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Article

Introducing Modern Energy Services into Developing Countries: The Role of Local Community Socio-Economic Structures

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Abstract: Sustainable energy technologies are widely sought-after as essential elements in facing global challenges such as energy security, global warming and poverty reduction. However, in spite of their promising advantages, sustainable energy technologies make only a marginal contribution to meeting energy related needs in both industrialised and developing countries, in comparison to the widespread use of unsustainable technologies. One of the most significant constraints to their adoption and broad diffusion is the socio-economic context in which sustainable energy technologies are supposed to operate. The same holds true for community-based energy projects in developing countries supported by the WISIONS initiative. Practical strategies dealing with these socio-economic challenges are crucial elements for project design and, particularly, for the implementation of project activities. In this paper experiences from implementing community-based projects are reviewed in order to identify the practical elements that are relevant to overcome socio-economic challenges. In order to systematise the findings, an analytical framework is proposed, which combines analytical tools from the socio-technical transition framework and insights from participative approaches to development.

Keywords: sustainable energy technologies; community-based projects; socio-technical transitions; WISIONS initiative

1. Introduction

The provision of modern energy services using renewable energy technologies offers multiple development opportunities to off-grid communities in emerging economies and developing countries. Several technical alternatives using renewable energy sources exist, which have proven to be adequate for responding to diverse sustainability challenges. Therefore, the promotion of these technologies is being widely sought as an essential part of the strategy aiming to alleviate poverty in developing countries [1–3]. However, although the deployment of renewable energy technologies has significantly increased in recent years, in terms of meeting the energy needs of individuals, communities and nations, the share of renewables remains rather low in comparison to conventional and fossil fuel based technologies. As a result, more ambition and decisive efforts are necessary to truly unlock their potential contribution to more sustainable development paths [4].

The transition to sustainable energy provision requires significant efforts in developing, testing and further improving technical innovations as well as in identifying and applying effective implementation strategies for those new technologies. It is not only technological issues that pose the greatest challenge; social and economical barriers are often even more difficult to overcome. There is no one-size-fits-all solution for the successful implementation of climate friendly technologies, but each initiative, project or programme gives rise to new findings and know-how that can help accelerate the transition process. The present study aims to build a framework for guiding the analysis and evaluation of the implementation strategies of community-based projects. The study is part of the on-going process of organising the findings of the WISIONS initiative. WISIONS was launched in 2004 and is supported by the Swiss-based foundation ProEvolution [5]. The aim of WISIONS is to improve the South-South and North-South knowledge transfer on good-practice implementation models for sustainable energy supply. The initiative provides financial support for the implementation of innovative energy projects and models via its scheme SEPS, Sustainable Energy Project Support. Over the last six years more than 50 projects have been selected for support—based on a framework of well-chosen sustainability criteria. In particular, community-based solutions have been supported, where residents are the beneficiaries as well as the agents of change.

Based on the experiences and findings from the WISIONS initiative, which is run by the Wuppertal Institute, this study starts with an overview of the relevance of socio-economic issues from both practical experiences and an analytical perspective in the process of innovation development adoption and diffusion. Subsequently, the explorative approach applied to review the design, and particularly the implementation, of community-based projects is described. The selected case studies from the WISIONS initiative are introduced in the fourth section. Results are organised and discussed in the fifth section. Based on the reviewed analytical perspectives, an analytical framework is outlined where the empirical observations are regarded as strategic elements for inducing socio-economic transformation during project implementation.

2. Towards a Framework for Understanding Community-Based Energy Projects

2.1. Lessons Learned—Experiences from Project Implementation

In the development of community-based energy projects local residents are not only the expected beneficiaries but also (and importantly) the agents of change.

Likewise, the socio-economic realities of the communities need to be considered as both "object" and "subject" in the design and implementation of project activities: (a) on the one hand, the underlying project goal is to improve the opportunities for social and economic development within a community; (b) on the other hand, achieving this goal requires the emergence of new social and economic structures, or the adaption of existing ones, which are able to overcome case-specific socio-economic obstacles.

(a) Socio-economic realities as "object": The implementation of sustainable energy solutions can contribute to improving the ability of individuals and communities to protect their livelihood and to unlock additional development options. The potential social and economic impacts are manifold and depend on the kind of energy needs that are addressed. Better conditions for education (e.g., lighting and access to modern communication and information systems), improved health conditions (e.g., running of cooling devices for storing vaccines and powering of medical equipment), and opening new or improving business opportunities (e.g., by providing the option to mechanise tasks) are some potential impacts that can derive from the reliable provision of electricity [6]. Innovations that improve the energy supply used for cooking may improve health conditions (by reducing indoor air pollution), free up time and/or reduce the cost associated with the provision of energy for cooking, or even contribute to improved sanitation (as in the case of some biogas options) [7].

(b) Socio-economic structures as "subject": Conditions that may hinder achieving the expected improvements are also diverse, as are the challenges of finding appropriate structures to drive the necessary changes. In the case of electrification initiatives, some notable aspects are: the need for broad consensus among different actors (e.g., users, future providers of operation and maintenance, administrative/governmental entities, suppliers of technology, donors, *etc.*) to ensure long-term success. Alternative finance mechanisms (probably involving a variety of actors) may be necessary to overcome the obstacle of financing the capital costs, which in most cases exceed the investment capacity of communities that do not have access to electricity. Adequate technical and managerial skills, as well as clear and widely accepted contracting practices and rules, are crucial in ensuring the proper and sustained operation, maintenance and management of power generation and distribution systems. In the case of technical interventions to improve cooking practices, some notable issues are: adopting new cooking technologies involving changes for users in their daily practices, of which the latter are most likely based on traditional methods and customs. Existing supply structures for appliances and fuels have evolved together with traditional cooking practices; diffusion of improved technologies will therefore require the adaption of those existing structures or the establishment of new structures. The exchange of products and services related to traditional cooking technologies does not always take place as a commercial transaction. The lowest income population, in particular, may depend on non-commercial structures for the provision of appliances or even fuel for cooking.

2.2. Two Analytical Perspectives of Socio-Economic Structures and Adoption of Innovations

Socio-technical transitions approach: The difficulty in overcoming the inertia to making the change from conventional energy systems is a substantial element of the political and academic agenda in industrialised nations. Important analytical efforts to understand the underlying mechanisms and forces that hinder the more rapid diffusion of sustainable energy technologies have (re)focused attention on the social construction of technology. From this perspective, socio-technical regimes can be understood as "relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and networks that determine the "normal" development and use of technologies" [8]. Regime shifts comprise multiple adaptations of skills and infrastructure at company level, but wider changes in terms of institutional issues (e.g., values, regulations, norms, *etc.*) that go beyond company structures are also needed [9,10]. The dynamics that can result in the transformation of the technological regime are better described in a "multi-level" perspective, as proposed by Geels [11]. In this context the regime may experience pressure to adapt from broader changes of economic, ecological or cultural trends (landscape level), from internal misalignment amongst regime actors (regime level) or from the growing relevance of new technological solutions that have been supported by a (generally small) network of actors outside the regime (niche level) [12]. Socio-technical niches play a crucial role in the development of innovations and, eventually, in influencing regime shifts. They are protected spaces for "societal experiments", networks of actors sharing expectations of new concepts for dealing with (also shared conceptions of) persistent problems [13,14].

The dynamics that lead to the emergence, structuration and growth of socio-technical niches are of special interest when it comes to induce purposive socio-technical transformations. This application oriented strand of research organizes the tasks for socio-technical transition management within a cyclical framework containing four governance activities [15–17]:

(1) **Problem structuring and establishment of a transition arena:** Activities in order to build both: shared understanding of problems and guiding principles for the envisaged solutions, as well as networks and partnerships that can provide "resources" (e.g., knowledge, legitimacy, capital, *etc.*) during the process.
(2) **Developing visions and pathways:** These are tactical activities where specific objectives as well as concrete concepts for technologies, managerial concepts, or even policies are conceived.
(3) **Execution of transition-experiments:** Based on the developed visions, pathways and concepts, practical measures are carried out (experiments). These operational activities generate new experiences, which will form the basis for further evaluations and adjustments.
(4) **Monitoring and evaluating:** These reflexive activities involve both monitoring the impacts (*i.e.*, whether expected changes are actually happening) as well as evaluating whether adjustment to the guiding visions and/or principles might be required.

Participative approach to development: The highly significant relevance of socio-economic structures in driving or hindering the adoption and diffusion of innovations has also been recognised by scholars and practitioners dealing with development cooperation projects [18,19]. As a response to the often disappointing experiences of top-down approaches to development in the early 1980s, interest grew for more participative and learning-based approaches to development [20–22]. The central idea is that the project beneficiaries are not simply passive recipients of assistance but the key actors in the process of shaping social and economic development in their own local context. In this approach, understanding local realities is regarded as a key component of project design and implementation; this entails considerations such as recognising the "actual" needs of the population involved, the existing capabilities (e.g., organisational, technical, managerial, *etc.*) and the potential inputs from the local population. In this context, implementation tends to be a rather gradual process, where progress is uncertain and requires a flexible managerial approach and strong capacities for on-going problem-solving.

2.3. Community-Based Projects in the Light of Both Analytical Perspectives

Both analytical perspectives, the socio-technical transformation and the participative approach to development, offer valuable insights into the structural challenges faced by projects aiming to introduce innovative energy solutions to the socio-economic reality of communities. From both perspectives the process takes on a rather evolutionary character, where designs, user practices and perspectives as well as local socio-economic structures coevolve, so that innovations become part of people's daily routine. In the context of socio-technical change, community-based energy projects offer experimental spaces where innovation is nurtured, *i.e.*, artefacts as well as institutional structures and practices can be tested and adapted in order to give an appropriate response to the specific energy related needs of individuals and/or the community. Building alliances between actors, articulating expectations, securing "protection" for and learning from experimentation are all key functions to facilitate the process [23].

The participative approach to development offers detailed insights into organisational and managerial practices that facilitate the bottom-up building of local capacities. The implementing organisations become facilitators, which ensures the reshaping of socio-economic structures and the transformation of existing development practices [24]. In this way, project activities may lead to the (re)configuration of networks of local and external actors that are able to supply services and goods related to the provision of modern energy services.

Although both analytical frameworks offer valuable insights, they provide little indication about more concrete elements regarding the design and, particularly, implementation of community-based energy projects. Although many socio-economic challenges faced during the implementation of energy projects are common (e.g., social acceptance, motivation and consensus, shaping new supply structures, establishing adequate finance mechanisms, *etc.*), strategies to deal with these challenges should be adapted to each project's particular circumstances. This know-how is a crucial "asset" of implementing organisations with considerable experience in the field. The following analysis aims to identify the practical components that play a relevant role in dealing with socio-economic challenges during the implementation of community-based projects supported by WISIONS. Subsequently, we will attempt to organise these empirical observations using tools and insights provided by the analytical approaches described.

2.4. Applied Methodology

An explorative empirical approach was adopted in order to identify components that contribute to overcoming socio-economic constraints faced by projects aiming to improving energy access in rural communities in developing countries. Therefore, the experiences from community-based energy projects that were implemented with WISIONS support have been analysed. Standardised documentation, which is part of the communication between the implementing organisations and the WISIONS team, was used as base data.

The first step describes the main objectives and core activities of the different projects, followed by a detailed analysis of activities, measures and strategies taken to meet the socio-economic challenges faced. The relevance of different strategies in the creation of more favourable socio-economic conditions for the adoption and the long-term use of energy technologies is then discussed. As a result of these previous steps a general framework is established which organises project components in terms of their relevance for the implementation of community-based energy projects. The proposed framework is an attempt to combine central elements of the socio-technical transition approach and the participative approach to development with experiences made during technology applications.

3. Case Studies

In the following chapter four projects, which have been successfully implemented under the WISIONS supporting scheme "SEPS-Sustainable Energy Project Support", are presented as case studies. All four project models have a participative implementation approach. The projects are located on different continents, apply different renewable energy technologies and represent different kinds of (participative) implementation models. Table 1 gives an overview of the four case studies and the strategies adopted to meet the socio-economic challenges. For more detailed information regarding the four case studies please visit the project website [5].

Table 1. Overview of analysed case studies.

	Project A Karnataka, India	**Project B Cajamarca, Peru**	**Project C Xiengkhuang, Laos**	**Project D Kagera, Tanzania**
Energy Need	Cooking	Electrification	Cooking	Lighting & low power electric services
Technology	Biodigesters & small biogas distribution network	Stand-alone wind energy systems	Improved biomass stove	Solar PV & LED lamps
Assessment of User Requirements	Baseline assessment of cooking needs & socio-economic aspects	Socio-economic baseline survey of all households	Suitability assessment of new stove designs with direct involvement of households	No baseline assessment, resulting in adjustment during implementation
Awareness Raising & Motivation	Continuous interaction with local committee & integration of income generation opportunities	Information activities according to actors: users, potential entrepreneurs, local authorities	Integrated information/training activities addressing different actors: organisations, users, manufacturers, retailers	Integrated information/training activities addressing manufacturers/entrepreneurs
Support Structures	Establishment of local committee based on well known & accepted practices	Establishment of local committee based on well known & accepted practices	Close cooperation with well-established provincial organisations	Cooperation with an organisation working in the region & involvement of local micro-finance groups

Table 1. *Cont.*

	Project A Karnataka, India	Project B Cajamarca, Peru	Project C Xiengkhuang, Laos	Project D Kagera, Tanzania
Management System	Cooperative enterprise for dairy business & biogas distribution	Communal implementation; operation & management by local entrepreneurs	Fostering the establishment of a regional supply chain	Local manufacturing "micro-factories", maintenance and marketing of low cost lamps.
Capacity Building	Training in operation/ management tasks, support & adjustments during start of operation	Training activities, according to future roles of actors, support & adjustments during start of operation	Learning by doing and learning by using. Support to provincial organisations	Intensive training of local entrepreneurs

3.1. Project A: Small Scale Biogas Digesters in Rural India

This project was implemented by the Asian branch of the International Energy Initiative (IEI). The aim was to establish small enterprises in rural areas in Karnataka, India, to provide biogas as clean cooking fuel. This enterprise consists of a dairy for income generation and associated household biogas supply systems, replacing the existing traditional biomass stoves. The biogas requirement per family was estimated on the basis of the present biomass use. To meet the needs of all the village families, eight biogas plants were planned (six of 8 m^3 and two of 10m^3 capacity). To deliver biogas to every household, a mini-grid piping system was installed between each digester and the group of households it serves. Each kitchen is provided with a double-burner stainless steel stove. Based on suggestions from the users regarding their cooking timings, gas is provided for three hours every morning and one and a half hours every evening.

Integration of participative strategies and socio-economic aspects: The project site was selected based on interaction with local organisations and a survey of ten villages in a neighbouring district. The focus was on economically disadvantaged areas, indicated by the level of possessions and the dependence on daily wage labour. To ensure the involvement of all families a village assembly, grama vikas sabha (GVS), in which each household is represented by one member, was formed under the guidance of the project implementing organisation. This was followed by a formal agreement between the GVS and IEI, the implementing organisation, regarding the proposed energy enterprise. The dairy is operated in a labour-intensive manner, in order to provide employment and income to the unemployed villagers who were trained to carry out the required tasks such as collecting and transporting substrates, feeding and maintaining the biogas plant. A competent supervisor was appointed (from a neighbouring village) to oversee the activities and to keep records and accounts, with an assistant from within the village. The accounting system consists of the daily recording of inflows and outflows and weekly verification and electronic recording of the relevant details by the implementing organisation (IEI). *(All information is based on the "Final project report", submitted to WISIONS by IEI)*

3.2. Project B: Small Wind Power Systems in an Andean Village in Peru

The project was designed to electrify a rural community, including a school and a medical centre in a village in Peru. The selection of the village was based on the wind potential and the willingness of the authorities and the population to contribute to the project. The project, which was carried out by ITDG Peru, started with a detailed socio-economic survey on energy demand within the community and the current expenditure on energy. Based on the results it was decided to provide independent power for each building. As a result, 22 stand-alone wind power generation systems were installed in 2007 and 13 additional systems were set up in 2008. The implementation of the projects was based on the active and effective participation of the community in almost every aspect. The District Municipality took over the legal ownership of the electrical systems and, to ensure the future sustainability of the project, a local management model was established.

Integration of participative strategies and socio-economic aspects: Baseline information about the community was collected during the first phase of the project. It included two main aspects: (1) basic data on potential users, such as the average income of households, current energy use and cost, and (2) information about the community organisation, such as the number and kind of local associations, as well as a qualitative assessment of the perception of individuals towards those organisations. In general, both aspects were shown to be favourable. To facilitate communication and coordinate activities with the community, a local "electrification committee" was established. Their main tasks were awareness raising and organising local logistic and labour contributions. ITDG Peru further applied an interaction model, which takes into account social and political structures and relationships. It consists of four actors (owner, private entrepreneur, control unit and users), whose responsibilities and interactions are ruled by written contracts and/or customary norms. The basic features of the model are: the owner of the system hires a (local) private entrepreneur who takes over the operation and maintenance of the systems and the collection of fees from the users. The entrepreneur, on the other hand, closes individual contracts with the end users. A "control unit" is established with representatives of the owner entity and the users. The control unit supervises the services provided by the entrepreneur and acts as the conciliation and decision entity for the whole system. Furthermore, several information and training activities were carried out. These included technical basics and the maintenance of small wind power systems, electro-technical basics for household installations and managerial instruments for small energy entrepreneurships. Once the training was completed the responsibility for the system was transferred to one of the trained technicians. During the initial months, the entrepreneur received intensive support (guidance) from the team of ITDG. At the time of the last visit scheduled within the implementation strategy, in May 2009, the management model was functioning and the perception of the users towards the system was very positive. Some families were already using electricity to set up and run small businesses such as a radio broadcasting station, a sweater-making business and a cheese factory. *(All information is based on the "Final project report", submitted to WISIONS by Soluciones Practicas)*

3.3. Project C: Promoting the Diffusion of Improved Wood Stoves in Laos PDR

The aim was to introduce more efficient wood stoves to an area suffering from fuel wood shortage in Laos. The project consisted of three phases: (1) Within the first phase, two stove types were tested by locals with the intention of collecting information on the suitability of the stove models for the local conditions and of measuring and comparing fuel wood consumption. The improved cook stove design chosen for the project was not the most efficient stove design but the most suitable for the local conditions. (2) In the second phase, local artisans were trained in the manufacture of the improved stoves. At the same time a promotion campaign was started to target potential users. (3) In the final stage of the project the results were published and disseminated among provincial and national authorities. By the end of the implementation period a final survey on the end users' perception was carried out. More than 90% of surveyed users perceived a significant reduction in both smoke and firewood consumption.

Integration of participative strategies and socio-economic aspects: The project was proposed and coordinated by the Technology Research Institute (TRI), an organisation that is part of the Prime Ministers Office of Lao PDR. It provided the technical and managerial skills for the realisation of the project. The cooperation with two provincial organisations was crucial, as they provided local staff and access to local networks. The active involvement of end users, particularly women, was a crucial requisite for determining baselines and evaluating the performance of new stove designs. Transferring know-how to local manufactures was part of the activities designed to trigger commercial supply structures for the improved stoves. As well as training, special tools to manufacture the new designs were also provided. Furthermore, a promotional campaign was launched in order to trigger the demand for the improved stoves. For this activity the women's union took the leading role by making use of its network and the regular activities of its village branches. Three public events attracted over 600 people and the first 127 stoves from local manufactures were sold. Although retailers became interested in offering the new stoves, many of them were not willing to take on the risk of investing in a first trial. To overcome this barrier the project team decided to fund an initial market trial. During the whole project the staff of the TRI provided assistance to the manufacturers and the women's union in order to solve different technical problems. *(All information is based on the "Final project report", submitted to WISIONS by TRI)*

3.4. Project D: Village Micro-Factories in Tanzania for LED-Based Household Lighting Systems

This project, implemented by CAMCO, sought to improve access to low cost LED lighting systems by establishing local micro-factories at village level in Tanzania. Two types of lighting systems, designed for use in developing countries by a US based company (Green Energies LLC) were selected. The systems combine local low-cost materials, such as empty water bottles and imported components (manufacturing toolkits including PV solar cells). At the beginning the project team identified existing local groups as suitable local entrepreneurs. These entrepreneurs were trained to produce and maintain the lights. During the project 7 micro-factories were established, which have sold 270 LED lighting systems to rural farmers to date.

Integration of participative strategies and socio-economic aspects: Several aspects affected the acceptance and success of the project. First of all, existing local groups were convinced of the benefit to take part in the project and to build up the micro-factory groups. This meant that there was no need to establish new groups, which would have required time and often entails potential conflict. Also favourable for the project was the fact that due to the former political system, many community groups exist in Tanzania and the people are used to working in collective groups. Secondly the project has benefited greatly from an ongoing programme carried out by SCC-Vi Agro-forestry. The SCC-Vi Agro-forestry local project worker was the contact person for the communities and collected the funds for the purchase of the new components from the United States. The financial management system was another important aspect in the implementation. The manufacturing tool kits for the first installations were loaned to the micro-factories with payment only being made once all the systems had been assembled, installed and sold. The groups were trained in management issues and made their own decisions about the price of the single lighting system and their profit margin. On one hand, the responsibility for the marketing success fully rested in the hands of the local groups while, on the other hand, the burden of the financial responsibility was lowered by the loan. In parallel the future acquisition for new lighting systems was assured. All project steps together led to the identification of the local groups with their new business. The local groups actively solved any problems that surfaced during the project. *(All information is based on documentation submitted to WISIONS by Camco, Kenya)*

4. Results—Strategies for Dealing with Socio-Economic Challenges

The four case studies represent exemplary project models that aim to implement modern energy services in communities with poor energy supply. In all examples it becomes apparent that various aspects affect the performance of the projects and influence their success, regardless of technical feasibility, suitability or geographical conditions.

The most striking and common socio-economic components are highlighted below. They are arranged in five categories following the chronological course of the implementation process:

- User requirements and acceptance
- Raising awareness, motivation and identification with the project
- Support structures for implementation
- Configuration of management and financial system(s)/business and financial management
- Capacity building to ensure project provision and sustainability after implementation period

4.1. User Requirements and Acceptance

Clearly, it is essential to target the specific (energy) requirements of the users and try to meet their needs. To ensure that these needs are met, it has proven to be helpful to analyse the users' needs before choosing an implementation strategy. The experience with the four sample projects showed that it is important to continue gathering feedback during the whole implementation process.

In the Indian biogas project the detailed survey of the specific user requirements was important for the acceptance and success of the biogas system that was introduced. The dairy and biogas plants were constructed based on the average daily household need for cooking. This level was doubled to ensure supply for future increases in demand. In addition, the delivery of gas was based on user suggestions regarding their cooking times. This meant that gas was not being provided all day, but at times when it was needed most. The miscalculation of these needs could have led to the failure of the whole project. In the Tanzanian LED-lighting project the requirements of the users were not totally covered by the new technology. The need for energy to charge mobile phones was not considered. In addition, the brightness of the lights was not sufficient for all rooms and potential users did not appreciate the unattractive design of the lights. In general, technologies that are used in urban areas or industrialised countries often have a better reputation compared to low-cost appliances made for poor rural populations. In the Peruvian wind project, a socio-economic survey was the first stage and this ensured that energy needs and the potential financial contribution of each household could be estimated on a realistic basis. Furthermore, the information gained about the community structure and organisations helped to design the appropriate form of management. To evaluate the performance of the new stove design in Laos, participating "test-households" were involved through questionnaire surveys and direct interviews. During the market introduction of the stove, additional user surveys found quality defects in the manufacture. After some analysis and tests with different clay mixtures, an appropriate ratio was found that better matched the mineral characteristics of soils in the region.

4.2. Raising Awareness, Motivation and Identification with the Project

All four projects presented in this study depended on the active participation of the community members and technology users. To engage the communities in the project areas it was important to raise awareness and encourage users to identify with the projects. This step contributed significantly to the successful implementation of the four projects.

In Laos the user workshop and promotion campaign were important for raising awareness about the advantages of new efficient stoves. The local manufacturers, who were supposed to include the new stove in their product portfolio, and the local stove retailers, were not easily convinced. This meant that the initial financial risk for the new stove had to be covered by the project organisations. In the Tanzanian lighting project, the entrepreneurs had to be motivated during the training workshops at the start of the project, because after the training the implementing organisation left and the manufacturers were responsible for the production, quality, marketing and installation of the lighting systems. Only the financial burden of the initial investment for the materials was covered by the project grant. As a consequence, the entrepreneurs were responsible for the success or failure of the project and they accepted this responsibility. The information on how to use the wind electricity system in Peru was presented in an illustrated brochure that could be understood by all villagers, including children and illiterates. In combination with an information workshop at the beginning of the project, these measures helped to prevent the misuse and overcharging of batteries and also helped to lower the users' expectations. The fact that the local radio station runs on the new electricity system and that new small businesses were established also increased the acceptance. Likewise the new dairy and biogas plants in the Indian village changed the life of the community. To ensure the equal participation of the villagers, a grama vikas sabha, a common form of Indian community group, was founded with one member representing each household. All households receive equal levels of biogas and have had to adapt their cooking to the use of biogas stoves. In addition, fresh milk became available from the dairy and several villagers secured work there, which also increased the acceptance of the project.

4.3. Support Structures for Implementation

Experiences show that communication between the implementing organisations and the local population is not always easy. To facilitate and improve the communication process it has proven to be helpful to work with local committees or similar associations. In the regions where the sample projects were implemented, different kinds of community associations already existed. Our analysis confirmed that working together with these organisations was a key step to facilitate implementations of the four projects. These structures also supported the coordination of activities that involved active participation of the local population. The participation in certain activities (e.g., transporting materials or carrying out civil works) had further positive effects in the communities, e.g., strengthening their identification with the project, building practical skills and reducing cost.

In Peru the windmills were set up collectively by all villagers, which helped them to identify with the new technology. For the development of an adequate management system the existing committee structure and perception of the villagers were analysed and later adopted. In Laos the cooperation with existing local women's groups and other local and provincial organisations was crucial, particularly for the testing and marketing phases. Also in Tanzania, the involvement of existing local microfinance groups and the connection of the project with a regional long-term programme for local farmers significantly contributed to the project's successful completion. In the case of the Indian village, the support structure can be seen in the selected community itself. All villagers belong to the same low-income group, which minimises the inequalities. The implementing agency had learned lessons from observations from other projects that had failed because of perceived inequalities (e.g., only those owning cattle had to supply dung), or those that were restricted to private endeavour (e.g., those households who could afford the costs had their own plants). It was also helpful to use the local tradition of establishing a grama vikas sabha as a democratic committee/decision group. The people were used to this kind of group and therefore accepted the concept.

To sum up, for the projects outlined above, it would have been very time consuming and also risky to establish new or different group structures in the relevant communities. Using existing and known group structures is a significant success factor for community-based energy projects.

4.4. Configuration of Financial Management and Business System(s)/Business and Financial Management

For long-term success, beyond the initial implementation phase and after the outside project team has left, it has become apparent that it is important to set up a sound and well-structured management system. To form such a management system, the local situation and community structures have to be taken into consideration. Empirical research has shown that weak management systems with no clear responsibilities have a high risk of failure, including the risk of corruption or favouritism. Particularly in cases where external control or supervision is not possible, these aspects have to be taken into account. Some common aspects considered in the four case studies include: defining ownership of the equipment; defining the responsibilities for operation and management; setting a scheme of tariffs or prices; and establishing entities responsible for supervising, conflict solution and decision-making.

Particular attention was given to cultural particularities and power structures that facilitate the configuration of appropriate management systems. These settings of "rules of the game" helped to assure the provision of e.g., electric power and other related services.

On the financial side, the high initial costs are often a barrier for the users/buyers, who normally belong to low-income population groups. This barrier can often be overcome by either supporting the initial investment or bridging the investment through loans or revolving funds. The latter is also helpful for ensuring funding for expenses such as maintenance or to fund further project extensions.

In the Indian biogas system a new enterprise was established, meaning that the management system had to be developed with great care. Both the dairy and the biogas plant are sensitive systems that need to be well organised to run efficiently, so the sound management of the technical processes also had to be ensured. The implementing organisation stated that, in particular, feeding the biogas plant had to be regulated. Consequently the management system included clear and fixed tasks and responsibilities: daily accounting and a transparent and fair payment system. For the recording, an external supervisor from a neighbouring village was recruited.

4.5. Capacity Building to Ensure Project Provision and Sustainability after Implementation Period

Based on the analysis it can be stated that technical and managerial skills are a key asset to ensure the continued operation of the implemented energy systems. Local technicians have to be trained to be able to tackle failures of installed systems. Additionally, electrification measures can include components that promote the productive use of electricity in order to enable income generation activities and improve the overall financial sustainability of projects. The promotion of the productive use of electricity can for example include training in entrepreneurship and support in accessing new markets.

All four projects considered this aspect and technical training was always one of the first implementation steps. Even in the case of this technical training, the particular conditions of the location must be taken into account; e.g., for the dairy activities in India, it took longer than expected to train the employees in the daily routine required as they did not have regular employment before the enterprise was established. This fact had not been considered in the planning process.

5. Discussion. Outlining an Analytical Framework for Community-Based Projects

The common aim of community-based energy projects is to ensure the long-term adoption of innovations, which have evolved to a point where they provide an appropriate response to people's energy related needs. As discussed before, the fulfilment of this objective requires a socio-economic transformation. This means that community-based energy projects can be understood as interventions aimed at *triggering* and *accompanying* transformative processes within socio-economic structures. The chosen field of intervention commonly coincides with small geographical and/or administrative areas. Within the context of the participative development approach, implementing organisations are understood as facilitators of transformation. Therefore, emphasis should be put on the wording: "triggering and accompanying". This recognition of the need of endogenous transformative dynamics is consistent with observations from complex system theory, which indicate that external entities may have some influence in the processes. However, ultimately, the actual system's reshaping is the result of negotiations within the system itself [25].

The transformative task appears to be clearly recognised by the organisations implementing the case studies. Establishing local structures that are capable of delivering the services and products related to the new energy solution is a clear objective of the implementation strategies. Already available capacities constitute the basis for establishing those new structures; e.g., available models of community organisations like the case of grama vikas sabha in India and community committees in Peru; organisations with long track records in the region such as the women's groups in Laos and the agro-forestry program in Tanzania; existing entrepreneurial activities, like traditional stove manufacturers in Lao and local micro-finance institutions in Tanzania. Transferring know-how and developing skills are the central means of upgrading or building the required capacities within the local structures.

The project implementation period can be seen as a transition phase from the current state (use of traditional practices, energy needs that are not fulfilled and/or linked to detrimental social, economic and environmental effects) to a target scenario where innovative (more) sustainable technologies are a real option for individuals, specific sectors or the community in general. The implicit assumption of each community-based project is that by implementing the planned activities a socio-economic transformation would take place where the target scenario can emerge. In this way, the implementation period represents the experimental setting to test the validity of that implicit assumption. As an experiment, the possibility of adjusting/modifying certain variables is central. In the case of energy projects these variables can be elements such as features of devices, practices (of users, suppliers or other actors) or institutional arrangements. The experiment also requires a "feedback loop", *i.e.*, a monitoring function to identify possible failures and unexpected or undesired effects.

Examples for on-going problem solution and adjustment can be found in the analysed case studies: modifications of technical features according to feedback from users (finding an adequate clay mixture for the stoves in Laos or offering additional services to users of PV LED solutions in Tanzania) and adjusting implementation plans (the decision to support the first trial of stoves for commercial distribution in Laos or the decision to hire a person from a neighbouring village in order to bring expertise and neutrality to the dairy cooperative in India). Because undesired or unexpected effects may appear during any stage of implementation, assuring effective communication between actors involved in the projects emerges as a central issue. This monitoring function can also cover planned activities, like the interim surveys of users' perceptions in the case study in Laos.

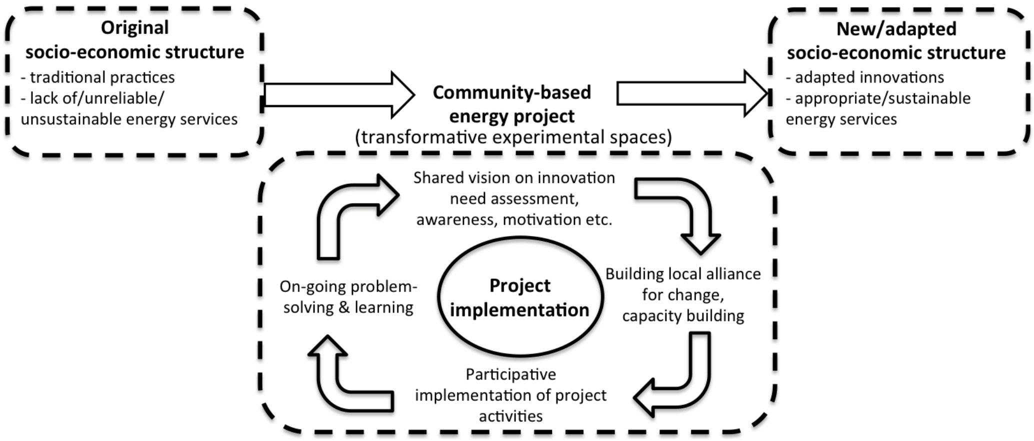
The transformative and experimental character of community-based projects stresses the contradictory field in which project management takes place: On the one side, achieving motivation and identification of local actors with the project may require some sort of certainty of the expected positive outcomes. On the other hand, the transformative task of community-based projects implies a certain level of novelty, which actually increases uncertainty. Novelty can be found in different components of the project concept. Some notable examples are: new devices (wind turbines); new technical features of known devices (improved stoves); new procedures for operation (collection transport, mixture of substrates in order to feed biodigesters); new interactions among actors (setting a system of feeds for electrification services and the required rules and contracts).

Analytical tools for understanding and bringing into operation this complex challenge of influencing societal change towards a vision of sustainability can be found in the literature on socio-technical transition. One central assumption is that societal change is a result of the interaction between relevant actors at different levels. And although it recognises that the inherent complexity of societal systems implies a low level of control, it suggests that "there are generic patterns and dynamics that could allow for intelligent forms of planning based on learning" [16]. In this context the process of influencing socio-technical (purposive) change entails four basic governance activities: strategic, tactical, operational and reflexive activities [16,26]. This approach to socio-technical transition management has been mainly applied in the context of industrialised societies. However, the concept of influencing societal change can also describe the implementation process of community-based projects in developing countries, such as in case studies presented here. The implementation strategy of such projects can be understood as an interrelated group of activities providing the means to meet four fundamental functions:

(1) **Developing a shared vision** of innovative solutions for specific energy needs. This may include assessment of actual needs, awareness about the potentials and limits of a new technology, creating motivation amongst the target population and/or strategic actors, *etc.*
(2) **Building local alliances** that support the transformation process. Some common elements of this function are concluding cooperation agreements with existing organisations, setting up training activities to improve or build technical, managerial or other capacities.
(3) **Participative implementation of activities**: Active participation of the local population and/or organisations can take different forms, such as the direct contribution of resources (e.g., labour, capital or land) or assuming the coordination of specific activities.
(4) **Continuous learning and problem solving**: This is the recognition of the experimental character of community-based projects, where progress is uncertain and requires on-going interaction. The central elements of this function are the establishment of mechanisms for gathering feedback from all relevant actors; some practical examples are the scheduling of surveys of user perceptions and building clear communication channels between involved organisations.

These functions do not necessarily take place in a successive manner but influence each other interactively. They are the means to create and maintain the experimental and transformative space needed to move towards socio-economic structures, where (more) sustainable energy practices are applied and further developed. The proposed framework is schematically described in Figure 1.

Figure 1. Community-based energy projects as "transformative experimental spaces" and the implementation activities as an iterative process.



6. Conclusions and Outlook

The real significance of socio-economic structures in driving or hindering the adoption and diffusion of sustainable energy technologies has been recognised in both contexts, promoting sustainable consumption and production structures in industrialised nations as well as shaping opportunities for sustainable development in developing countries. Correspondingly, local socio-economic conditions often turn out to be the most challenging obstacles to overcome for community-based energy projects.

All the case studies reviewed in this article already included strategies that addressed specific aspects of the socio-economic conditions of the communities involved. Such strategies are not only found at a single stage of the implementation, they are present along the different phases of the whole intervention process; from the initial assessment of actual needs, through setting up support structures for the implementation, to establishing appropriate business/management models to ensure long-term operation and necessary capacity building amongst local/regional actors.

The analytical framework outlined is based on the four central functions for enabling socio-technical transition, which do not necessary take place in a successive manner, but rather influence each other interactively:

(1) Developing a shared vision of innovative solutions for specific energy needs
(2) Building local alliances supporting the transformation process
(3) Participative implementation of project activities
(4) On-going learning and problem-solving

The practical strategies applied in the analyzed case studies can be well organized as activities for fulfilling these four central functions. The framework offers an analytical basis to compare the implementation strategies of different types of community-based energy projects. This kind of "ex-post" analysis, combined with an assessment of the long-term impacts of projects, may bring additional insights into the inherent mechanisms that determine the success of community-based projects in triggering socio-technical transformations at a very local (micro) level.

The framework outlined implies a rather unconventional approach to community-based projects. It presents the project implementation period as an "experimental space". In this kind of space, the actors involved can test but also adjust the new practices. Additionally, an underlying aim of the experiment is to induce a purposive transformation of the socio-economic structure. Under the new socio-economic configuration the use of superior (more sustainable) energy solutions becomes common practice. The experimental character of project implementation opens up questions regarding the way supporting programmes are designed and how to evaluate the progress of single projects. Fixed terms of reference or other forms of requirements could prevent the introduction of changes in-progress that might improve the outcome of a project. Framing the requirements of a programme in a way that reflects the experimental nature of community-based projects may help to improve the impact of both supporting programmes and single projects.

Conflict of Interest

The authors declare no conflict of interest.

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