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Village-level solar power in Africa: Accelerating access to electricity services through a socio-technical design in Kenya

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ABSTRACT

Village-level solar power supply represents a promising potential for access to electricity services. Increased knowledge is needed for the development of solutions that work for the users and are viable in the long run. This article analyzes a solar power model developed and tested through action research in collaboration between a community in Kenya and a team of social scientists and technical experts. The analysis includes the reasons for its socio-technical design, and the actual functioning of the model. The research shows that an energy center model can cover basic electricity needs in areas with dispersed settlement patterns, where mini-grid based systems as well as conventional grid extension meet significant challenges. Such areas are representative for large geographical areas in Africa. We show that portable lanterns and low prices may enhance access to suitable services. Committed follow-up of the local actors, and a flexible socio-technical design – allowing for improvements after implementation – contribute to economic sustainability and smooth functioning. Close attention to the socio-cultural context and the challenges of users, operators and managers is required. Our research draws on theories of socio-technical change and users' innovation, and presents a five-step analytical framework for analysis of village-level power provision.

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1. Introduction[1]

Globally, 1.2 billion people lack access to electricity [1]. While conventional grid extension has been the predominant mode of electrification in almost all the countries around the world, they have important shortcomings. First of all, centralized grid-based electricity systems often do not reach remote areas and tend to offer services only to the more privileged groups, whereas many poor individuals, households and enterprises remain unconnected [2–4]. Secondly, many conventional systems are based on the use of fossil fuels which have detrimental effects on the global climate and the local environment. Dependence on the import of fossil fuels with volatile prices also makes countries – and institutions and individuals – financially vulnerable. Solar power and other decentralized off-grid electricity systems at the village-level[2] may potentially provide sustainable electricity supply to a variety of users in a more democratic way [1,5]. Other energy technologies such as modern cooking stoves, as discussed by Lambe et al. [6] on renewable energy in Africa, may have positive distributional and environmental effects. However, electricity is a crucial, conditioning factor for a range of modern services such as information, communication and light, which are generally desired amongst populations who do not have access today (e.g., Tenhunen [48]; [7]; Matinga [49]). The issue of how to provide increased electricity access therefore deserves attention in research and in practice.

The solar resource is vast and available in most places where electricity access is needed. The solar photovoltaic (PV) technology can be placed in or near settlements, is technically easy to operate, scalable and can be dimensioned according to shifting demands.

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[2] Village-level systems usually consist of a central array of solar cells in combination with a battery bank to store electricity for night-time use, and a local distribution system such as a mini-grid to connected households or a distribution system for pre-charged lanterns.

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Not least, compared with large regional or national systems, electricity systems at the village-level have some interesting features, which motivated our research. Village-level power supply systems seem able to provide a *larger portion of the population in each rural community* with access to electricity services than conventional grid extensions or solar home systems[3] in poor, rural communities [8,9]. This point is related to affordability, physical accessibility, and flexibility of use. Another advantage of village-level systems, in contrast to solar home systems, is that the investment in equipment and responsibility for operation and maintenance do not remain the responsibility of individuals but of implementing agencies and local entities, except for repair and replacement of appliances used within the house. Moreover, the development of village-level systems potentially gives end-users more influence in deciding how electricity may best be used to benefit the village as a whole.

An important question to ask in attempts to use village-level solar power is how it can actually be initiated and organized in practice to create electricity supply that can be sustained, expanded and scaled up, and meet the users' demand. As we have accounted for in another publication on the experiences with decentralized systems in India, which also provides an extensive review of the empirical literature [10], some of the challenges on the supply side include difficulties in getting access to financing of investment costs, insufficient training and support of local operators and lack of experience with maintenance and repair as well as supply chain for spare parts. Over time, the allocation of electricity among the users as well as the payment and revenue collection has also tended to be difficult. These challenges have negatively affected the potential to achieve economic self-sustenance, which is an important goal for village-level projects. Another core challenge in research and practice has been a lack of focus on the socio-cultural and gendered contexts in which electricity is introduced (for treatments of these issues see, e.g., [7,11]). Such knowledge is required for providing solutions for electricity that is affordable and accessible to all [10,12–14].

There is a strong need for increased academic and practical knowledge on how to develop approaches to village-level solar power supply that overcome such challenges and accelerate their implementation. There is need for solutions that can be implemented widely and contribute to societal transformation toward a more equitable and green global society. Many academic studies on off-grid electricity supply concentrate on technical and economic issues, for instance by focusing on providing cost-effective technical solutions and optimization of resource use [8]. However, more attention is needed in terms of how local energy systems can be socially organized and how the social and technical elements of the systems interact and affect the long-term viability of the systems. It is also important to give attention to contextual factors at different levels of society, such as the socio-cultural, material conditions and political factors which influence 'the room for maneuvering' during implementation and when the new energy solutions are provided and taken in use.

In this article, we present experiences from a demonstration project in which a solar-based energy center was established. The objective is to raise some central issues with regard to how village-level power supply can be socially organized, sustained, expanded and scaled up in order to achieve desired qualities mentioned above. The results derive from an action-research project carried out by a team of social scientists and practitioners from Kenya, India, Austria and Norway. The first part of the research included an in-depth case study on village-level solar systems in the Sunderban Islands in West Bengal, India. Then, building on insights obtained from the Indian example and other contexts, the team conducted action research in a remote village in Kenya. An innovative model for supply which took the form of an energy center gradually developed in close cooperation with the village community. This practical project was commissioned in March 2012 and has thereafter been improved and expanded.

In Sections 2 and 3, we discuss the theoretical framework and methodology. In Section 4, we describe the results of the action research in terms of the energy center model, some of the challenges encountered, and adjustments made underway. We aim to show how emerging practices of local actors influence and develop a local electricity system as it evolves over time. Our purpose is not to provide a case study of the experiences of one single locality. Rather, we use the conducted action research to demonstrate aspects that may be important to take into account in research and practice on localized solar power supply in general. In Section 5, we conclude with a critical analysis of the social and economic qualities of the power supply model, including the degree of access to electricity services among various groups in the community, and the system's degree of financial self-sustenance, long-term viability, independence and ability to expand. Dilemmas between such qualities are discussed. We also discuss the replicability of the model in terms of how governments, NGOs and private businesses could build on these results and other emerging initiatives for replication elsewhere.

2. Theoretical framework

Our research draws on concepts of socio-technological change and transitions to sustainability. (For a similar approach focusing on micro-hydropower in Tanzania, see [15].) This cluster of theories provide a useful perspective for examining the dynamic interaction between people and technology at various levels, including the way end-users contribute to the innovation of socio-technological systems such as village-level solar power supply. After explaining some key theoretical concepts below, a framework for the case study will be presented.

2.1. Understanding socio-technical change

The socio-technical systems perspective emphasizes that technology and society develop in mutual interaction – they co-evolve, creating socio-technical change, not only technological change [16–18]. Technology and society shape each other and are deeply intertwined. A co-evolution of the technical and the social takes place both at the micro-level of the practical use of the technology and at more structural levels of society where policies, regulations, and laws are interdependent with technological infrastructures and knowledge production.

A socio-technical system has been defined as a configuration of heterogeneous technical and social elements, including technical devices or artifacts, organizational aspects, involved actors and social practices in the implementation and use as well as competences linked to the technologies [19–21]. Power relations, discourses and meanings related to the technology and ways of using the technology are also important [7,22,23].

One may think of socio-technical systems in a macro-perspective, for example in terms of the global system for production and use of fossil fuel, which has held a hegemonic position within modern energy supply for decades. For such well-established systems, the comprehensive co-evolution process has led to integration and mutual adaptation between technologies,

[3] A solar home system is a system for individual buildings that consists of a solar PV panel in combination with a battery and a charge controller, supplying direct current (DC) electricity to run small appliances like CFL/LED lamps, fans and TVs.

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