enterprises with financial institutions and microfinance institutions through a range of technical, financial and programmatic support. The goal of this partnership was to develop a "revolving fund" within Solar Energy Foundation to offer financing options to customers for the purchase of solar products and to design and test a management information system to track payments.

Solar Energy Foundation and Arc Finance has developed a portfolio of financing options for customers in Ethiopia, following an in-depth analysis of target client ability and willingness to pay, operational and human resource capacity, and local access to finance. Under the revolving fund, customers can purchase solar products over the course of 1 to 3 years with a range of repayment terms – monthly, quarterly or annually. Solar Energy Foundation has established a standard revolving fund application approval process, whereby clients undergo an assessment of household and microenterprise income and expenses, a character check with local leaders and government chairpersons, and an evaluation of pledged collateral. Once approved, the customer then makes a down payment at the nearest Solar-Center in the range of 20 - 40% of the total system cost depending on the length of loan period, i.e. one and three year loan induces 20 and 40% down payment, respectively, which then triggers the installation. Customers must make instalment payments at the nearest Solar-Center, where the repaid money flows back into the revolving fund and is then made available to finance the next solar systems. A revolving fund scheme is a major key for bridging the gap of financing solar systems in Ethiopia.

The revolving fund has been designed to include robust reporting, internal controls, and an overall architecture for information gathering. Other critical elements include default-monitoring processes, penalties for late payment, and a portfolio of incentives for customers to encourage early repayment, referral and product upgrading, and incentives to encourage staff to maintain high loan portfolio quality. A custom management information system to streamline processes, improve revolving fund monitoring, and provide up-to-date information on outstanding instalments has been developed and is being tested in September 2009. Since January 2009, it has been sold over 800 standard 10 Wp SHS on an instalment basis through four Solar-Centers across Ethiopia.

Maintenance and servicing are free of charge during the first five years. After that time the people can sign a maintenance contract with a local Solar-Center. In this way the projects also serve as a long-term measure promoting the development of local businesses.

5.5 OUTLOOK TO THE WORK OF SOLAR ENERGY FOUNDATION IN NEXT MONTHS

For fastening the diffusion of solar energy in rural Ethiopia it is planned to open six more rural Solar-Centers throughout the country in the near term. Next step will be the expansion of available products for the network of Solar-Centers. It is planned to launch the final design of new products: from solar light to solar entertainment (TV, DVD, MP3, …). Ongoing training of new solar technicians makes it possible to spread solar knowledge around the country. 20 new solar technicians will start their training after the raining season. Solar energy in Ethiopia has achieved a level which makes it important to educate academic professionals in Ethiopia, therefore it is planned to setup a chair for renewable energies at an Ethiopian university.

In the larger scope it is planned to set up an institute for rural solar energy focussed on technological and empirical social research in the field of rural off-grid PV electrification. Besides academic research it is of utmost interests to establish a local PV industry for relevant components.

6 IMPACT OF RURAL PV DISSEMINATION ON RURAL SOCIETY

The access to solar electricity in rural areas enables a great chance of sustainable development of the rural society. In equator near regions, the main part of life of people happens between sunrise at 6am and sunset at 6pm. The commonly used kerosene lamps or candles spend poor light and show high risks for safety and health. Burning kerosene in closed rooms produces smoke in grave concentrations for health or even worse the open fire of the lamps is frequently responsible for burning down of houses [29].

Solar energy provides for this first and basic need for light a highly comfortable and suitable solution. Already basic PV systems of 2 Wp provide clean and bright light for two, up to three rooms in the house for several hours every day. This reliable and affordable opportunity enables regular activities after sunset and supports development. After the electrification of Rema the demand for education not only for children, but as well for adults increased significantly. As one result evening classes were started. Furthermore the access to light provides the opportunity to process the villagers' own products for upgrading and to develop small businesses and manufactures. Women in Rema may spend more time for their families as a direct result of PV in Rema, as solar powered water pumping has drastically reduced daily ways for freshwater supply [31].

One of the next steps of this development which is just triggered by light is an increase of social and cultural engagement. For example the first social center (including PV) for poor people and seniors without family in Rema was built with public support. This is in contrast to the tradition that generally just the own family has to take care of elder and ill people.

The availability and the increasing possibility to afford larger PV systems allows to feed the demand of people to operate e.g. refrigerators, which are used in health stations to conserve medicine as well as in bars to cool beverages.

Finally and generally very soon the demand of the rural population will be the connection to the world by access to multimedia and communication. Therefore Rema plans to install their first public television and surely the demand for cell phones will rise up soon.

7 CONCLUSIONS

Ethiopia is an example that off-grid PV is a highly attractive source of electricity for rural population in developing countries. Very short payback periods for small PV systems offer high financial savings which can be spent for other needs like education. A fast and successful dissemination strategy has to include local availability of PV systems, training of solar experts, local solar businesses, exchange of information about end-users' needs and manufacturers, which might be achieved by local solar production, adapted appliances, financing schemes and model projects. Beneficial economics of PV in Ethiopia could generate additional purchasing power and PV service jobs in rural regions. Access to electricity has the potential for sustainable rural development and a new "enlightenment" in rural areas.

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