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The PSS quality framework for solar home systems

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Abstract

In September 2015, the United Nations General Assembly has adopted the Sustainable Development Goals; they include SDG 7 targeting universal access to electricity by 2030. Reaching this goal implies huge investments in generation capacity, grid extension and densification. However, according to the International Energy Agency, 70% of the world's population currently excluded from electricity services can only be reached by decentralized solutions such as Mini Grids and Solar Home Systems.
The use of Solar Home Systems (SHS) has shown mixed results in the last decades. In literature, 'quality' is often mentioned as an important success factor. However, the term 'quality' often stays undefined and actors have various understandings of it. The authors propose a framework for the definition of the quality of SHS with a focus on the economic benefit of the end-users and based on the concept of Product-Service Systems. In this approach, products and services are equal parameters. This enables a flexible design and dimensioning of SHS without implying a fixed set of international quality standards. Doing so, the PSS Quality Framework for SHS avoids creating preferences for products from industrialized nations and underlines the enormous potential of local manufacturing and services in developing countries, particularly in Sub-Saharan Africa.

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Keywords: Solar home systems; quality standards; Product-Service Systems; local manufacturing; MRO.

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1. Introduction

During the United Nations summit in September 2015, the Sustainable Development Goals (SDGs) have been adopted. They include SDG 7 targeting universal access to electricity by 2030. Reaching this goal implies huge investments in generation capacity, grid extension and densification as by today, 1.1 billion do not have electricity [1]. However, according to the International Energy Agency, 70% of the world's population currently excluded from electricity services can only be reached by decentralized solutions such as Mini Grids and Solar Home Systems (SHS) [2].

This paper focuses on electricity access in off-grid areas, where kerosene lamps, dry cells and car batteries dominate the local energy mix. Although the investment costs for these technologies are low, many studies have shown that accumulated energy costs can become very high: According to own investigations conducted in Uganda in 2008, the smallest kerosene lamp costs 200 UGX. One day-refill with kerosene costs already 100 UGX. The global economic significance of the off-grid sector is continuously growing: Whereas the conventional electric lighting market has a volume of 185 billion US$, the off-grid fuel-based lighting market amounts to 38 billion US$ with 17 billion US$ only in Africa [3].

1.1. Solar Home Systems

Within an SHS, solar energy is converted to electricity via a PV module. The electricity can be used immediately for instance to run a fan but in most cases, it is stored in a battery in order to use different electrical appliances, particularly lights during the night. SHS are also used to charge mobile phones, to run radios or televisions.

Already in the year 2000, more than one million SHS were implemented around the world. A group of experts have evaluated reports of several SHS World Bank projects. For our research, the evaluation of the technical performance is of particular interest:

Researchers found out, that in average 25 % of the systems were not longer functioning and an additional 20% were found only partly operational. Although inspected projects varied in terms of use period and delivery models, the researchers identified batteries and fluorescent lights as the components that cause most technical problems [4].

The most unexpected outcome of this evaluation regards the technical standards: "Some countries have standards for equipment to be included in national SHS programmes. International standards are promoted by PV-GAP and the World Bank. It is common to expect that imposition of standards will lead to higher product quality in the market and increased user satisfaction…However; no clear relation could be established... For example in India, SHSs are subject to tests of the Solar Energy Centre to become eligible for inclusion in subsidised governmental programmes. On the other hand, in Kenya no such standards apply to commercially distributed systems. However, in both countries a similar fraction of about 66% of installed systems is in good order. This shows that, at least for the moment, factors other than standards appear to be more important in determining how well systems operate after some time." [4].

In fact, 'standardization' is subject to controversial discussions among experts and practitioners in the field of SHS. Particularly policy makers and entrepreneurs from the Global South underline that the enforcement of quality standards often undermines opportunities for an active participation and development of a local manufacturing industry for SHS. High quality standards are easier to fulfil by firms from industrialized countries and thus, shuffle market conditions to their favour.

However, functionality is not the only aspect of quality which is discussed among stakeholders in the field of SHS. In a discussion paper summarizing the results of a workshop on energy and development at the Yale School of Management, understandings of quality were as various as the number of cited experts: Some understand quality as the conformity with western standards, others refer to after-sales services or underline the importance of customization. Further experts spotlight life cycle aspects, particularly recycling or accentuate the relevance of local participation in the whole process [5].

1.2. Research Objectives

Generally, it can be observed that there is no definition of quality in the field of SHS that takes the observations of the Nieuwenhout study regarding standards into consideration and supports the design of a robust SHS that functions and ensures users a return on their investment. In this paper, we are presenting the results of a literature review and different empirical studies undertaken in Tanzania and Uganda. As a result, a quality framework for SHS has been developed and tested. The Quality Framework for SHS is expected to support SHS system integrators, energy entrepreneurs and policy makers optimizing and developing SHS and their eco system.

2. Methods

For the development of the Quality Framework for SHS, a literature review was undertaken focussing particularly on the diverse understandings of the term 'quality' within experts and practitioners in the field of SHS. Furthermore, two field studies were conducted in Uganda and Tanzania. In the scope of these studies, 29 SHS were technically inspected during their usage phase. The usage pattern and the system performance of 13 SHS have been monitored with a smart meter during one week. Furthermore, semi-structured interviews were conducted with individuals and groups: They were asked about their savings on conventional energy sources and their additional income. Further questions addressed their experience with the technical performance of the system. Answers were compared with the results of the technical inspections and the monitoring.

3. Results and discussion

The typical target group of SHS are households and SMEs living in a structurally underprivileged eco system. Beside energy, they often have other unfulfilled vital needs and limited resources. Even basic investments compete with each other. For this reason, business models for SHS distributer are favourable, that do not require a large pre-investment from the end-user, such as a fee for services model or a microfinance approach. A prerequisite is that the incremental payment is adapted to the savings and additional income generated through the SHS.

Accordingly, the Quality Framework for SHS privileges SHS that enable users to generate a fast Return on Investment (ROI). This can be done by:

- Increasing the productivity of the end-user's business
- Supporting end-users saving on their current expenses for energy

Subsequently, a central requirement towards a SHS is its functionality till the accomplishment of the ROI. Particularly in case of a microcredit, functionality is required during the loan repayment period (LP). In most countries of Sub-Saharan Africa, microcredit loan periods vary between 2 months to one year [6].

3.1. Functionality of inspected SHS

Assuring the functionality of a SHS during the period where the ROI is generated is an important quality requirement. To get a sharper picture of the functionality of SHS, technical inspections were undertaken during their usage phase in Tanzania and Uganda.

The technical inspections confirmed the results of the Nieuwenhout study: Most factors hindering or diminishing the functionality of the SHSs were related to an unsatisfactory or non-existing service and not to the compliance of hardware components to international standards. Generally, it was observed that incentives for the delivery of proper service activities were either missing or displaced.

Accordingly, a Quality Framework for SHS has to consider the quality of the hardware product in dependence of the quality of services. Services in turn require a human network infrastructure and a delivery model. For the development of the Quality Framework, the authors propose to use the academic concept of product-service systems (PSS) as an integrating tool to describe the interference between hardware and their required services.

3.2. Product Service Systems

Product-Service Systems (PSS) is a concept integrating products and services in one scope for planning, development and delivery, thus for the whole lifecycle. Since years many research projects all over the globe concentrate on the integration of products and services from engineering, economic or social viewpoints [7]. Furthermore, PSS have been linked tightly to sustainable development or eco-design [8,9].

The basic idea of PSS is to overcome considering products and services separately but to focus on a defined result [10]. In the field of SHS, a defined result can be a warranty for the system’s functionality for a clearly defined period of time, preferably until the customer has generated sufficient returns on his investment. This requirement can be fulfilled by either a robust and costly product (hardware) or an adapted service. It is up to the PSS designer to balance both possibilities in order to find the right mix. This mix is depending from many factors such as costs (PSS Costs), willingness of different stakeholders to take responsibilities and local availability of hardware, human resources and skills for the required services.

In the following sections, it will be shown how a focus on PSS Costs can support a quality assurance strategy and lead to different PSS designs in the microenergy sector. PSS costs include hardware costs, costs for technical services and costs for financial services. Sometimes subsidies are available to reduce these costs.

3.3. The Microenergy Quality Framework

The MicroEnergy Quality Framework for SHS offers the possibility to evaluate the impact of SHS on the economic situation of the target group. It can also be used to improve existing SHS programmes. For this purpose, the following equation is set up: [Additional income through energy savings + additional income through productive activities > Cost of Product + Cost of Service + Cost of Capital]

The PSS Quality Equation in Figure 1 shows the conditions under which a SHS fulfils the quality requirements of the MicroEnergy Quality Framework: A SHS is a benefit for its users if the ROI generated with the SHS during one day, or in case of a credit, during the loan repayment period, surpasses the costs generated by the PSS. These costs can be reduced if the PSS is eligible for any type of subsidies. A successful SHS program (QProgram) enables an environment for these successful MES.

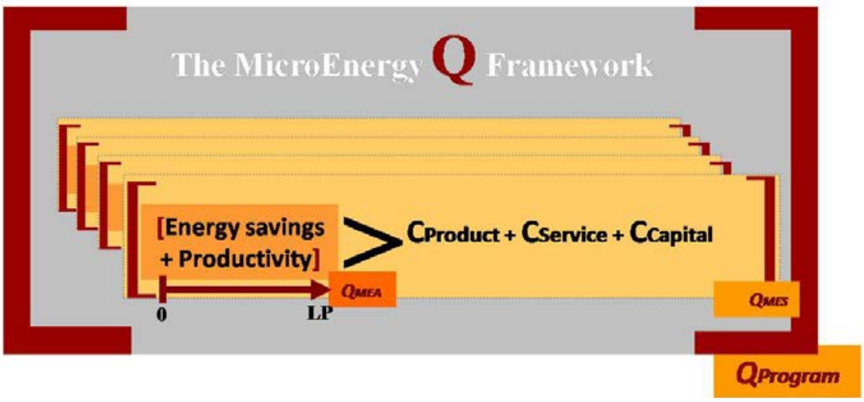

Fig. 1. The quality equation for SHS.

3.4. Evaluation of the PSS Quality Framework for SHS

In the following, the PSS Quality Framework for SHS was applied to different SHS use cases in Uganda. The data have been collected during an own field study in Uganda, where 52 households and businesses using SHS have been interviewed. The SHS were offered in combination with a 6-months microcredit:

- SHS for productive mobile phone charging business. As no light is used, only charging costs for the own mobile phone can be substituted. Users mainly generate income by offering charging services to others. One phone charging typically costs 500UGX (=0.2 €).
- The second application combines the mobile charging business with home lighting. This is possible, because most end-users run their business at the same place where they live. By using the light of the SHS, savings are made on former expenses for kerosene.
- The SHS in the third application is so small that only lighting and private mobile phone charging is possible. Accordingly, income is only generated through savings on former expenses.
- In a next step, the PSSCosts have to be assessed. In this case some assumptions had to be made due to a lack on detailed information.

3.5. Performance of the SHS Use Cases in the PSS Quality Framework for SHS

The application of the PSS Quality Framework for SHS to the three use cases described in the former section show that it is principally easier for larger systems to perform well. This is mainly due to the fact that costs for services are almost independent from the size of the SHS. Other observations that can be made:

- As regular loan periods for microcredit in Uganda are short (max. 1 year), the investment into a better battery does not make an important difference in the MQF. Only an extension of loan periods let an SHS with batteries having a longer lifetime perform better.
- An important observation was that smaller SHS, although profiting from ‘pro-poor’ social subsidies, will never generate profits with these applications. Extended loan periods just increase the losses of the end-users over the years!
- Larger SHS perform better with a cheaper battery and more costs for services. This opens up opportunities for attractive local and service based business development: PSS stakeholders might start to develop their market with larger SHS. With growing density of SHS, service and specially transportation costs can decrease continuously. Doing so, end-users who can only afford small SHS can be included step by step.

4. Conclusions

The PSS Quality Framework for SHS is a tool that helps to evaluate individual SHS and SHS Programs with the focus on the ROI of end users. Furthermore, it can support all kind of stakeholders working in the field of SHS to improve delivery and financing models, subsidy schemes and quality requirements. According to the example, it can even be in favour of local technologies as long as a better local technical service is guaranteed. This opens up huge opportunities for local jobs in the SHS servicing and spare part industry, clearly reshuffling the value creation towards the last mile.

To guarantee and enforce adequate local technical service activities and to equip them with the right monitoring and incentives is subject of further research of the authors. On the one hand, sophisticated methods are developed to analyse and predict technical failures of SHS, on the other hand, adapted servicing strategies, including the use of smart controllers and remote monitoring technologies are explored.

The authors are interested to collaborate with other scientists and practitioners working in the field of service engineering and vocational trainings for solar technicians. Many training centres encourage trainees to develop own businesses. The authors see enormous potential of mutual learning with these kinds of actors.

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