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BUSINESS MODELS FOR RENEWABLE ENERGY BASED MINI-GRIDS IN NON-ELECTRIFIED REGIONS

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ABSTRACT: Access to electricity is a matter of course to most people on earth. Still there are far too many people that do not have the possibility to use electricity either privately or for business. Renewable energy based mini-grids can be a solution for electrifying rural regions. The past has shown that mini-grids can be established through grants but this is no option for the large majority of the 1.3 billion people still not electrified. For guaranteeing sustainable energy supply, business models have to be developed that are profitable for all players involved. This paper demonstrates reasons for failure of mini-grid projects and shows key elements for success of sustainable business models for renewable energy based mini-grids. Finally two examples for existing best practice models are presented: KAÏTO Energie and INENSUS.

Keywords: business model, mini-grid, photovoltaic, rural electrification

1 MOTIVATION

There are 1.3 billion people without access to electricity worldwide [1]. Especially in Africa and South-East Asia there are countries with high population but only few people have access to electrical energy. Most people without electricity are living in rural areas far away from the national grid. However, electricity is the essential basis for the improvement of elementary needs like light, communication, education, health and safety. Further, electricity is often the first step leading to commercial and industrial activities. In consequence of rising fuel prices, renewable energies become more and more interesting and especially photovoltaic (PV) systems are an adequate technology for rural electrification since it is easy to install and to maintain while solar energy is available everywhere for free. Several PV-based off-grid systems are available on the market [2].

Solar home systems (SHS) are one kind of possible PV system types bringing electricity to rural regions. These systems for single households' electrification are suitable for very small energy needs and involve small investment costs. Mini-grids on the other hand can offer whole village electrification and are flexibly expandable to react to growing demand. Mini-grids have much higher investment costs than SHS but by reason of higher power and flexibility they offer the chance of commercial usage and economic growth. A mini-grid requires people living close to each other in a village or a settlement. Otherwise long electric cables make the investment rise substantially and the system uneconomic. For scattered houses SHS are much more suitable.

Due to the additional focus on commercial and industrial activities in this work, mini-grids are emphasized in the following. An overview of literature reports on mainly PV-based mini-grids is given by Werner and Breyer [3]. Self-sustaining island systems often provide the only opportunity to bring electricity to people living in rural areas and to grow local economy.

The technology of self-sufficient mini-grids does work well and is sufficiently tested. Cader et al. show that PV-based mini-grids are economic in many parts of the world [4]. Payback times calculated in comparison to diesel grids indicate that PV-based mini grids are not only technically favorable but profitable as well. Nonetheless there seems to be hardly any public renewable energy based mini-grid which works without subsidies, yet. But systems granted by donors are not a viable solution. It can be a way to help some of the people concerned but to help all of them sustainable business models have to be established so that a win-win situation for all players leads to reproduction and spreading.

The aim is to bring electricity to those in need of it by not only providing the system, but by establishing sustainable business models which guarantee serving energy on a long-term and might be reproducible. The challenge to demonstrate cost effectiveness of mini-grid systems is that it is about regions which are not electrified yet. For regions with running power plants like a diesel based energy supply, it is easier to demonstrate cost effectiveness by calculating electricity costs for a hybrid system against the present costs. However, in poor regions without access to electricity, people often have high costs for poor quality energy solutions [5], but costs are to assess and hard to compare with those of hybrid systems or diesel generators.

Key elements for sustainable business models have been figured out by literature analysis and experts interviews. They lead to an overview on reasons for failure and success of business models for renewable energy based mini-grids in non-electrified regions. Insights are presented, in particular which players are involved in an electrification project and what role they have to fulfill. Existing best practice examples show how this can be successfully realized.

2 METHODOLOGY

The key question has been to figure out market potentials and requirements for sustainable mini-grid business models. To analyze the actual situation concerning renewable mini-grids, first a literature overview has been created and analyzed. In that step, literature dealing with mini-grids has been evaluated related to their focus. In total about 150 papers and reports have been taken into account, published mainly during the last 15 years and covering most off-grid regions in the world. Documents like the report “Hybrid Mini-Grids for Rural Electrification: Lessons Learned” of the Alliance for Rural Electrification (ARE) [6], or International Finance Corporation (IFC) report “From Gap to Opportunity: Business Models for Scaling Up Energy Access” [5], have been top rated for their comprehensive characterizations of lessons learned or recommendations concerning business models. These documented lessons learned have been basis for the following step.

In a second step a questionnaire-based interview has been prepared and carried out with 21 experts from the field of rural electrification having different backgrounds including research, consulting, project development, finance, system integration or operation. Answers and insights have been analyzed and reasons for failure of business models have been collected. Key elements for success have been identified and a structure has been developed to systematically show the constellation between different players of an electrification project and their functions needed for sustainable renewable mini-grids. First approaches for sustainable business models have been found and are presented in this paper. In parallel a country ranking has been generated containing relevant requirements of a country being considered for starting business models of PV-based mini-grids. Results are published separately [18].

3 RESULTS

3.1 Reasons for failure of mini-grids

Failures of mini-grids in the planning-phase are often caused by political conditions and financing problems. Governmental licensing procedures can be complex and take a long period of time without certainty of success. Often there are no regulations concerning mini-grids in the laws of a country, which can lead to tough negotiations. For this reason, a government’s attitude towards renewable energies and mini-grids is of high importance as it can create or remove barriers [5] [7]. Secondly, high import tariffs can increase the already high investment costs and with it tighten the financing problems. Third, the availability of credit is poor because of high transaction costs, excessive financial payback periods, uncertainty of political stability, currency risks and a lack of confidence from banks to project development.

Operating mini-grids often fails through high running costs when these are not covered by tariffs [6] [11]. The same problem occurs for reparation or spare parts if reserves are missing. Maintenance is complicated if there is no local expertise or the responsibility is not assigned clearly. Further problems can be caused by disregarding local culture and people or the impact that electricity can have on the people [8].

3.2 Key elements for success

The key elements of success have been determined and separated into three categories. They are listed below:

Cultural Aspects:
- Communication with community
- Integration of local participants
- Training of users and operators
- Clearly defined responsibilities
- Generation of commercial activities
- Patience

Economic Aspects:
- Cost covering and affordable tariffs
- Consideration of financiers’ requirements
- Reserves accumulation

Technical Aspects
- Guarantee of reliability
- Ensuring maintenance
- Establishment of technical expertise on site
- Creation of expandable system

However, solutions always have to be cultural adjusted and a mini-grid has to be recognized as a comprehensive organizational challenge. Further it is important to address the financing early.

3.3 Levels and participants of electrification projects

To show the relevant players of electrification projects, three different levels have been identified. One is the premise level, one the operational level and linking those two is the level of project development. Figure 1 shows the levels with the respective participants. Important for a sustainable business model is, that each player involved in the project is able to benefit from it [12].

At premise level there are governments, investors and financiers, as permission aspects and financing of a system have to be clarified before integration and operation. The operational level is represented by operator and customer. This combination has to work for the whole duration of the system and thus has to be prepared very well. Between these two levels the system integrator acts as project developer. Significance of this level becomes comprehensible by realizing that the system integrator has to plan successful operation on a long-term having only short time slots themselves and probably being confronted with vague general conditions.

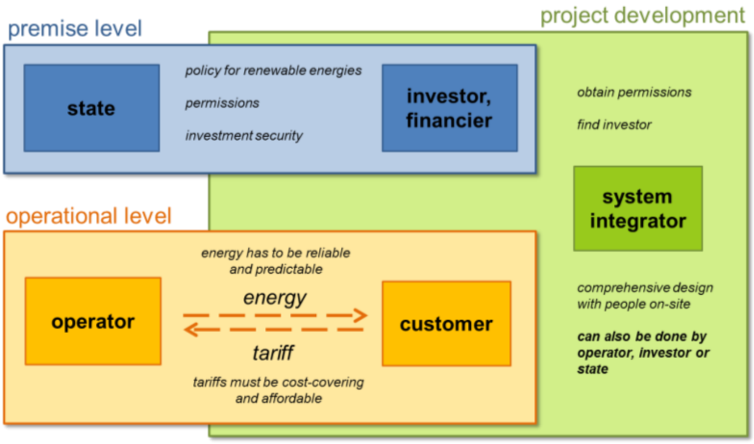

Figure 1: Different levels of players for electrification projects.

3.3.1 Premise level

Conditions for electrification projects regulated by the state are highly dependent on the government's position on to renewable energies and private energy supply. Skepticism or denial can be reasons for big hurdles. Such a project also requires permissions like for selling energy to end-users or for tariffs that are typically higher than in the national grid. On a long-term, governmental framework is unavoidable for enabling reproduction. The financing requirements are mainly to secure the capital investment. This is complicated by high costs and relatively long financial payback periods. Further there is the uncertainty of success, as there are hardly any successful pilot projects, and the risk of political and economic stability, which make the financing difficult.

3.3.2 Project development

The system integrator has to create preconditions for a successful project. That means he has to obtain permissions and to find investors and financiers. It is important that his actions lead to a sustainable operation of the system, thus comprehensive planning is required which involves local people and structures. Cultural aspects can be very different depending on the region so the system must always be adapted to the local situation. Even economic and technical aspects are affected by cultural impacts. All mentioned duties of the system operator are essential and stand in equal priority since even one omission would likely lead to failure. Thus all aspects have to be considered right from the beginning.

Problems caused by missing legal framework can lead to project cancellation. The system integrator might have to arrange the framework but this can be a long process without any guarantee of positive results.

System integrators can be entrepreneurs, larger commercial companies, national energy providers, foundations and development aid organizations. All of these players can also act as the operator.

3.3.3 Operational level

The operational level is the one that has to function on the long-term. There are some conditions that have to be met for a sustainable operation with regard to the product "energy" (Figure 2). Part of the operator's main functions is to offer the technical service and financial implementation. This requires local technical expertise for maintenance and reparations. Further financial reserves for spare parts have to be generated. Everyone working connected to the system requests an appropriate salary. These are technicians, sales people interacting with the consumers e.g. selling prepaid cards, or other involved people. For a proper calculation, the energy related costs for operating the system should be assumed as high as the energy related capital investment costs [13]. All this must be included in pricing of tariffs even if tariffs become much higher than in the national grid.

In order to have a sustainable system, consumers have to understand it in its main features. They have to be willing and able to pay the consumed energy. For that it is relevant that they can start commercial activities and this again leads to the capability of the system to react to growing demand. To generate commercial and industrial activities it might be advisable for the operator to directly support income generating activities, which leads to positive impacts on the community and assures ability to pay on a long-term [6] [9] [10].

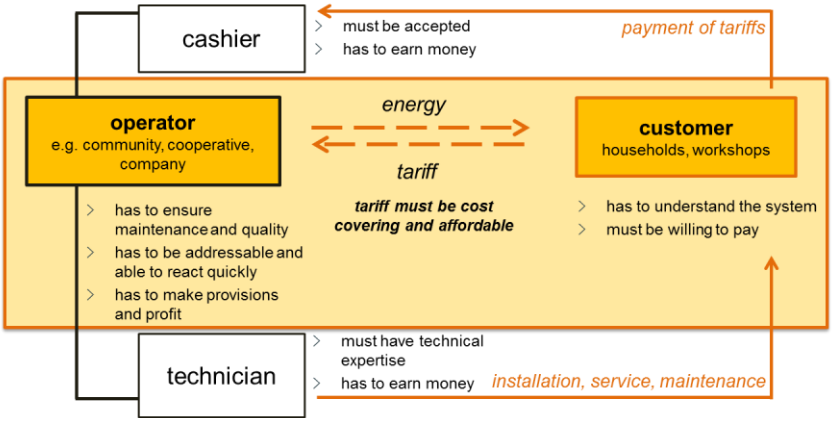

Figure 2: Operational level of a mini grid.

3.4 Existing best practice models

There are first signs of successful business models. First here are presented different approaches which can be a good way to success if they were embedded in a whole functioning project. Further, the companies KAÏTO and INENSUS are presented as having promising master plans which have been already started.

3.4.1 Different approaches

Several kinds of business models differ in financing, kind of operator and tariff structure. There are different possibilities which might be reasonable depending on country and region. For example there can be tariffs regulated by the state for sociopolitical reasons. Then direct governmental subsidies or cross-subsidies from the national energy provider can be part of a sustainable business model. Subsidization of capital investment for instance is possible by low interest rates.

The ownership of system and grid can be handled in different ways. If all parts belong to one operator, this could be for instance the national energy provider. This solution opens up especially for government-subsidized projects. The national energy provider has necessary expertise and funds but problems might be encountered due to distance when there is no local branch office. A private external entrepreneur who acts as local operator can react faster. But he is a foreigner who has lots of power as he can decide who gets energy or who does not. This can lead to dissatisfaction. If the system is organized by the village community on its own, technical problems and lacking know-how can lead to failure quite fast. But if there is a high community spirit and motivation, this model can have significant advantages.

Tariff structure can be different depending on cultural backgrounds. However it has to be considered, that flat rate tariffs include a risk of overloading the grid and that post-paid billing can lead to high debts. Prepaid energy without time limitations do not have the advantage of planning reliability. Intelligent tariffs that include fluctuating availability of renewable energies stimulate consumer’s understanding for the technicalities and protect the system.

3.4.2 KAÏTO’s concept of phases

The KAÏTO Energie AG based in Munich has developed a phase concept which starts with small energy services that can lead to AC-coupled village electrification and later to a regional grid connecting multiple villages [14]. Different phases are illustrated in Figure 3.

In the first phase KAÏTO builds several energy kiosks in different villages. These are run by local small-scale entrepreneurs who offer mainly DC-oriented energy services, like charging batteries and lending battery systems for lightning. Operators are trained by KAÏTO and can carry out simple installation jobs as well. The offered services are paid by consumers with a small fee that covers all costs including payment of operator and revenues for the investor.

The second phase includes selling or lending of individual dimensioned energy systems to public facilities and small companies with higher consumptions. Installation is paid for by the customer and KAÏTO staff conducts the maintenance. Depending on needs these are AC- or DC-systems.

The third phase starts if the energy demand of a village exceeds the offered energy services and especially if machines shall be used. All available PV-systems of the village will then be coupled to an AC-grid and an additional power plant will be added for balancing fluctuating solar energy and covering higher demand. Depending on local conditions the additional power plant shall be a cost effective energy source like plant oil biogas or wind power. To be connected to the mini-grid, consumers have to guarantee a minimum purchase. For micro consumers the kiosk remains available.

In a fourth step, different village electrifications can be connected to a regional energy cluster. The energy provider can supply a whole area with energy this way. In Senegal for example, this is even required to apply for a concession of energy supply.

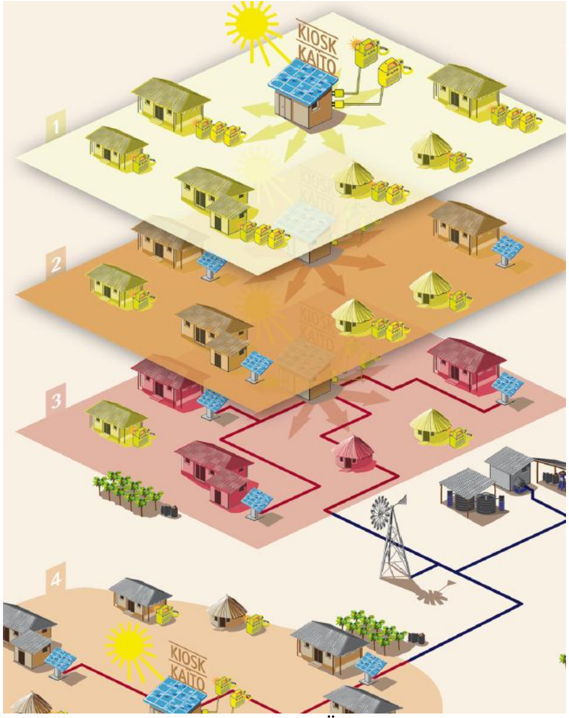

Figure 3: 4-phase-concept of KAÏTO Energie AG [15].

KAÏTO's concept of phases is characterized by gradual extension of a first small DC-application to an AC-coupled village electrification that offers the possibility to run machines and thereby secures a sustainable commercial development. This approach allows a slow acclimatization to the use of electrical energy. The system is only extended if the customers can pay for it and if the demand is high enough. Thus social and financial risks are minimized. A similar approach has been initiated by Solarkiosk GmbH which started with a solar energy kiosk in Ethiopia [16].

3.4.3 INENSUS Micro Power Economy

The concept of Micro Power Economy is a business model developed by INENSUS GmbH [10] [17]. In contrast to KAÏTO, an AC mini-grid is directly implemented. That means that different conditions are required. Conditions are tested by INENSUS in several villages before deciding which ones meet the requirements. The relationship between participants is significant, as are the tariff and billing structure. Micro power economy is based on a public private partnership with a private investor owning the production units. He acts as power station operator. A "Village Power Committee", founded by the village community, owns fixed assets like the grid, paid by a public investor. The separation of property leads to mutual quality check and allows all participants to quit the business relationship when contracts are not complied with. As a further player, a micro finance institution provides micro credits to the end-users to allow investments in machines and commercial activity and to start village businesses.

The tariff model is based on the purchase of "electricity blocks". One block includes a specific energy limit and power limit. Buying several blocks means increasing amount of energy as well as power limitation. Purchased electricity blocks have to be consumed within a certain time. If there is the need of additional energy or higher power, it is available for higher fees produced by a diesel generator. In periods of six months, contracts are renegotiated and if necessary the system will be adapted to higher or lower demand. This period allows on the one hand having planning reliability for dimensioning the system, on the other hand it is compatible with short planning habits, which are often found in developing regions. Further, the business partners can break their relationship in case of dissatisfaction.

A central component of the micro power economy is the load management and accounting unit (LAU). It is pictured in Figure 4. This represents not only the connection to the households, but also a charging station for prepaid cards and shows the account status for the current period by using a chip card. Furthermore it stabilizes the mini-grid by disconnecting certain users at impending overload of the grid. This happens by user priorities ensuring that buildings of highest priority, such as medical stations, never get disconnected.

Even trading with energy blocks is possible because of the LAU. Users who need more or less energy than they expected can trade among each other.

Figure 4: Load Management and Accounting Unit (LAU) [17].

The concept of micro power economy is characterized by planning reliability and flexibility in expanding the system depending on demand. Nearly all of the requirements stated in section 3.2 important for sustainable business models are met. These features, which are also shown by the phase concept of KAÏTO, are reached on very different ways in the two business models and while the KAÏTO approach is very good only step one and two have been shown so far. INENSUS has shown its model working now for more than two years in Senegal.

4 SUMMARY

Literature and interview analyses have shown that sustainable business models for mini-grids are still more a vision than a reality. In order to show how such business models are possible, conditions for success and reasons of failure have been presented. The latter are often caused by poor planning of long-term finances and disregarding cultural aspects, but are also often influenced by external effects like political regulation framework. Based on these experiences, key elements for success have been elaborated and specified which show that addressing the financing sufficiently early is found to be the most important condition for success and followed by a cultural adjustment of the financing solutions. A mini-grid must be considered as a comprehensive organizational challenge.

Finally, already existing best practice models of KAÏTO and INENSUS have been presented. KAÏTO with its 4-phase-concept from charging station to AC-grid connected energy supply give people the chance to get familiar with the use of electricity and only expand the system if it is required. INENSUS follows the Micro Power Economy model, which separates ownership of production units and fixed assets to be flexible and supports growing of commercial activities with providing a micro finance institution. The two models demonstrate that sustainable business models of mini-grids are complex challenges, which need expertise in all levels of implementation.

1.3 billion people live without access to electricity. While electrical energy has the potential to improve people's living situation sustainably, we hope there will be entrepreneurs implementing, optimizing and spreading renewable energy based mini-grids in future.

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