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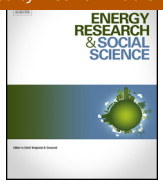

Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages

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ABSTRACT

In this article, we explore the process of economic change following the NGO-led implementation of a small-scale off-grid hydropower system in Tanzania. We examine how the implementing actor deals with economic challenges and local ownership in order to achieve sustainable electricity supply. The qualitative case study shows that the NGO, ACRA-CCS, has overcome a number of constraints, which are sometimes associated with donor funding. This has been achieved by having multiple donors, an integrated approach and a longer presence. The 'logic' of implementation included active enhancement of productive electricity use, community services and benefits. As a result of these actions, the customer base grew quickly, rather than it taking many years to develop. The case illustrates the process whereby an off-grid system becomes economically viable. Local ownership has led to the project becoming an arena for community collaboration and problem solving, and creating values such as effective load management and protection of infrastructure. We suggest that attention should be given to possible public private community partnerships (PPCPs) – involving communities as crucial partners. The choice of a socio-technical system perspective was fruitful and provided crucial insights into how different factors manifested, interacted and played out in practice.

1. Introduction

In this article, we are concerned with access to electricity for poor people in East Africa and specifically study a case of rural electrification using off-grid mini-hydropower in Tanzania. The hydropower system of 300 kilowatts (kW) was built by an Italian non-governmental organization (NGO) in partnership with the local church and funded by international and national donors. Since 2010, the system has been supplying electricity to customers. The aim of the project was to provide access to electricity and thereby contribute to social and economic development of the area.

Electricity is a powerful resource that has the potential to catalyze societal change by providing opportunities for a new range of activities and services. However, previous research shows that such positive outcomes – such as social and economic development resulting in improved quality of life and improved livelihoods for rural populations – do not always result. In fact, many rural electrification initiatives do not produce the sought-for development outcomes and even fail to deliver electricity services over the expected system lifetime [1,2]. This is commonly attributed to the way in which the electrification initiatives interplay with existing local conditions and especially how developers and implementers handle the challenges associated with implementing reforms in agrarian, seasonal economies where people generally have low incomes.

We focus our discussion on a few aspects that previous research highlight as prerequisites for sustainable small-scale energy systems in poor rural areas: achieving economic viability, a high degree of local participation and development of local expertise [2–6]. The most important overall factors that make these goals hard to achieve are rural poverty and poorly developed rural economies and markets. These factors result in low demand for electricity services, slow development of economically productive electricity use and a weak customer base [7–10]. For private and commercial entities, economic viability includes recovering investment costs, and making a profit. For donor-funded, non-commercial initiatives, cost recovery is not necessary, and economic viability is defined as covering the costs of operation, maintenance and, in this case, future reinvestments. However, development aid – in many areas, not only electricity – has been criticized for not resulting in economically viable installations or

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self-sustaining organizations. According to this critique, development aid maintains structures of economic and organizational dependence on external actors [11].

In contrast, NGOs are often considered champions of local participation and empowerment. The NGO that is the focus of this article is no exception; the project has been ambitious in involving local communities and building local competences. The project has also included complementary investments and cross-sector coordination, other features identified by scholars as important for success [12]. Therefore, the case we study here displays what literature has identified as both negative determining factors – donor dependency and working in a poor area – and positive determining factors – a strong emphasis on local ownership, capacity building and complementary investments. What will this mean for the sustainability of the project and its impact on the local economy?

Our aim is to explore the process whereby a donor-funded off-grid electrification project using renewable energy, implemented by an international NGO, translates into an organizationally and economically viable local utility, and a growing local economy. The case is of general interest because it provides insights for the development of mini-grids based on hydropower or other renewable energy sources in poor rural areas all over Africa, the subject of this Special Issue, as well as for other parts of the world with similar energy needs (see also Eder, Mutsaerts and Sriwannawit [13], and Hancock in this special issue [14]). It is also of wider interest as decentralized electrification in African countries is often carried out by non-governmental entities [6,15] and non-profit entities and community-based organizations are likely to play an important role in future development of renewable energy systems – sometimes in partnership with commercial actors or as social entrepreneurs.

Scientifically, we contribute to existing knowledge by providing a rich description of how and why various factors come to matter. A theoretical and empirical contribution of the article lies in its investigation and analysis of system dynamics. Electrification processes are unique and play out differently in each place, but the system understanding guides us to what is likely to be important, what to look for and what questions to ask. The study fits well into the ambition of *Energy Research & Social Science* to investigate the social system surrounding energy technology and hardware. It engages with some of the research questions and areas highlighted in the first issue of this new journal, in the articles by Sovacool [16], Stern [17] and Stirling [18]: it applies human-centered research methods and field work in an exploratory study of human–energy interactions. The electrification process is viewed from the perspective of multiple actors, including citizens in their roles as users, customers, and members of the local utility.

The article is organized as follows. In Section 2, we explain the theoretical perspective and the focus of the case study, and summarize key points from earlier research. Section 3 gives a brief description of the project and of the area and the economy in which the project was implemented. Based on this, the aim of this paper is specified into concrete research questions directing the analysis (Section 4). A method section follows (Section 5), before the case study results are presented and discussed (Section 6). Finally we sum up the findings and relate them to theory and earlier research (Section 7).

2. Theoretical perspective and previous research

2.1. A socio-technical approach to electrification

This paper argues that our understanding of system dynamics in rural electrification is greatly enhanced by taking the literature on socio-technical systems seriously. This literature contributes a perspective that sees technological and societal change as interrelated [19]. Socio-technical approaches highlight co-evolution of technology and society, the multi-dimensionality and complexity of technological change, and multi-actor processes [20]. Researchers have applied socio-technical approaches in analyses of large-scale infrastructure development and the development of new renewable energy technologies, mainly within industrialized countries [20–22]. As yet, few studies apply this perspective to small-scale energy systems in East Africa ([23,24], see also Ulsrud, Winther, Palit and Rohracher in this special issue [25]).

We theorize electrification as a dynamic process of formation of a new socio-technical system, which brings people, technology, institutions and resources into specific relationships (see Fig. 1 for the theoretical conceptualization). In small-scale hydropower systems, actors, institutions and networks form around the concrete system of energy production and distribution. Networks connect local actors to one another as well as to district, national and international stakeholders, thereby providing important support. The system is shaped by and shapes its environment, with dynamic and emerging outcomes. As the system develops over time, the relationships produce outcomes that transform the dynamics as well as the system design in itself.

Scholars in the field of socio-technical systems pay close attention to the role of technology [26] and how technical systems come with specific demands, possibilities and restrictions, that condition development. They acknowledge the importance of actors and human perceptions as well as relations of power – although the consideration of power relations is still an emerging issue in the field [20]. In our analysis, we focus mainly on the implementing NGO, the local utility, and local users. The implementing actor plays a key role and works according to a certain 'logic', namely: (1) the NGO's ethics and objectives, (2) its choice of system design and mode of operation, and (3) the strategies for implementation and system sustainability. Our focus is on how the NGO handles the economic challenges (related to rural poverty and the need for economic viability) and the challenges of building from scratch a local organization to independently own and manage the system, after the NGO exits. We analyze how the relationships develop over time between the NGO, the local utility and people in the communities.

2.2. Existing critique of NGO-led development

To enhance our understanding of the implications of the 'logic' by which electricity is introduced, this article also departs from the scholarly discussion on NGO-led development and the vices and virtues of the aid industry in general [27–29]. NGOs have often been conceptualized as a grassroots alternative to supposedly corrupt and inefficient government agencies, and their involvement has been held to safeguard a participatory, bottom-up approach to development and social improvement [30,31]. Yet although initially welcomed by policy-makers and academics alike, NGO-led development has in more recent times come under closer and more critical scrutiny [32,33].

One important critique directed toward NGO-led development in recent years is related to NGOs' dependency on donors. The literature argues that this dependence risks placing NGOs in a patron–client relationship with donors, where the activities and interventions are more or less donor driven. Scholars also raise serious questions about whether the NGOs are primarily accountable to the donors or to the targeted communities [34]. It is also argued that this might divert resources into tangible and visible projects undertaken to please potential contributors, at the expense of more complex and long-term processes with potentially higher, but less easily measured, impacts [35–37]. According to this logic,

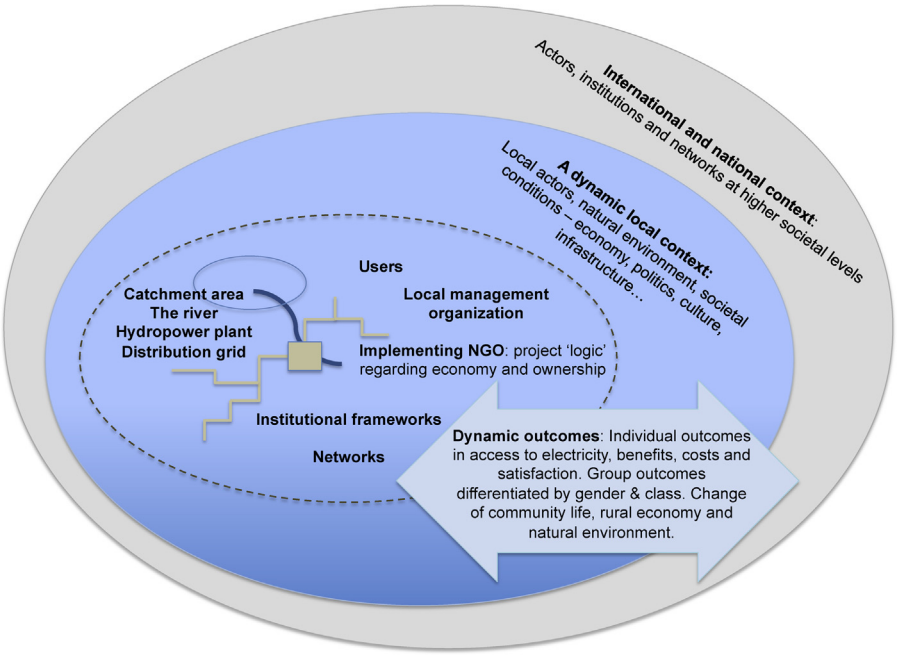

Fig. 1. Conceptual understanding of small-scale rural electrification from a socio-technical perspective. A new socio-technical system (the inner circle) forms around the technical system and energy source. The system develops in relation to and constrained by the local context (the circle in the middle) and higher societal levels (the largest circle).

NGOs may risk becoming technical transfer agents, overemphasizing short-term quantitative outputs over qualitative impact [38]. However, the literature also argues that if an NGO has the ability to sustain a broader funding base, some of these pressures can be mitigated [33].

The debate over the role of NGOs in development also speaks to a general debate on issues of ownership and results-based management. While ownership by states over their national development agendas is being widely promoted within the new global aid architecture, there are growing concerns that foreign actors still determine much of the development agenda. That is, the emphasis on ownership has in some instances been shown to be difficult to combine with donor priorities, especially since donors face increasingly strict demands from their own governments or funders [39].

The discussion on ownership also relates to the local level. Many NGOs have almost exclusively become service providers rather than facilitators of collective action and empowerment, which some observers argue is inconsistent with the operation of organizations claiming to promote qualitative change [40]. Some scholars argue that whether or not a project is able to deliver on its promises depends crucially on the ability of NGOs to foster true local ownership and capacity [31]. A perhaps more fundamental critique of how NGOs 'do' development regards the widespread use of 'participatory approaches'. These are seen by some observers to be a technology of 'developmental rule' that creates a space of exception outside the normal arena of politics – and depoliticizes problems into something needing a technical solution [41].

Taken together, non-profit actors such as NGOs are considered important actors for small-scale off-grid electrification in areas outside coverage of the national grid. But electrification initiatives face important challenges relating to economic viability and local ownership. According to the theoretical starting points of this study, in order to understand outcomes for the system as such and for the community, we must map the system components and analyze the dynamic interplay between the logic of implementation and the context.

3. Rural electrification in Ludewa District, Tanzania

Tanzania's Southern Highlands has a temperate climate and hydrological conditions suitable for the development of small-scale hydropower systems. There are many non-profit hydropower installations, in areas where the national grid does not reach, owned and operated by local churches or community organizations. There are also some pico-hydropower[1] installations developed by local entrepreneurs. The initiative to build a mini-hydropower system in the Kisongo river basin in Ludewa District came from the local church, to the diocese in the neighboring region of Njombe, Tanzania. The diocese contacted the Italy-based international development cooperation organization ACRA-CCS (at the time ACRA–Cooperazione Rurale in Africa e America Latina) and asked them to help find funding and carry out the implementation.[2] The organization is active in 16 countries, has around 275 staff and in 2013, the total budget spent on projects in the areas of environment, water, food, education, health and economy, was over 9.5 million Euros. In 2006, with funding from the Italian government and citizens, ACRA-CCS started to implement the first phase of the 'Mawengi Integrated Rural Development Program', in collaboration with the Catholic Church and local government. They built a so-called run-of-the-river system[3] of 300 kW, and a mini-grid supplying electricity to nearby villages.

Formulating the objectives of its intervention in Mawengi, ACRA-CCS aimed "to maximize the benefits of access to energy and sustainability of the service" [44]. The NGO adopted a "participatory and integrated approach for the purpose of providing sustainable

[1] According to common definitions, pico-hydropower systems have power outputs below 10 kW, micro-hydro 10–100 kW and mini-hydro 100–1000 kW in power output [42,43].

[2] In 2013, ACRA partners with CCS (Centro Cooperazione Sviluppo).

[3] A run-of-the-river system has none or little water storage. The system diverts part of the river flow into the hydropower system, but does not alter the normal river course. After passing into the penstock and through the turbine, the water is directed back into the river downstream.

access to energy for 20,000 people in the district of Ludewa" and favoring "the socio-economic development of the rural communities of the basin of the river Kisongo" [44].

The national electric grid does not reach the area in which the project was carried out. Like most rural areas of Tanzania, this area has a seasonal economy; communities depend on the agricultural cycles of planting, cultivation and harvest, following the patterns of rainfall. The analysis here draws on a baseline study on local livelihoods done by ACRA-CCS (2012), and original data on the local economy.

In this particular area, maize and beans are the most important crops. Some households also grow wheat, coffee, and a variety of vegetables and fruits. Most households (72% in 2012) keep livestock for self-consumption. Nearly all families (99%) grow maize for self-consumption and the rest is sold. During the months after harvest, people pay school fees and make investments. Money is set aside to buy agricultural inputs for the following planting season. Extra money is invested in domestic animals, land or tree planting. Many households in the area have no economic buffer. In time of crisis, families sell animals, timber or land, or travel to town for temporary employment to cope with economic stress. From observation and informal discussion, it appears that very few people are undernourished. But, as in many other areas, many people die from diseases and in road accidents, and a lot of families have lost members of productive age. Currently, Njombe has the highest prevalence of HIV (14.8%) of all regions in Tanzania [45].

Although 25% of households have a member who is formally employed, the few people who receive regular paychecks are mostly government employees such as teachers. Some people have temporary employment in forestry, on farms and in construction. About half of the households are engaged in small businesses for extra income throughout the year. For most entrepreneurs, there are two seasonal cycles: the agricultural growing season and school semesters. Every weekend there is a market, and people come from nearby villages to sell their produce. Once a month, a larger market is held in the area, attracting business people from Njombe and Ludewa, 2–3 h by road in the dry season. Banking services are available in nearby towns but less than 10% of households have savings accounts. In our interviews with local entrepreneurs they express lack of access to investment capital to be a major problem, as banks often charge high interest rates and demand collateral (see also [46], and Haselip, Desgain and Mackenzie in this issue [47]).

4. Research questions

The following questions structure the analysis:

1. According to what logic does the NGO implement the electrification project, and what constraints have come with donor funding?
2. What strategies has the NGO used in order to achieve economic viability and local ownership?
3. What economic and organizational challenges has the local utility faced? Have there been any positive consequences of local ownership?
4. What are the outcomes in terms of electricity demand and impact on the local economy?

5. Method

We chose this project for our case study because national-level stakeholders consider it to be highly promising and because the project includes extensive local participation. It hence displays dimensions seen in literature as important constraints as well as opportunities, and the findings are therefore of interest for the broader community of scholars and practitioners.

The analysis is based on extensive empirical work conducted by the first author in 2012 and 2013. After an initial one-week visit to the project in 2012, an in-depth qualitative case study was carried out in 2013. The first author collected data during three months in Tanzania, with about seven weeks in the villages of Madunda, Mawengi, Mdete and Mapogoro, and five weeks in the nearby town of Njombe.

She conducted three sets of semi-structured interviews, with the help of a Tanzanian interpreter: (1) 90 interviews about the project (21 with project staff, 62 with villagers, and 7 interviews and meetings with local and district government); (2) a small qualitative survey on land rights, savings behavior and use of electricity in 14 households, carried out with help of a German student; and (3) a set of 38 interviews, plus visits and group discussions with rural entrepreneurs in the project area and in Njombe on the related topic of constraints and opportunities in the local economy. These helped us to understand the rural economy of the area and the challenges faced by rural businesses.

The seven weeks in the villages were spent partly with a family, and partly renting a room from a local landlord. The stay in the village helped the researcher position herself as separate from the NGO staff, who spend most of their time in the village but who always return to town during weekends. With the help of a villager as a local guide, the researcher and her Tanzanian female interpreter walked or used local transport, independently of the project staff. The NGO and the local utility openly shared project documentation and unpublished baseline data, with the expectation of getting feedback on the project later.

Importantly, the results and conclusions presented in this article were validated in a participatory workshop with the NGO and the local utility in Mawengi in April 2014. The discussion was documented and has contributed to the analysis. Project staff have provided the researchers with follow-up information and project evaluation reports as late as August 2014, including an update on new tariffs that came into effect on 1 August 2014. ACRA-CCS staff have read and commented on the article draft.

The analysis is structured according to a coding scheme, based on the conceptual framework (Fig. 1, Section 2). It maps the technical system, the roles of the actors involved, the relations (networks) among them and the institutional frameworks. Further, the analysis traces the electrification process over time, and maps measurable and perceived benefits and drawbacks for different individuals and groups in local communities. We identify factors that have been critical for these outcomes to emerge and evaluate the degree to which the project has become a catalyst for socioeconomic change.

Most material has been coded using coding software, and all interviews have been checked for concordance and divergence [48].[4] The tracing of events, information and statements has been triangulated. Validation of results with respondents and stakeholders has been crucial for credibility in interpretation and analysis.

6. The Mawengi hydropower scheme: understanding reasons for outcomes of small-scale electrification

This empirical section provides a rich description of the Mawengi electrification process, in relation to the research questions posed. Section 6.1 answers research question 1 on the type of

[4] This means that in the analysis we go through interviews and make comparisons between them to find whether there are points of disagreement and contradiction, or whether respondents have similar views, concerns and explanations. This is part of the process of interpretation of data and helps assess the credibility of inference.

Table 1
Summary of important program activities in the Mawengi Integrated Rural Development Program.

Year	Important program activities	Donors
2005	Feasibility study Proposals for funding	The Italian Ministry of Foreign Affairs, co-funded €2.69 million (2005–2009)
2006–2010	Phase I: Partnership with local church and public meetings Construction of the hydropower plant and grid Reforestation of river banks November 2009: The non-profit community-based utility LUMAMA is legally registered under Tanzania's framework for NGOs June 2010: Plant starts operating End of 2010: Handover of property rights of energy systems to LUMAMA	The Region of Lombardy, co-funded €0.89 million (2007–2009) Private donations through Intervita Onlus €0.54 million (2009–2011)
2011–2014	Phase II: November 2011: Program inauguration by the President of the Republic of Tanzania 2012–2014: construction of medium voltage and low voltage lines in upstream communities 2010–2014: Integrated development program: Further studies: land use, risk for soil erosion, local value chain development Natural Resource Management component: • Reforestation activities • Farmer training on sustainable agriculture, forestry and livestock keeping • Establishment of farmer groups and pilot plots • Land use planning in collaboration with District Government • Environmental awareness campaign Business program: Capacity training and support to 20 small and medium enterprises School and education component Rehabilitation of water supply systems 2012: Environmental impact assessment 2012: Installation of second turbine 2014: Shift to pre-paid meters and payment system 2014: (August) ACRA-CCS program exit	Private donations through Intervita Onlus €1.38 million (2011–2014) The European Commission through Ministry of Finance Tanzania, co-funded €1.83 million (2011–2014) The World Bank through Rural Energy Agency of Tanzania, funded €0.41 million (2012–2013) Other donors: Ministry of Energy and Minerals Tanzania District Council Ludewa

Source: Based on interviews, ACRA-CCS homepage and public presentation by ACRA-CCS.

implementation logic and constraints that came with donor funding. Section 6.2 addresses question 2, and so on.

6.1. The logic of NGO-led rural electrification

6.1.1. Project implementation logic: phase I

ACRA-CCS designed the technical system based on a feasibility study in 2005. During implementation, the details of the technical design were decided and the system adapted to local environmental conditions. There are two turbines, each with a capacity of 150 kW. The system is designed to work at full capacity even during the dry season. The work started with construction of the hydropower plant in the Kisongo river and a distribution grid to supply three downstream communities: the villages of Lupande, Mawengi and Madunda. In the construction phase, ACRA-CCS expected the communities to make a substantial contribution to the project in terms of manual labor and general help. Local government leaders were asked to support the project and help mobilize the people to come to meetings and carry out voluntary work in the project.

Based on its belief in local participation as key to sustainability, ACRA-CCS wanted the hydropower plant to be owned by the communities themselves. Therefore, in 2009, a community-based utility was created under the Tanzanian legal framework for NGOs. The utility was named LUMAMA after the initials of the three villages connected; ownership of the electricity system was handed over to LUMAMA in 2010. The first 260 customers had electricity switched on in June 2010.

Table 1 provides a summary of program activities, from the initiation in 2005, the construction in phase I (2006–2010), to the scale-up and program ending in phase II (2011–2014).

Toward the end of the first phase of the project, ACRA-CCS identified a number of threats to the sustainability of the plant: the construction was not fully completed according to plan and the average consumption was only around 40 kW; LUMAMA revenues were not sufficient to cover the costs of operation and maintenance, or of depreciation costs. There was also low consumption of electricity for productive uses (only 30% of total energy production). Organizationally, LUMAMA did not have enough capacity to manage the service efficiently and independently. The project staff explained how some constraints arose from being an NGO, such as the short time scale of project funding and difficulties with the evaluation of results. The first project phase was not long enough to reach the targets set.

6.1.2. Phase II: meeting the challenges by changing logic – project expansion and integration of components

These challenges were addressed in the second phase of the project. The 'logic' by which ACRA-CCS worked through the second phase was to build on what had been achieved in the first phase and expand it. ACRA-CCS raised new funding from multiple donors, which made it possible to undertake a range of activities in parallel. Thereby, the NGO could finalize planned construction and then expand the grid to reach more customers and communities. It could also build local management capacity and work with communities to find solutions to challenges. The electrification scheme expanded to include activities in education and health, because the NGO reasoned that electricity connection for public services such as schools and healthcare institutions would result in long-term positive impact on quality of life in the area. Other components focused on natural resource management, agriculture, business development and water provision. The parallel activities targeted problems and challenges that emerged in relation to the new system. The NGO had discovered how complex a rural electrification scheme can be, with cross-cutting social, economic, political and technical challenges. Only by working together with individual villagers, community groups and LUMAMA, as well as government authorities at multiple levels, could ACRA-CCS drive the project in the desired direction. Had it not been for the activities undertaken in the second phase, the project would likely have been another failed development project, without lasting results.

Table 2
Characteristics of the technical system.

Turbine: Francis Turbine horizontal axis, nominal power: 168 kW
Real output: 150 kW
Rotation speed: 1500 RPM
Second turbine installed October 2012: doubling the capacity to 300 kW
Micro-grid installation 2009: 15 km of MV lines, 9 transformers, 15 km LV network
Micro-grid expansion 2014: 39 km of MV lines, 17 transformers, 40 km LV network
Total at end of project: 26 transformers, 54 km MV line, 55 km LV line
Energy production:
Commissioning of plant and start of service delivery in June 2010: 260 connections
Average daily consumption June 2011: 40 kW (minimum 5 kW, maximum 70 kW)
Incomes from electricity sales = 20% of cost for operation and maintenance (O&M)
July 2013: total 700 connections
June 2014: total 1200 connections
Average daily consumption June 2014: 80 kW
Peak load: 200 kW
Average monthly income 2013–2014: 6 million Tanzania shillings = 92% of O&M cost

Source: Based on interviews and ACRA-CCS project documentation material.

During 2014, ACRA-CCS is phasing out, and it is now up to the local utility to manage the system sustainably. At the time of the last visit by the first author in April 2014, the distribution system reached 9 communities, with a total of 26 transformers. The customer base had grown to 1200 paying customers (i.e. 1200 connections, whereas the number of users is much higher), with an average load of 80 kW. Through the project, a number of electricity services have been made available to the people in the area. Hydropower has the advantage of being a continuous energy source, making electricity services available 24/7, and very reliable with few unplanned blackouts. The service is also of high quality, with very little fluctuation in frequency. The technical characteristics of the system are summarized in Table 2.

6.2. Economic and organizational challenges

6.2.1. A strategy to ensure economic viability

There is a business plan for how to make sure the project is economically viable over time. ACRA-CCS has defined economic viability as managing the monthly budget and raising enough income to cover costs of operation and maintenance, as well as saving for unexpected events and for the long-term depreciation cost. In order to achieve this, the first priority was to finalize the construction and establish enough connections to reach a certain level of income for LUMAMA from the electricity fees. In order to raise capital for future investments, a number of tree plots for timber production have been established as LUMAMA property.

In its approach to households, ACRA-CCS aims for social impact. Since connection fees represent an important barrier for most rural customers, they were requested to only cover the cost of internal wiring. The typical cost of connection[5] is 180,000 Tanzanian shillings (TZS) (about 80 Euros) and this investment was made easier by a credit scheme for customers, set up in the first phase.[6] As a point of reference, the basic needs poverty line in Tanzania in 2011–2012 was around 36,000 TZS per adult per month [49]. This has made it possible also for middle-income families to afford connections, thereby enlarging the potential customer base. However, many families live in houses that do not meet the minimum construction standards for connection to the electricity grid. According to the baseline undertaken by ACRA-CCS, only 16.2% of buildings in the area are eligible for grid connection. Further, households that wish to connect must also dig a trench for the underground cable from the cabin up to the house. Some families cannot manage this work by themselves and must hire labor, thus incurring extra cost.

At the beginning of the project, tariffs and cost of connection were lower than the national average in order to enhance access for households. The focus on social benefits also included free connection of schools and health centers, in order to improve public services. These public institutions pay only for consumption. The downside of the relatively low tariffs is that incomes from sales of electricity have been low, and that LUMAMA has many customers who lack an economic buffer. In June 2011, the majority of households and public institutions paid flat tariffs, based on the number of power points in the premises (2500, 3200 or 5000 TZS/month). Household and public users with meters paid a unit cost of 120 TZS/kWh. Larger consumers and workshops had meters and paid per unit of electricity consumed. Milling machines paid 150 TZS/kWh and workshops and businesses paid 200 TZS/kWh.

ACRA-CCS's initial position on the appropriate level of tariffs was revised over time. In the second phase, NGO staff encouraged LUMAMA to increase tariffs in order to reach the economic targets set in the business plan (based on 1400 paying customers). Currently (August 2014), LUMAMA is generating sufficient income to manage operation and maintenance. During 2014, the system with flat tariffs has been replaced by a pre-paid system with meters for all customers. Fig. 2 provides details of the current tariffs, as from 1 August 2014.

The change from flat tariffs to pre-paid meters was motivated by the need to simplify the administration of payments as the number of customers grew. As can be seen from Fig. 2, the new tariff system has five different categories of customers – depending on the type of customer and use. Customers pay a monthly service fee plus their own use of electricity, according to the electricity charge for the specific category. The cost per unit (1 kWh) is 150–330 TZS (around €0.067–0.148), which is comparable to the tariff of the national electric company Tanesco of 100–350 TZS per unit (kWh) [50].[7] With service charges, the average monthly cost for rural customers of the national grid is somewhat higher [51].[8] The LUMAMA budget for 2014–2015 foresees an average monthly income of 11.4 million TZS and average monthly cost of 9.6 million TZS. The yearly surplus for 2014–2015 is expected to be 16 million TZS, partially covering the depreciation cost of 57 million per year. LUMAMA plans to be able to save the full amount of depreciation cost from year 2018.

As can be seen in Fig. 2, an important share of LUMAMA's income comes from the milling machines (category 4) and businesses (category 3). The 21 milling machines are the largest loads, and consume many energy units each, generating more income for LUMAMA

[5] Representing the cost paid by a customer with 3 lights and 2 sockets for materials, administration and technical installation.

[6] Initially, ACRA-CCS helped LUMAMA establish a revolving fund that supported investment in internal wiring with 80%, meaning that customers only paid 20% up front. However, the time for repayment (1 year) did not match with the rate of new applicants, therefore the fund finished and LUMAMA had to delay connecting new customers who needed credit. In order to speed up connections, the conditions of the fund were changed to provide 50% credit (payback over 6 months).

[7] The prices are in effect from 1 January 2014 according to *The Citizen*.

[8] Tanesco has no service charge for the smallest consumers. Customers consuming above 75 kWh per month pay a service charge of around 3800 TZS. Before the price increase in 2014, the 'average cost per month paid by rural households by source of energy' was, according to national statistics, on average 8926 TZS for electricity from the national grid, and the corresponding cost for electricity from diesel generator was 28,170 TZS in 2011.

Customer category	Montly service fee (TZS/m)	Electricity charge (TZS/kWh)	No. Customers (end of July 2014)	Expected typical electricity consumption (kWh/connection*m)	Total category consumption (kWh/m)	LUMAMA expected income from electricity (TZS/m)	LUMAMA income from service fee (TZS/m)	Projected total LUMAMA income from category (TZS/m)	Average consumer cost (TZS/kWh)
1	2 500	150	600	15	9 000	1 350 000	1 500 000	2 850 000	317
2	2 500	170	250	20	5 000	850 000	625 000	1 475 000	295
3	2 500	200	310	25	7 750	1 550 000	775 000	2 325 000	300
4	5 500	270	21	500	10 500	2 835 000	115 500	2 950 500	281
5	5 500	330	25	60	1 500	495 000	137 500	632 500	422
			1 206		33 750	7 080 000	3 153 000	10 233 000	
				TOTALS					
				LUMAMA income cat 1+2+3		3 750 000	2 900 000	6 650 000	
				LUMAM income cat 4+5		3 330 000	253 000	3 583 000	
				Projected total LUMAMA income		**7 080 000**	**3 153 000**	**10 233 000**	

Category 1 = households with 1-7 power points
Cateogry 2 = households and institutions with more than 8 power points
Category 3 = businesses
Category 4 = milling machines
Category 5 = other electric machinery

Fig. 2. New tariff system of LUMAMA (applied from 1 August 2014).
Source: LUMAMA budget 2014–2015.

than all the 600 customers in category 1 – households with the lowest consumption. These households use electricity mainly for lighting and for charging of mobile phones, and some use much less than the expected average – as little as 5 kWh per month. In order to stimulate productive use of electricity, ACRA-CCS established a business program that has supported 20 local businesses to start up new income-generating activities, including the provision of electric machines by grant (up to 4 million TZS) and training on how to use them. Almost 30% of all customers are using electricity for business, accounting for 58% of the electricity sold. The NGO also supported local farmers within the frame of the agricultural component in diversifying local agriculture and developing the production of certain crops identified by the farmers and the NGO as having commercial potential.

The activity of milling maize was identified by ACRA-CCS as socially important, because almost all households in the area eat maize flour porridge, *ugali*, on a daily basis. In comparison to using diesel for operating the mill, electricity from hydropower has a lower production cost. ACRA-CCS wanted this cost saving to benefit the customers rather then the businesspeople. Therefore, the NGO regulated the number of milling machines that could be connected (one or two per transformer) as well as the price of the service of milling. Businesspeople who wanted to invest in an electric mill applied to the village chairman of the transformer, who selected a candidate. LUMAMA and ACRA-CCS advised on the purchase of equipment and subsidized 50% of the cost for electric installation. The milling machine owner paid the rest of the capital investment and agreed to apply LUMAMA milling tariffs. As a result, the price for milling services was halved, benefitting all families in the villages and improving their cash flow.

6.2.2. *A strategy to create local ownership*

The other main priority in phase II was to build the managerial and organizational capacity of LUMAMA, in order to create real ownership and a sense of local responsibility. From the perspective of NGO staff, the local population's low level of education, and lack of exposure to and knowledge about electricity made the process harder.

To strengthen LUMAMA, ACRA-CCS provided a management expert to work closely with the local utility and to sit in weekly meetings with the staff. From interviews directly after the meetings, it is clear that it has been a mutual learning process. Over the years, problems, progress and actions have been discussed in a continuous dialog between ACRA-CCS, and LUMAMA management and board. The NGO also provided training, for example on management and administration, accountancy and good governance (with emphasis on the principles of transparency and non-corruption). The technicians, the manager and the accountant are all villagers who live in the area. They have been recruited and trained, and are appointed by the LUMAMA board. Over time, they have developed the skills necessary to manage the system on a daily basis.

ACRA-CCS assisted LUMAMA in developing the organizational structure (Fig. 3) and adapting the organization's regulation to accommodate the growing number of customers. The regulation secures democratic decision-making, and prevents political leaders from gaining positions of leadership in LUMAMA. All customers are LUMAMA members and are perceived by the staff and board as shareholders in the hydropower plant and distribution grid. Also, ACRA-CCS worked to ensure the support of district government and the church partner by giving them positions on the utility board. It can be seen as a deliberate attempt at encouraging powerful institutions to invest in the continuation of the energy system and the survival of the local utility.

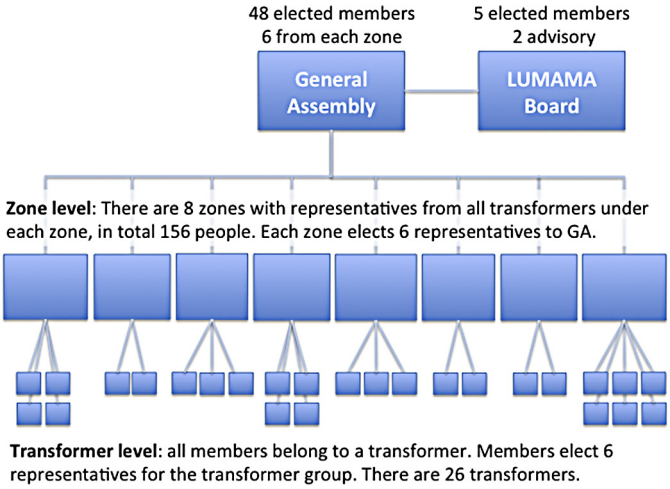

Fig. 3. LUMAMA organizational structure.
Source: interviews with LUMAMA and ACRA-CCS staff and project documentation.

As can be seen in Fig. 3, the members are organized into three levels, electing their representatives every third year: at each transformer, at zone and on the General Assembly (GA). The GA meets a minimum of twice a year and holds a number of powers, including electing the board, deciding on tariffs and changes in the regulation. The GA members also discuss and approve of the yearly budget and thereby they gain insight into the utility's economic situation. The board meets with the employed staff on a regular basis and oversees the operational work and finances.

The managerial capacity of the LUMAMA staff and organization has developed substantially during Phase II. Between 2012 and 2013, there was a clear difference in how the staff viewed their own capacity and the ability for LUMAMA to manage independently. In 2012, the manager explained: "LUMAMA cannot manage by itself, not now, but when we have more costumers and can raise the money we will be able to manage by ourselves." In 2013, he explained in detail the skills he had acquired over the last year, and his wish to receive further training on professional management.

However, interviews in 2013 showed that the large majority of local people, including staff, did not think the utility could be economically independent. Villagers and LUMAMA members frequently expressed their hopes that ACRA-CCS would continue to provide whatever external funding was needed in the future or find other donors. "[We hope that] it is possible for ACRA to write a proposal, even for you [the researcher] to help us, to write to people for help to buy the material we need [and] to find a new donor." They also doubted whether the local utility – that is, the communities themselves – could raise enough capital for pay for future expansion and reinvestments. The business plan anticipates yearly savings of 57 million TZS to cover the large reinvestments that will be required once general components need to be replaced (the expected lifetime is at least 20 years). From the villagers' point of view, anything could happen before then, and the scale of investment makes it seem impossible. The chance for LUMAMA to actually succeed is likely to increase if it has external managerial support and advice, even if it sustains itself economically.

6.3. The future of LUMAMA – a local non-profit utility

During data collection in 2013, ACRA-CCS was phasing out and preparing to exit the project in August 2014. LUMAMA was in charge of the system. In order to address question 3, we now shift perspective to that of utility staff and members, analyzing what challenges the local utility has faced, and then positive consequences of local ownership. The analysis reveals how economic and organizational aspects are intertwined.

6.3.1. The relationship between LUMAMA and local communities

Today, LUMAMA is embedded in the local community but is not yet the grassroots organization it aspires to become. All staff are recruited locally, live in the area, and the office is in the center of Mawengi village. Initially, LUMAMA membership was voluntary and at the time of the first visit in 2012, few customers were members. In 2013, membership was made compulsory for customers and open also to non-customers. With the new regulation and organizational structure, a larger number of customers are involved in matters relating to LUMAMA, but not all feel like they are a meaningful part of the organization.

During these first four years of service delivery, there were a number of frictions between the local utility and the villagers and local economy. LUMAMA relies on incomes from the sale of electricity only. Because the system is off-grid, the local utility cannot sell electricity to the national grid. Until 2014, the majority of customers paid flat tariffs, and all customers paid for their consumption at the end of the month. In this area, people have no previous experience of paying monthly bills or reading customer contracts. In 2013, the accountant explained that LUMAMA was facing a challenge because many customers did not pay their bills on time, which led to a budget deficit for the utility. From the perspective of LUMAMA, this posed an economic challenge, but it also challenged their ability to live up to their own and ACRA-CCS's expectations. During the first years, the NGO was adding extra funds on a monthly basis to allow LUMAMA to cover its running cost, but with the increasing number of customers, the local utility was expected to reach a balance and then a surplus. Utility staff have taken very seriously the task of becoming an organization that can stand on its own and successfully manage the hydropower plant and electricity services. The 'good governance' ethics promoted by ACRA-CCS have been taken to heart as having the finances in order and treating all customers equally, according to the regulation. The rules for customers are spelled out in the customer contract. Initially, the contract stipulated that customers were to be disconnected after three months of delayed payment. Later, LUMAMA changed the rules and reduced the time. Since July 2013, customers have to pay within one month or they will first be warned, and then disconnected. The motivation for imposing such strict rules was that "the revenues [from] the bills payment are the ones which are used to pay the salaries of the workers [LUMAMA staff]. If somebody has not paid the bill it means the workers are not going to be paid" (ACRA-CCS management expert). Villagers must adapt their behavior accordingly, or they risk being disconnected. Further, between 2010 and 2013, tariffs were increased on multiple occasions, in order to reach economic viability.

These actions by LUMAMA – imposing stricter rules of payment and increasing the tariffs – caused discontent among villagers. In interviews with paying customers, most say that it is legitimate to disconnect those who do not pay their bills, but very few felt it justified to do so after only one month of delay. They argued that LUMAMA should show consideration for how poor people are. There are multiple aspects related to poverty, and to the structure of the local economy, that interviewed customers explain have caused them to not pay their bills on time, such as: (1) low incomes; (2) seasonal incomes; (3) lack of habit to pay monthly bills; (4) low education, making it hard for customers to read contracts and plan their expenses; (5) distance and lack of transport (up to 2 h walking distance); and (6) expectations relating to the service and the local ownership. In the following paragraphs, we elaborate on some of these.

Electricity services for households are a new experience for the villagers. Some have lived in town and are familiar with electricity, but for the majority, it is the first time they are paying monthly bills, and getting used to it has been more or less difficult. As one of the ACRA-CCS staff put it: "people in the villages have no habit of saving money or calculating costs; for them it is not easy to adapt to monthly payments. But the money is there." In his view, the fact that customers did not pay their bills was as much a cultural problem as a lack of income. The assertion that delayed payments were not always due to lack of income was confirmed in some interviews. A number of families with regular incomes had been disconnected because they did not realize there was a strict deadline. And when LUMAMA introduced stricter rules for payment, they had to disconnect many customers in the first month, because people did not expect the rules to be enforced.

The strict regulations on payment and disconnection had a deterrent effect on a few potential customers. An old man explained that he could afford the materials and cost for the connection, but his wife worried about being able to pay the bills: "We are afraid of having electricity because if you don't pay for 3 months they will come and cut off your electricity". Another man had connected but now found himself without money for paying the next bill.

This seemingly contradictory situation was due to his – and many others – seasonal cash flow; whereas people are used to making larger investments after harvest, they also have periods without any income. Most customers stated that the tariff was acceptable and that the cost of electricity was lower compared to the money that most households spend on buying kerosene, but signing up as a customer takes away the possibility of not spending at all if things get really bad. The risk of becoming indebted is still there, even with the new payment system, as the service fee has to be paid monthly. Here, factors such as the economic vulnerability of households, short average length of life and lack of safety nets combine with the system design to constrain access.

Household economic constraints and behavior cannot alone explain difficulties with making people pay for electricity. It is also a matter of expectations coming with local ownership. LUMAMA is not a commercial business run by an outsider, like the national electric company Tanesco or the mobile phone companies that people are used to. It is locally owned, and the staff and members of the board and the GA are well known by all customers. Therefore, villagers expect LUMAMA to behave differently than a commercial investor would. Thus, there is a certain tension between being locally embedded and functioning as an independent professional utility.

Two examples illustrate this tension, the first relating to ordinary people and the second to local leaders and people with higher social status. In 2013, many villagers – both connected and not connected to the micro-grid – expressed in interviews the opinion that LUMAMA should prioritize the benefits for the community at large, not just cater to the richest people with businesses. They expected to be involved, informed and asked for their opinion, and complained in interviews that this was not happening. As one woman explained: "they don't announce, when you go and pay the bill you just find that the tariff has already increased and you have to pay for the new contract as well. They should have told us that at the end of the year there will be an increase. I am not at all happy with this". Despite knowing the staff and the office being nearby, a few customers felt as if there was no arena for them to participate in what was happening. This indicates that communication between LUMAMA and the customers did not function very well during the early years. At this stage, the transformer groups had existed for less than a year, and although they had started to hold meetings, the level of activity varied a lot between groups and not all customers had been to one.

The second example has to do with LUMAMA's relation to local leaders. LUMAMA staff, board and members of the GA have taken the approach that all customers must be treated alike, and that powerful people should be given no special treatment. The possibility, coming with this particular technology, to disconnect an individual customer, has proved a strong sanction that helps enforce rules. Once one is disconnected, one has to pay a fine of 25,000 TZS (€10.7) to be reconnected. A number of local leaders who were not paying their bills have been disconnected and fined. Through the act of disconnecting people, LUMAMA has established its authority and the importance of rules.

But the authority of LUMAMA is still disputed. A number of customers – all of them people of high social status – perceived the relationship between the local utility and the customers as unbalanced. Having started by explaining the many benefits of the new electricity service, one man expressed his ambivalent feeling toward the project:

> "It becomes difficult because now we don't even know how to take precautions, how to run [the technology]... we are just depending on other people who know it. ..What I am seeing, it is like, they are managers on that side and we are the people on the other side. They are the ones to tell us to do this and that. But now, if we are to share, even trying to suggest [an improvement], I find that it is difficult."

The way he framed it indicated that he wanted to be on an equal footing with LUMAMA. Also other people were uncomfortable, depending on a "monopoly" for electricity. They argued that the contract stipulated the responsibility of the customer only, and not that of the utility. Again, this indicates their feeling of entitlement, but also a critique of LUMAMA not being 'professional' enough. It was also clear in interviews, that some villagers consider the local staff members as incompetent, and they expected the local utility to fail on its own. Being locally embedded therefore leads to a certain degree of mistrust.

Despite the complaints, the majority of customers considered LUMAMA to be doing a good job. But there was also a clear worry about what would happen once ACRA-CCS left the project: will LUMAMA be able to manage themselves? How will they be able to continue without external funding? The local utility "cannot even afford to buy a motorbike" as one villager said. How could they possibly manage without help?

6.3.2. LUMAMA's economic outlook

People with leadership positions in LUMAMA proposed two sets of strategies to achieve economic viability. One set of activities would target the communities and provide business training for local enterprises and students, promote modern agricultural practices, and assist development of local banks. These strategies aim to diversify the local economy, reduce its seasonality and increase people's incomes. It is expected to lead to a stable customer base that can buy electricity services throughout the year and afford higher tariffs. The second set of strategies refers to the development of LUMAMA. It is projected that the system will expand both in terms of the number of customers (up to 2000) and in terms of consumption per customer.

Since August 2014, the system with flat tariffs has been replaced with a new payment scheme with pre-paid meters (Fig. 2, Section 6.2.1). In comparison to before, the new tariffs represent a significant increase in price per unit. However, the increased tariffs do not necessarily translate into higher cost for customers, as they are likely to consume less electricity now that they have to pay for each kWh. For the smallest users (households that consume 5–10 kWh/month), it is expected that the total cost per month will hardly increase.[9] Customers will now pay up-front instead of at the end of the month. The change in system design to pre-paid meters allows for domestic customers to consume more when they have income.

LUMAMA also needs to plan for and cope with seasonality of electricity demand among its business customers. For example, the owners of the milling machines have very few customers before harvest and the tailors get important income from making school uniforms at the beginning of each semester. The implication is that sales of electricity will vary over the year, increasing the seasonality of incomes for LUMAMA. The local economy places higher demand on organizational planning capacity in order to adapt.

6.3.3. Positive consequence of local ownership

Load management is another important issue in small-scale distribution systems that place demands on the organization, to regulate consumption and plan ahead for growing demand. Overload, that is, too much current demand on the circuits in electric

[9] The expected total cost will be 3250–4000 TZS per month.

systems, leads to protection devices cutting off the current flow, causing a system shut down and therefore a temporary blackout. In Mawengi, if the hydropower system stops due to overload, a technician has to go to the plant and manually restart the system, a process that takes a few hours. This technical condition has motivated both management and users to manage loads.

Locally embedding LUMAMA facilitates people voluntarily agreeing to manage the load. In 2013, the rains came late and the water table fell below what LUMAMA and ACRA-CCS thought was the minimum needed to keep the system running at full capacity. There was a risk of overload. In response to the reduced water flow, LUMAMA called a meeting with all owners of milling machines, i.e. the heaviest loads (largest consumers of electricity) in the system, to decide on voluntary distribution of service hours during periods of stress. The risk of blackout, if all machines were to run at the same time, proved a strong incentive for competing millers to collaborate and make voluntary agreements. The arrangement was still working well six months later. The experience strengthened LUMAMA in its role as a management organization. Also, the willingness to collaborate has an economic value, that is, voluntary and observed agreements on load shedding bring the opportunity to maximize the use of, and thereby incomes from, the existing capacity, allowing for more customers and higher overall loads than would otherwise be the case.

Another value that has been achieved as a result of local ownership in this particular system is protection of the grid infrastructure and the ability to hold individuals responsible for damage. In 2011, a villager felled a tree across a newly built extension line to one of the villages, breaking the new rules for what activities could be undertaken close to electric lines. Whether it was by accident or not, the man refused to pay for the damage. The villagers expected ACRA-CCS to pay for the repair. But the grid was the property of LUMAMA and they had to solve it themselves. It took about six months before the local leaders and LUMAMA could put enough pressure on the man to make him pay. After that, there have been other cases of people felling trees over the lines, but the utility staff have solved these together with the village leaders within a few weeks (damage has amounted to a total of around €3000). This is a valuable protection of the infrastructure and shows a sense of responsibility rarely achieved in commercial systems. Rather than it ending up in a court case, LUMAMA and the local authorities are holding individuals responsible for damage to the infrastructure and community services, and are quickly reaching solutions.

6.4. From service delivery to impact

The final question is what economic impact the project has actually had on the communities and whether the demand for electricity is increasing in a way that can provide the customer base LUMAMA needs. A quantitative assessment cannot be done, as the baseline study carried out by ACRA-CCS was done in 2012, when the project had already delivered services for a couple of years. Still, the qualitative study provides some insight into what changes have occurred.

6.4.1. Electrification as a driver for economic change

For households in the electrified villages, the major economic impact is the 50% reduction in the cost of milling services, and, for connected households, the cost reduction from replacing kerosene with electricity for lighting [52]. Households without electricity consume an average of 3.5 liters of kerosene per month at a cost of 6120 TZS,[10] compared with 4750 TZS for a customer consuming 15 kWh per month. As noted earlier, the basic needs poverty line is about 36,000 TZS per month. Firewood (and to some degree charcoal) remains the dominant fuel for cooking, even in households having electricity. For people with light at home, the survey and interviews suggests the majority stay up one or two hours longer in the night, and if they have television (6.6% of households in 2012), spending time in front of the TV. Communications have improved, with easy access to mobile phone charging – in 2012, 68.5% of households owned mobile phones. "Before electricity, the difficulty in charging was the factor that most discouraged people from buying a mobile phone. . .. [T]he issue of communication has improved a lot". There is a range of new services using electric appliances that were not there before, such as fridges, electric sewing machines, electric razors and photocopy machines. Some people said they saved time and money from not having to travel to the nearby town for these services. A handful of people also state that people from other villages now come to their village to use the new services, which helps the local economy grow. Future evaluations will reveal if the expected long-term benefits from the project-related improvements of education and healthcare will impact positively on local livelihoods.

In terms of businesses, the provision of electric light has led to longer opening hours. Many business people, such as barbers, butchers and restaurant owners, say that since the number of customers has increased after they got light, they make more money (these are likely to be local customers who went to other places before and now have changed their preferences). A few businesspeople interviewed have been able to expand their services and employ more people (often one or two new assistants to the shopkeeper). There are also new enterprises, supported by ACRA-CCS's business program, including sunflower oil pressing machines, mechanical workshops, poultry farming and fruit processing. However, there are examples of carpentry owners who lay off workers when they get electric machinery. The statement that electrification generates jobs needs to be qualified, because some jobs disappear at the same time as new opportunities arise when the economy is reshaped and local cash flow is redirected, and not all new jobs are paid better than the old ones. Unless there is an inflow of resources from external sources, the size of the local economy may not grow.

Lack of electricity is just one of the constraints for local businesses. For example, some carpentry workshops have been able to increase their speed of production and to some extent also the quality of their products due to investments in electric machinery. However, the final products cost the same, and they sell mainly to the local market. Low quality of raw material results in poor quality products (only slightly better than before) that cannot compete in external markets. Poor road infrastructure, seasonality of demand and lack of investment capital are other important barriers to increasing productivity. In the service sector, increasing competition for customers can also become a problem. This was the case for a woman who was among the first to have electric light in her small restaurant in Mawengi. The initial boost in her business did not last, as other restaurant owners also put in electric lights.

A visitor returning to the area will see the visual changes of a growing economy. Over the past five years, the number of motor vehicles in the downstream villages has increased from just a few motorbikes in 2012, to tens of motorbikes, a few cars and even one truck in 2014. One of the local businessmen explained that he was

[10] Whereas the price per liter of kerosene in Dar es Salaam was 2040 TZS (€0.92) on 3 September 2014, rural prices were substantially higher. According to a study from 2012, rural consumers pay 23% more for kerosene [52].

buying a car now that there were new business opportunities in the sunflower oil market thanks to electricity. House constructions are visibly on-going at multiple locations in each village, and according to statements from a handful of villagers, people choose to build in a place where they can be connected to the new grid, given that they can afford to buy land. If this is a general and sustained trend, it will lead to denser settlement patterns in the longer term. This, in turn, will facilitate grid expansion by reducing distance and thereby cost of investment. There is also evidence that some people have come back to the area and found themselves employment or started new businesses. Other people have migrated to the area because they felt that there was an opportunity to make a living.

7. Conclusions and final discussion

The Mawengi hydropower project displays an interesting combination of factors that earlier research identifies as being key to success as well as to the possible failure of small-scale off-grid electrification. It is an NGO-led and donor-funded project, and such development interventions are criticized as being economically unsustainable, donor-dependent, short-term and top-down interventions [33,38]. There are also the contextual challenges, identified by previous research as negatively influencing economic viability, related to implementing this kind of project in a relatively poor area of Tanzania where the demand for electricity and the level of industrialization is very low, and the majority of inhabitants are farmers with seasonal spending patterns [1,9,12]. On the positive side, the case is characterized by a high level of local involvement and capacity building – factors identified by previous research as prerequisites for sustainable small-scale electrification [2]. The socio-technical system perspective and theoretical framework have assisted us in probing and understanding the significance of, and interactions and tensions between, these important factors in the process of system formation. We will now answer and discuss each research question.

7.1. The logic of integrated development

The first question is: *According to what logic does the NGO implement the electrification project, and what constraints have come with donor funding?* Our analysis of the implementation 'logic' included attention to the NGO ethics and objectives, choice of design and mode of operation of the system, and the strategy of implementation. The case shows that specific circumstances and key actors shaped the initial logic of implementation and the system put in place. The good relationship between the local church and the international NGO, ACRA-CCS, allowed these actors to mobilize donor funding for the project, and use high-quality equipment. The priorities, objectives and interests of both actors corresponded well and resulted in a non-profit development initiative.

In the first phase of construction, ACRA-CCS played a fairly conventional role for an NGO – arriving in the community with external funding and expertise, constructing a mini-hydropower system and grid infrastructure according to predefined design and within a set time frame. However, the staff realized that they would not achieve project objectives without changing the logic, from a focus on providing infrastructure to working with the actors and institutions that would guarantee system sustainability. They needed more time to finalize construction but also funding for other types of activities that had not been foreseen at the initial planning stage. This required a broader funding base. As ACRA-CCS was successful in acquiring funding from multiple donors for the second phase, the staff could focus on building the organizational capacity and institutional protection of the local utility LUMAMA. For example, their support included on-the-job training for staff, being present at the office on a weekly basis, joint weekly meetings and managerial advice. The exit strategy of the NGO was to make sure the utility could own and manage the energy system independently and achieve economic viability.

Another dimension of the change of logic had to do with staff increasingly understanding the cross-sector linkages between the factors that challenged the sustainability of the energy system. This was addressed when ACRA-CCS launched various parallel components, in order to create synergies between sectors. This is interesting because lack of complementary investments and cross-sector collaboration is considered a barrier to rural electrification becoming a catalyst for socioeconomic development [12,53]. The Mawengi case offers a possibility to substantiate these policy recommendations with evidence of the actual benefit of complementary investments. According to ACRA-CCS staff, the ability to work with parallel components has transformed the project and has had significant positive impact on what could be achieved. Interviews with LUMAMA staff and villagers strengthen this conclusion. By addressing complementary issues, ACRA-CCS gained a larger degree of support for the project and trust of local communities. It also produced better technical and social outcomes.

7.2. Strategies to achieve economic viability and local ownership

The analysis explored in more detail two aspects of the NGO logic: the economic approach and the view of system ownership. Our question was: *What strategies has the NGO used in order to achieve economic viability and local ownership?*

As expected, based on the emphasis on rural poverty as a barrier to electrification [54], we have found that there is friction between the economic needs of LUMAMA and the structure of the local agrarian economy and livelihood base [9]. But it became clear that seasonality of the economy plays a role that is equally important as low levels of income. Fundamentally, the challenge lies in the need for LUMAMA to generate enough income and manage the budget on a monthly and yearly basis, in a rural setting where people's incomes and spending are related to harvest and planting, as well as the school year. Importantly, rural economies differ in their seasonal patterns due to specific combinations local climate, state of infrastructure, and livelihood composition. Obviously, cash flow dynamics in coastal and inland communities are likely to differ and it may be relevant to adapt financial strategies and budget plans accordingly.

The project had a strong social orientation from the start. In order to make electricity affordable for more than the high-income households, cost of connection and tariffs were subsidized and, in the Tanzanian context, comparatively cheap. This approach finds support in literature, among scholars who argue that financial subsidies are needed to cover the high up-front cost of technology [5,9]. Interestingly, the NGO went one step further and used the possibility to regulate the market for, and consumer price of, the socially important milling services. As a result, the villagers benefitted from a 50% reduction in the price for milling their maize, which improved cash flow and purchasing power for many families. Also the strategy of actively supporting the local businesses in making use of electricity is in line with earlier evidence on the benefit of doing so [5]. The resulting level of productive electricity use (58% of the electricity sold) is high in the Tanzanian context and indicates that providing access to machinery by grant or credit, together with business training for local entrepreneurs, can speed up the development of productive uses substantially. Together, these strategies improved the economic situation of villagers both in terms of allowing for increased consumption or saving, and by facilitating investments in local production. From a system perspective, the

initially low tariffs and credit scheme for connection facilitated the growth of the customer base and created popular support for the project, but placed a financial burden on ACRA-CCS and LUMAMA. Over time, the tariffs were increased to reach a balanced budget, and customers enjoyed less favorable conditions. But by then, the customer base had been established and the local economy had seen an initial boost.

There are different possible interpretations of 'economic viability' in the context of rural electrification. ACRA-CCS defines it as covering costs of management and operation, new investment in infrastructure as the system expands, and long-term reinvestment when infrastructure components need to be repaired or replaced. ACRA-CCS believes economic independence of the utility and ability to cover future reinvestments are important in this context. In contrast, the churches running hydropower installations in the area have a different approach[11] and rely on their external networks for donations in case more expensive system components need to be replaced or repaired.

The approach to local ownership also changed in its logic in phase II. The initial organizational structure did not accommodate for the continued construction of the distribution grid and connection of new villages. It was also top-down in the sense that it lacked a clear institutional base among its customers. In 2013, ACRA-CCS staff framed this as a problem and the motivation for changing the organizational structure. The new regulation of LUMAMA created a wide membership base that aimed to secure the engagement of local communities and protection of infrastructure.

ACRA-CCS has also aimed to strengthen the local utility by involving the church and district government on LUMAMA board. It is seen as important for balancing the interests of strong actors and ensuring strong supporting networks. Without strong support, the staff perceived a risk that the new organization would be outmaneuvered by existing, more powerful and established actors. The analysis shows that the networks with actors at higher decision-making levels have proved valuable at numerous occasions, when relationships with local political actors have been tense. Rather than implementing the project as a 'technical' project outside the realm of politics (Korf 2010), the NGO has admitted to the deeply political character of the intervention and used the available political channels, from village level up to national level. ACRA-CCS has also complied with national legal frameworks with the result that government stakeholders at district and national level consider the project a role model.

7.3. Becoming an arena for collaboration

In our analysis of the third research question – what economic and organizational challenges has the local utility faced? Have there been any positive consequences of local ownership? – we shifted perspective to that of LUMAMA and of the people living in the area.

In the process of building LUMAMA as an organization, social relationships between local people have been partially transformed. Utility staff and members with leadership positions have taken on new roles in relation to their neighbors. They have become "the people of LUMAMA". As a local organization, LUMAMA needs to balance satisfaction among the users against its need for incomes and 'good' customer behavior. So far, the local utility has used rules and the sanction of disconnecting their electricity, to teach customers to pay their bills on time. The strict enforcement of rules is interpreted differently depending on the situation. Some local leaders who did not pay their bills on time complied with the rules only after LUMAMA used the sanction of disconnection. This may be part of the reason why a majority of villagers in our study consider LUMAMA to be non-corrupt and doing a good job. However, disconnecting a poor family is not considered equally legitimate. This indicates that effective regulation based on an all customers alike principle is not necessarily perceived as fair. Our analysis has identified six reasons why ordinary people do not pay their bills on time (Section 6.3.1). The act of disconnecting customers has, under certain circumstances, reflected negatively on LUMAMA. There are also elements of shame and fear related to being disconnected, as shown by previous research [55], which deter some potential customers from connecting to the grid.

We consider community ownership and responsibility to be important factors that have contributed to the positive outcomes. In particular, LUMAMA is doing well because of the broad membership base, the competence of the staff and the regulatory protection against elite capture. The local utility has developed into a democratic organization with decision-making power and an arena for community collaboration and problem solving. In parallel to the formal regulations there are emerging informal institutions in terms of shared norms and values among members of the LUMAMA GA and board. For example, we interpret the decisions made by the GA to raise tariffs on multiple occasions to express: first, a shared (or at least dominant) understanding that electricity services are valuable to the communities; second, an idea of what constitutes responsible action; and third, support for the principle that economic viability is a prioritized goal. However, interviews indicate a lack of communication with villagers who are not directly involved in the organization. Also, some villagers question the competence of LUMAMA staff, on the basis of them being local, 'uneducated' people. Therefore, a drawback with local ownership has been a certain degree of mistrust between villagers and LUMAMA, which reflects ideas about who is an expert and what knowledge is valued[12] [56].

Local ownership has combined with technological factors to create positive synergies. Here, we want to highlight the important role played by the technology in creating positive incentives. Small-scale hydropower comes with particular technical characteristics and modes of operation, which place demands on management. These demands have reinforced the process of organizational development. The need to manage peak loads, avoid blackouts and have security regulations to prevent accidents all call for collaboration across village boundaries and enforcement of rules. In the process, trust is strengthened and mutual learning takes place. Demands of the technology combine with the institutional frameworks and good relationships to local and external actors, resulting in values for the utility that are often missing in other small-scale electrification processes. In particular, the voluntary and respected agreements on load management, and protection of the grid infrastructure against damage by individuals are important economic and social values for the utility. Is it possible to replicate these elements in other off-grid systems? Could it also be done in a commercially run system? We have not seen this elsewhere in Tanzania, but argue that there are lessons to be learnt here from how system characteristics can provide incentives for individuals and collectives to develop a common agenda for the system.

7.4. Significant economic development

Our fourth research question was: *What are the outcomes in terms of electricity demand and impact on the local economy?* Our

[11] We know this from visits at other hydropower installations in the area and discussions with the responsible church leaders. They emphasized the social responsibilities of the church and had no business plans.

[12] For an in-depth discussion on expertise in relation to formal education see [49].

analysis has shown that the Mawengi Integrated Rural Development Program is having substantial impact on daily life and economy in the communities connected to the electric grid. Can this really be true, considering that the number of households connected is just a small percentage of all households in the area? The cost saving from cheaper milling of the staple food, maize, improves the cash flow for nearly all families in the area. Further, both public and commercial services have been improved, bringing immediate and long-term benefits for the population. We are not saying that future benefits are guaranteed or that there are only positive consequences. Clearly, the analysis shows the economic complexities and ambiguous outcomes as well. All people interviewed agree that electricity – they thought it a dream and never expected it to come true – has brought important changes. The customer base is still growing. Theoretically, our analysis shows how the introduction of electricity and accompanying investments and opportunities are having a material impact on daily life.

People say that their 'remote' villages are developing fast. However, it is very difficult to say which changes are due to having electricity in the village, in itself, and which are part of on-going changes in the rural economy that would have occurred also without the project. What change would have happened due to the change in administrative status of the nearby town Njombe, from town to region, which is bringing new investments in terms of roads and communication? We argue that the exercise of 'attribution' misses the point. Based on our theoretical perspective, we argue that the introduction of electricity and all the other activities undertaken by ACRA-CCS enhance and merge with processes that are already taking place at various levels.

7.5. Final reflections

In conclusion, the findings from this study corroborate many of the claims in the existing literature. The case of Mawengi lends support to other case studies and comparisons holding factors such as community ownership, capacity development, and stakeholder engagement as crucial success factors [8,9]. In addition, the case study shows the importance of coupling energy programs with complementary activities such as, for example, education and agricultural processing [5,12]. The rich case description contributes to existing literature by filling these rather vague concepts with concrete content. The conceptualization of the electrification process as the formation of a new socio-technical system has assisted the explorative analysis as well as provided explanatory power, by directing our attention to the way relationships develop between the new and previously existing technologies, actors, resources and institutions and how these co-evolve over time – thereby transforming the context as well as the socio-technical system.

Further, many of the economic, political, and social challenges that previous studies have identified as constraints – such as aid dependency, lack of local managerial capacity, risk of elite capture, low electricity demand and business skills – are clearly visible in Mawengi as well. The main lesson learned from this study, however, is that many of these challenges can be overcome by: having a long time frame, acknowledging the challenges, and having the resources to restructure the program accordingly [4]. In terms of cost, the project has been expensive. Total cost amounts to about €6 million, for a system of 300 kW capacity. Off-grid electrification of poorer areas requires public investment or donor funds; return on investments is not an option unless the system can sell excess electricity to a large customer – preferably the national grid. But the Mawengi case shows that even off-grid systems can become economically viable in terms of covering the cost of operation and maintenance after a few years.

It is our conclusion that the positive synergies between factors should be actively sought in other projects. In particular, the incentives and associated values that emerged out of the combination of local ownership, integrated development and technological requirements are also of interest in more commercial projects. Also, proponents of commercial, for-profit, rural electrification will find it worthwhile to consider partnerships or hybrid models that combine commercial and public financing and establish partnerships between private investors, local communities and the government. In fact, what it suggests goes beyond the idea of so-called public private partnerships (PPPs) to public private community partnerships (PPCPs) – involving communities as crucial partners with a strong mandate and shared ownership.

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