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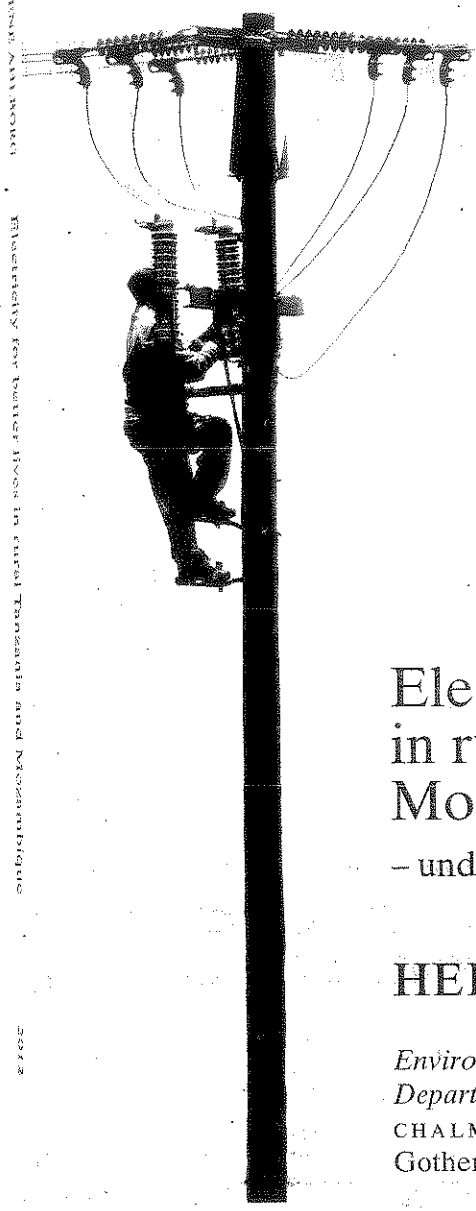

Electricity for better lives in rural Tanzania and Mozambique

HELENE AHLBORG

Electricity for better lives in rural Tanzania and Mozambique

– understanding and addressing the challenges

Environmental Systems Analysis
Department of Energy and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2012

Dear Boaventura
Thank you for kind assistance and hospitality
Helene

THESIS FOR THE DEGREE OF LICENTIATE OF PHILOSOPHY

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ABSTRACT

Provision of electricity is essential for economic and social development. It renders possible modern communications, industrial and business development and provision of public services such as improved education and healthcare. But in rural Tanzania and Mozambique, less than 5% of the people have access to electricity from the national grids, and at the current pace it is unlikely that the majority of the rural population will be connected to the grid within a foreseeable future. Therefore decentralized, off-grid electrification is needed as a complement. These countries are rich in renewable energy sources, which could be utilized to meet the energy needs of rural people.

The overall aim of the thesis is to identify and understand – from the perspective of involved actors – country-specific drivers and barriers, and prerequisites, to rural electrification in general, and off-grid electrification using renewable energy technologies in particular. The thesis includes a review of previous literature, presenting an exhaustive list of barriers to rural electrification (RE) in sub-Saharan Africa. The theoretical contribution is a bridging between research fields, done by a conceptualization of RE processes that combines a socio-technical system perspective with a user perspective that focus on how actors gain, control and maintain access to electricity and related benefits. It opens up for a valuable discussion on system functionality and sustainability. There is also a methodological contribution and discussion, developed in article 3, which highlights the importance of scale of observation and epistemology in research on complex processes of societal, technological and environmental change.

The empirical work is based on qualitative interviews, project site visits in Tanzania and Mozambique and literature review. The results are presented in articles 1 and 2. The findings are in line with previous studies, but some barriers not previously emphasized in literature come out as important and ambiguous. The thesis also discusses why productive uses of electricity, which are seen as highly important, do not occur as much as hoped for and the multiple roles that private sector actors can take in RE, as producers, electricity consumers and service providers. So far, RE projects have not paid enough attention to what happens after introduction of electricity, and to possibilities for enhancing the capabilities of local actors to make full use of development potentials.

Keywords: Rural electrification, Africa, Rural development, Renewable energy, Off-grid, Drivers and barriers, Access to electricity, Socio-technical systems

STEEP-RES

STEEP-RES is an interdisciplinary research programme initiated in 2008 in collaboration between Environmental Systems Analysis, Department of Energy and Environment at Chalmers University of Technology, and Department of Political Science, Göteborg University, Sweden. Within the programme, a number of research projects contribute to integrated social, technical, economic and environmental assessments of the development of sustainable and renewable energy systems for increasing the welfare in rural areas of sub-Saharan Africa. The programme was initially funded by Stiftelsen Futura, and is now funded by Sida/SAREC, and Formas. Generous grants have also been provided by Adlerbert Research Fundation.

LIST OF APPENDED PAPERS

Paper 1.

Ahlborg, H. and L. Hammar (submitted to scientific journal)

Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off-grid and renewable energy technologies

Paper 2.

Hammar, L., H. Ahlborg and S. Molander (submitted to scientific journal)

Productive use and private sector in rural electrification of Mozambique and Tanzania

Paper 3.

Ahlborg, H. and A. Nightingale (submitted to scientific journal)

Mismatch between scales of knowledge in Nepalese forestry – epistemology, power and policy implications

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1 Introduction

What is electricity? Is it an energy carrier enabling humans to carry out heavy work that would otherwise take the effort of many people? Is electricity an invisible 'thing' that can hurt you if you don't know how to handle it? Is it the electrical appliances, the ironing and the battery charger, or the possibility of having light in the evening, listening to the radio or watching TV? Is it the pleasure of cold drinks, the provision of school evening classes or improved healthcare with sterilized equipment and storage of vaccines? Electricity is all these things, but in many places it is also a symbol of being modern and rich, a safety measure to keep spirits and thieves away in the night, and a feeling of disgrace and anxiety when the bills cannot be paid at the end of the month.

As a technology, electricity has many dimensions, beyond the current itself or the technical artefacts. The appliances and services related to it have huge impact on daily life and our social relations. But for more than two billion people, access to modern energy services is not part of daily life (UNDP 2004, 2005). Especially in developing countries, and in the rural areas of these countries, the large majority of poor people rely on bioenergy to meet their energy needs, in terms of wood, charcoal, energy crops of different kinds and agricultural residues. In cities, people may burn waste, plastic bottles or whatever is at hand, if they cannot access wood or charcoal. Without access to electricity, poor people pay dearly for sources of light such as kerosene, candles and lamp oil, batteries for the radio, or diesel for mechanical power. Lack of access to modern energy services is a contributory cause of poverty, and providing modern energy services in rural areas removes a decisive barrier to socioeconomic development and poverty alleviation (SEI 1999; Wilkins 2002).

Modern energy services are often a key aspect in other development areas, such as industry and business, water and sanitation, health and education and environmental security. Energy systems that are damaging to the environment may have short-term gains, but from the long-term perspective have negative effects on people's wellbeing, by causing health problems and degrading the ecological base of livelihoods. The many dimensions of energy and its decisive importance for development and poverty, are captured by UNDP (2005) in its report on the relation between modern energy services and achievement of the Millennium Development Goals (MDGs). UNDP states that development of energy services is a prerequisite for achievement of each of the eight goals (see Appendix), and that access to energy services – if strategically integrated with other development efforts – can be "an

important instrument in helping promote economic growth, social equality, and environmental sustainability" (UNDP 2005: 1).

This thesis focuses on rural electrification (RE) in Tanzania and Mozambique. Provision of electricity is essential for modern communications, industrial development and provision of public services such as street lights, improved education and healthcare. Providing electricity in the rural areas of these countries is very important, but where basic fuel needs are not met, electricity is a luxury item that few people can afford[1] (UNDP 2005). But integrated with other development efforts, the short- and long-term benefits of electrifying rural areas can be substantial. RE removes a barrier to economic development and creates opportunities for sustainable livelihood strategies.[2] Electrifying the countryside is also considered a possibility for slowing the urbanization process by providing better economic opportunities and quality of life for the rural population (e.g. Wilkins 2002; Winther 2008).

The popular demand for electricity is generally very high, and is a political priority in East Africa (Winther 2008). However, less than 5% of the people in rural areas of Tanzania and Mozambique have access to electricity from the national grids, and at the current pace it is unlikely that the grids can be extended sufficiently to provide the majority of the rural population with electricity within a foreseeable future (Karekezi and Kimani 2002). This situation with low rural access and slow RE pace is what motivated the research presented in this thesis. There are some options for faster development: the actors now extending the national grid could improve their performance, off-grid electrification (stand-alone, decentralized systems) can complement grid extension, and new actors from civil society and the private sector could engage in both activities.

What then are the prospects, the drivers and the barriers for faster grid extension and off-grid development? Grid extension efforts are constrained by costs and organizational capacity. Building up the energy infrastructure is particularly expensive in Tanzania and Mozambique, due to large geographical distances and low population density. There is little rural industry, and few households can afford the connection charges. It is a long-term and hugely expensive investment, currently funded largely by international donors and undertaken by the national utilities (EdM 2007; MEM 2009). So far, there has been no interest by the

[1] Therefore, when discussing the possibilities for providing rural people with access to electricity and related services, it should be remembered that electricity is often not the first priority for local people.
[2] Livelihoods are defined as "the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway 1991:7).

private sector to invest in transmission and distribution, as it is so costly. This thesis is concerned with possibilities for improved performance of the key organizations, but also what role the private sector might play in the future.

Off-grid systems based on renewable energy technologies (RETs) are nowadays acknowledged as an important complement to conventional RE and to diesel generators (WB 2008). In areas where the national grids do not reach, people rely on small-scale off-grid systems – primarily diesel generators – to generate electricity. Using off-grid electrification can be seen as a forerunner to grid access, but in many cases it is more than a temporary solution as there will be no other alternative within the coming decades. For very remote locations, transmission is so expensive that off-grid systems using RETs are considered an economically viable alternative by many scholars (Chakrabarti and Chakrabarti 2002; Katsaprakakis et al. 2009; Pepermans et al. 2005; Turkson and Wohlgemuth 2001).

RETs are promoted globally for environmental reasons, and there are hopes of sub-Saharan Africa avoiding the 'carbon lock-in' of industrialized countries and leapfrogging directly to modern and environmentally sustainable energy systems (Karekezi 2002). According to Karekezi (2002), a development towards renewable-energy-based decentralized systems would have important economic benefits in comparison to conventional and centralized energy systems, and is a particularly competitive option for delivering modern energy to Africa's rural poor.

It is however imperative, according to SEI (1999), that the primary goal of RET programmes is to meet the energy needs of the target population rather than promoting certain technologies, which leads us to ask whether small-scale RETs are suitable for that purpose in rural Tanzania and Mozambique. Small-scale RET off-grid systems differ in many respects (technically, financially and socially) from grid extension and diesel generators. There are some important advantages in this context that merit attention, the most important being that renewable energy sources are available also in remote locations, that they can be harnessed locally, and that transportation and distribution costs are minimized (Karekezi 2002; Wilkins 2002). But there are also, as will be shown in this thesis, barriers specific to off-grid systems and various RETs.

The use of RETs in off-grid installations in this region is still in an early phase, and experiences are varied. There are difficulties in making these systems function as planned, and many systems fail after some years. What is required for off-grid RETs to work

sustainably in rural areas of these particular countries? What lessons can be learned that go beyond each unique case and are applicable at a larger societal scale? Each case is indeed unique, but there can be types of processes and contexts that enhance problem-solving and sustainable management. By drawing on experiences of actors who understand local contexts and relating these to what has been learned in other contexts, for other technologies, systems and countries, obstacles may be identified and removed. Based on the ambition of providing modern energy services in rural sub-Saharan Africa, so as to improve people's well-being and contribute to rural development, various dimensions of sustainability must be taken into account and addressed in a rural context where the majority of people base their livelihoods on locally available natural resources.

1.1 Research aim

Based on the societal importance of electricity for rural development, the low level of access to electricity in Tanzania and Mozambique, and the slow pace of rural electrification, the overall aim of the thesis is to identify and understand country-specific drivers and barriers, and prerequisites[3], to rural electrification in general, and off-grid electrification using renewable energy technologies in particular.

This aim has two dimensions: one theoretical and one empirical. The *theoretical* aim is to bridge between two fields of research that contribute important insights to studies of the process of rural electrification, and combine a system-theoretical perspective and a user perspective. From a system-theoretical perspective, provision of electricity must meet certain requirements for the system to be functional in specific settings and sustainable over time. From the user perspective, people want access to electricity and related benefits, but an important question in this context is exactly what it is that they get access to. Does the technology correspond to people's needs and expectations? Is the technology seen as functional by the actors involved? My attempt to conceptually integrate these perspectives is presented in the theoretical chapter of the thesis.

The *empirical* aim is to explore the drivers and barriers, and prerequisites, from the perspective of power sector actors, and to discuss in more depth a set of questions of crucial

[3] Drivers and barriers refer to specific factors in the current situation that enhance and hinder wished-for development. They are part of the present state of things. Prerequisites on the other hand, are not necessarily in place, but the conditions under which the desired development can take place.

importance for providing rural people in both countries with functional and sustainable access to electricity and related benefits. The title of the thesis mirrors its general goal – by enhancing the understanding of challenges and building knowledge capacity among involved actors, a better base for addressing the challenges is provided.

1.2 Limitations of the thesis

The work presented here focuses on renewable energy technologies and sources for provision of electricity, so bioenergy for heating and cooking purposes are left out. Also, focus is on renewable energy sources that are readily available in the region – mainly solar and hydro, and in some places wind and geothermal – and technologies that are proven to be both commercially and technically viable in similar contexts. The question of what renewable energy sources are of interest has been left open in interviews, so as to let actors identify what sources they consider relevant. This is not a historical study, but draws a picture of what challenges the countries are facing today and in the near future, but of course actors often give historical reasons for today's situation.[4] Finally, the number of actors interviewed had to be limited, and apart from technical consultants, private sector actors are not represented. This is a weakness of this work that will be addressed later.

1.3 Outline

The thesis is outlined as follows: first I briefly present the two case study countries, and the state of the power sectors in Tanzania and Mozambique. Then comes a chapter on previous research and the current state of knowledge regarding the relation between rural electrification and development, drivers and barriers to RE in sub-Saharan Africa, and off-grid electrification based on RETs. In the following chapter, my theoretical points of departure are presented and I explain how I conceptually bridge between a system perspective on socio-technical change and a user perspective on introduction of electricity in rural communities. The chapter ends with my research questions. This is followed by methodology and method, explaining my methodological approach and how the research has been conducted. The results section summarizes the findings in the three appended articles. The discussion then

[4] The empirical work presented here does not include case studies of communities where electricity has been introduced, but case studies have been initiated and will be the focus of forthcoming publications.

refers back to the research questions – and takes one step further. Finally, conclusions are drawn, and the next step explained.

1.4 The case study countries

Tanzania and Mozambique are neighbouring countries, along the coast of south-east Africa, and they face similar challenges when it comes to rural development and poverty alleviation. The countries are rich in natural resources and have populations spread out over vast areas. There is very limited rural infrastructure, and industries and businesses are mainly concentrated in urban areas and some rural centres. The majority of the population lives in the countryside, but urbanization rates are high, draining rural areas of younger people. Tanzania is ranked 152nd and Mozambique 184th out of 187 countries on UNDP's multidimensional poverty index (UNDP 2011a, 2011b). The large majority of poor people rely on bioenergy to meet their energy needs, in terms of wood, charcoal, energy crops of different kinds and agricultural residues. In general, poor households have no extra disposable income, and resources are prioritized to cover basic needs. Expenditure on energy is mainly for food preparation and basic lighting. Expenditure on electricity is likely to be limited to replacing what is currently spent on kerosene and batteries, and electricity may not even be a high priority (EdM 2007).

There is little political and economic exchange between the neighbours, and there are important differences in their history, culture and social structure.

1.4.1 Life in rural Tanzania

The United Republic of Tanzania was formed in 1964 after independence from the United Kingdom. During the first 20 years after independence, the government, with Julius Nyere as president, ruled Tanzania according to his vision of African socialism. The socialist rule of Nyere was controversial, and he is remembered both as 'the Teacher' for trying to install national unity, making Kiswahili the national language and for enforcing the Ujamaa system and repressing political opposition (Hillbom and Green 2010). When Nyere handed over power in 1985, the economy had stagnated and the country depended on external aid. During the 1990s, economic and political reforms took place, including market liberalization and multi-party elections. During the past decade, economic growth rates have been around 6% and the economic prospects are currently looking bright (African Economic Outlook 2012b).

Key drivers of growth include private consumption, exports and gross fixed capital, tourism revenues, foreign investment and aid. The main economic sectors are agriculture, manufacturing, tourism, mining and infrastructure. However, poverty remains a major challenge and wealth is very unequally distributed. The population of 46 million is growing rapidly. According to UNDP (2011a) life expectancy at birth is 58.2 years and the adult literacy rate is 73%.

1.4.2 The power sector of Tanzania

Tanzania's electricity generation relies primarily on hydropower and natural gas, complemented by imported oil and cogeneration from agro-industry (MEM 2009; Otieno and Awange 2006). The dependency on oil imports is problematic and strains the national budgets. Renewable energy sources other than hydro, such as wind, solar and geothermal, account for less than 1% of Tanzania's national energy balance, but the potential is deemed good and of high importance (MEM 2009: 31). In 2008, the total installed power production capacity was 1100 MW, but due to climatic conditions with little rainfall, breakdown of installed infrastructure and mandatory shutdown for maintenance, only 630 MW on the average was being produced that year. The recorded peak demand in 2008 was 787 MW (MEM 2009). In 2008, generation was 4358 GWh of which hydro accounted for 2579 GWh. The technical losses amounted to 19% of generated power. The transmission grid reaches only part of the country, and large areas, particularly the sparsely populated western and southern regions, are still beyond reach. Here, district capitals and other important centres are supplied by diesel generators. The percentage of rural population that is connected to national grid electricity is estimated to be 2–3% while the urban rate is 14% (MEM 2009; Otieno and Awange 2006).

The power sector is dominated by the national electric company TANESCO (Tanzania Electric Supply Company Limited), operating under the Ministry of Energy and Materials. As part of the power sector reform over the past decade, the sector was restructured and the power market liberalized. Measures have been taken to attract private sector involvement, and some independent power producers have engaged in generation. A new government agency called the Rural Energy Agency (REA) became operational in 2007. REA is responsible for "promotion and facilitating access to modern energy services in rural areas of mainland

Tanzania" (MEM 2009: 8) including off-grid systems. Regulatory oversight of the tariff system is now ensured by EWURA (Energy and Water Utilities Regulatory Authority).

1.4.3 Life in rural Mozambique

Mozambique is among the poorest countries in the world. The country suffered a civil war during 1977–1992 starting two years after its independence from Portugal. Since the civil war ended, the country has seen positive economic development, with GDP growth rates at about 7–8% per year (African Economic Outlook 2012a), but starting from very low levels. According to the UNDP (2011b), the total estimated population is almost 24 million. The average per capita income was estimated to be 300 USD per year in 2006 (EdM 2007). There are large regional differences in poverty levels, with 80% of the population below the international poverty line in the poorest province, Inhambane (EdM 2007). The rural economy is primarily based on subsistence farming: in Mozambique 68% of men and 90% of women work in agriculture. People also keep livestock, grow cash crops, produce charcoal and survive on subsistence fishing along the coast. There is little large-scale farming or rural industry and most economic activities are small-scale. There are occasional industrial activities within, for example, forestry, mining and agricultural processing. Life expectancy at birth is 50.2 years (UNDP 2011b), seriously affected by the spread of HIV/AIDS. Among the adult population, 55% are literate and less than one third of the population speaks the official language, Portuguese. Of urban residents, 94% live in slums (EdM 2007).

1.4.4 The power sector of Mozambique

Mozambique has an estimated hydropower potential of about 12–14 GW, but there are also substantial reserves of natural gas and coal (EdM 2007). Electricity is almost exclusively supplied by the hydropower station Cahora Bassa with 2075 MW installed capacity, situated in the north-western part of the country. In addition to Cahora Bassa, there are only a few smaller hydropower stations and a back-up coal power station. Most electricity from Cahora Bassa is exported to neighbouring countries, but transmission lines reach main cities and supply many towns along the line. In 2004, peak electricity demand was 266 MW, with an annual energy consumption of about 1927 GWh. The Mozambican RE level is not well established but it is estimated that about 2–5% of the rural population is connected to the grid, based on provincial statistics (EdM 2007). Due to the long distances, transmission losses are

significant and the power supply becomes fragile at the outskirts of the grid. Numerous diesel generators have been allocated to supply smaller and remote districts. Among domestic customers, the use of electricity is on average 1590 kWh per year per household, ranging from 640 kWh/year in recently electrified regions to more than 2200 kWh/year in the Maputo metropolitan area.

The Ministry of Energy is responsible for national energy planning. The national electricity company EdM (Electricidade de Moçambique) dominates the power sector of Mozambique and is responsible for generation, transmission and distribution, although these segments have been legally open to private investors since 1997. Restructuring of the sector has been suggested by the World Bank, but the process[5] was halted after strategic analyses (WB 2007). In 1997, the Energy Fund Funae was established. It has the objectives of developing low-cost energy services in rural areas and for low-income urban households, and promoting sustainable use, conservation and management of energy resources. The regulatory agency CNELEC (initiated in 2006) monitors the performance of EdM.

2 Previous research and current state of knowledge

2.1 Electricity and development

There is a widely shared, and empirically grounded, assumption that electrification can contribute to positive societal development and increased quality of life. Evidence from sub-Saharan Africa shows that where access to electricity is provided, there have been substantial social benefits – related to lighting, education, health, leisure and security – of long-term importance for economic development (Davis 1998; Ellegård et al. 2004; Gustavsson 2007; Karekezi and Majoro 2002; Kirubi et al. 2009; Spalding-Fecher 2005). However, providing access to such services will not in itself – automatically – result in economic development. Assessments show that the impact of RE on economic development is often weak (D. F. Barnes and Binswanger 1986; Foley 1992; WB 2008). Holland et al. (2001) stress that electrification does not initiate development, but enhances development already taking place. "[C]ommunities which are very poor, with very little economic activity, are unlikely to derive

[5] The intended strategy was to unbundle and privatize EdM into generation, transmission and distribution companies. However, in 2005 the Ministry of Energy decided to stop privatization and instead seek to improve the performance of EdM through a Performance Contract for EdM, increased technical and financing support for EdM and establishment of CNELEC (WB 2007).

much economic benefit from an electricity supply, though they may derive substantial social benefits from better lighting and communication" (2001: 29). It is likely that many communities in the coastal regions of Tanzania and Mozambique will fall into this category of very poor communities.

Currently, the rural economy is severely hampered by lack of energy infrastructure. In the absence of electricity from the grid, rural industries, well-off farms, workshops, mills etc., rely on expensive diesel generators. Industry and manufacturing need power of high capacity and high quality, and diesel generators are often used as backup even after connection to the main grid (WB 2008; VPC 2008). Low power quality, exemplified by blackouts and power rationing in national grids, is a common phenomenon in sub-Saharan Africa, incurring costs associated with production stops and damage to equipment (WB 2009).

When economic development does take place, hindsight assessments of RE strategies and projects have repeatedly concluded that productive use of electricity – i.e. electricity used directly for income-generating activities such as agricultural production, refining of tradable goods, and commerce – is crucial if RE is to boost economic development in rural areas (Holland et al. 2001; J. Peters et al. 2009; Ranganathan 1993). For example, the study by Åkesson and Nhate (2006) of the RE project in Ribáuè and Iapala in Mozambique, showed that RE contributed to economic development and reduced poverty by positive effects on production of cash crops, farmers' incomes, increased purchasing power of households and local small-scale businesses. However, the project generated less employment and productive activities than expected by local government, a major reason being the lack of local markets, banks and adequate infrastructure.

Other examples from the region show that productive use of electricity in RE projects has been limited and less than expected (Ilskog and Kjellström 2008; J. Peters et al. 2009; Wamukonya and Davis 2001). What can be learned from earlier research is that productive uses of electricity should be a priority for RE policy so as to maximize the benefits of investments. However, since there is little rural industry, economic development will primarily take place at micro- and small-scale level. Further, a conclusion made by several scholars is that integrated development and coordination between actors are needed for access to electricity to generate economic growth (Kirubi et al. 2009; Åkesson and Nhate 2006).

There are hopes that RE will help reduce poverty, create employment and improve the well-being of people (MEM 2009), but it is clear that alleviating poverty by electrifying rural

areas is difficult, because RE primarily benefits the better-off minority who can afford to use the services (Ilskog and Kjellström 2008; Marandu 2002; WB 2009). Poverty is both a barrier to successful electrification and a problem left unaddressed in many places where electricity has lit the night (SEI 1999; van der Vleuten et al. 2007). SEI (1999) concludes that energy projects can contribute to poverty alleviation in economic terms, either directly – by delivering energy services to poor people that help raise incomes or decrease expenditures (Madubansi and Shackleton 2006) – or indirectly by creating economic growth that eventually generates employment and cleaner, less expensive energy services (SEI 1999). Energy services can also release time – especially for women – and the provision of social services such as street lights, better healthcare and education, water pumping and grain mills may all benefit the poor.

For the majority of rural people, there are a number of economic barriers such as connection fees, fixed charges, lack of access to credit and high prices of household appliances, taking electricity out of reach. Initially, electrification is combined with the procurement of electric appliances that can be very costly. In combination with the fact that rural livelihoods are adapted to a life without electricity, this means that many households will increase their electricity use very slowly or simply not use it at all. The access to micro finance or credits can be decisive for poor people's ability to afford electricity (Louw et al. 2008; SEI 1999; van der Vleuten et al. 2007). According to SEI (1999), where care has been taken to find least-cost solutions, to adapt regulations on payment and to target subsidies to the needs of the poor, the rate of electrification among the same has increased significantly. Based on these finding, I draw the conclusion that public and collective services, especially for improved health, education and easing of heavy and time-consuming work tasks, are vital for the poorest people who cannot afford connection to be able to benefit from RE. It is beneficial for the rural economy at large as improved health and education enhance the general productivity of the population.

The goal of poverty alleviation is still part of RE, but the primary focus has partly shifted. In the 1980–90s, the World Bank strategy on RE lending shifted from sector support towards promotion of energy sector reforms, with increased focus on economic efficiency and strong emphasis on private sector involvement (Nawaal Gratwick and Eberhard 2008; WB 2008; Weisser 2004). The emphasis on economic aspects has increased at the cost of the social aspects (equity, public services and 'electricity for all'). According to Zomers (2003),

the ongoing privatization trend is not induced by substandard performance of national utilities as these have performed well in industrialized countries, but is rather driven by neoliberal ideology. Most developing countries have undertaken, or are undertaking, energy sector reforms. Following suit, Tanzania and Mozambique have introduced energy sector reforms during the past two decades, including commercialization and market liberalization. Outcomes of reforms differ between countries, but results have not met expectations (WB 2009) and have been widely criticized (Karekezi and Kimani 2002; Wamukonya 2003; Weisser 2004; Zomers 2003). In essence, the criticism is related to the low interest of the private sector to getting involved in RE, due to weak rural markets, and the general failure of reforms to provide RE benefits for the poorest. These shortcomings on poverty reduction have been recognized in evaluations published by the World Bank (2008, 2009).

I understand that there is now awareness that power sector reforms must be sensitive to and address the challenges faced in sub-Saharan countries instead of prescribing privatization as a miracle cure, and that the role for private engagement in the power sector is not the same as that of industrialized countries. But what then exactly is the role for the private sector in RE in these two countries? This question will be addressed as part of the research questions, results and discussion.

2.1.1 Impact of electricity on daily life

Access to electricity changes daily life and rhythm, ways of socializing and livelihood opportunities. Electricity impacts social life in unexpected ways, but the social relations and norms also influence what uses and applications the new technology is allowed to take. Many development paths are possible. An excellent illustration of how electricity can change daily life in complex ways, is found in the study by Winther (2008) on electrification in Zanzibar, in the village of Uroa. Winther's in-depth analysis asks how and in what sense energy matters to people. She explores the complex and dynamic interface between people and technology by looking into what electrification means for things such as: people's views on development and modernity; their relation to the electricity company; how people use outdoor and indoor environments; norms of modesty and sharing; cooking habits and tastes in food; and relations of the family, gender and the spiritual world. Tastes in food are important for people in Uroa who are used to cooking with firewood, and electricity for cooking is considered expensive and less tasty.

Studies from the region show that the use of firewood does not stop when households get access to electricity while use of kerosene for lighting goes down (Ilskog, Kjellström et al. 2005; Madubansi and Shackleton 2006; Ilskog and Kjellström 2008; Louw, Conradie et al. 2008). At the current price of electricity, it is likely that wood will remain the primary fuel for heating and cooking purposes (EdM 2007). Introduction of efficient stoves are better targeted at reducing in-door air pollution from cooking. This shows why use of electricity and fuels are linked in complex ways and why an integrated approach can lead to better results in terms of both improved livelihoods and positive health effects.

The study by Winther also shows many other factors that influence the outcomes of RE and how outcomes differ between individuals, households and groups in society. In Zanzibar, in the village Uroa, there are winners and losers in relation to social and technical development. Electricity is a symbol of development and progress, and it reinforces the division between those who can afford it and are part of the new 'modernity', and those who cannot afford electricity. After electrification, Uroa has become a less egalitarian place (Winther 2008: 230).

2.2 Drivers and barriers to rural electrification

In discussions about rural development, the concepts of 'drivers' and 'barriers' are used to signify factors that enhance or hinder desired development. Also, in the context of rural electrification in East and Southern Africa, the concepts are part of common vocabulary and are used by many power sector actors. In this thesis, the concept of a barrier is defined in line with Wilkin's (2002) work, as any technical, economic, institutional,[6] organizational, political, social, geographical or environmental factor impeding the deployment of a new technology. Barriers tend to be interrelated and therefore it is difficult to isolate the impact of any single barrier. The definition of drivers mirrors that of barriers. Drivers signify any factor that enhances the deployment of a new technology.

Painuly (2001) has proposed an analytical framework for studying barriers to renewable energy penetration. Barriers can be specific to a technology, a country or region, and can thus

[6] In this thesis, institutions refer to both formal (e.g. laws, policies, regulations) and informal (e.g. values and norms, traditions and 'common sense') institutions shaping and constraining human behaviour. Institutions can be thought of as 'rules of the game' and different from organizations and their structures (Peters 1999). Wilkins's use of the concept of institutions is slightly different and she separates institutional and legal factors, and probably equates institutional to organizational factors.

be analysed at several levels (Painuly 2001). When reviewing the literature, I find that many studies identify various barriers to RE and RETs, but few studies (except Painuly (2001) and Wilkins (2002) that I know of) take a systematic approach to drivers and barriers, and much more attention is generally given to (a) barriers than to drivers, (b) to grid extension than to off-grid systems and (c) to national level rather than to local level. From my review of the scientific literature, reports by consultants and international organizations, and documents and homepages by power sector actors in respective country, I also conclude that, so far, most studies of electrification projects in sub-Saharan Africa are on large-scale, grid extension projects based on hydropower or fossil fuels. The development of RET-based off-grid systems in rural Africa is still in an early phase, which explains why off-grid systems and RETs are less studied than large-scale systems and/or grid extension projects. This thesis provides an overview of the challenges that is not provided elsewhere.

2.2.1 Drivers identified in literature

There seems to be a general lack of factors driving rural electrification in sub-Saharan Africa, while the number of barriers seems endless. The region is underpowered, and generation capacity has remained largely stagnant during the past three decades, according to the World Bank (WB 2009). There are plenty of unexploited energy resources, especially hydropower, and demand has outgrown supply. During the past decade, official development assistance to public investment in the power sector has been the main funding source averaging USD 700 million per year, while private investment has averaged USD 300 million per year. In recent years, China has invested heavily, on average USD 1.7 billion per year, primarily in large-scale hydropower (WB 2009). Some scholars (Akella et al. 2009; Wilkins 2002) suggest that the Clean Development Mechanisms[7] can become an important source of funding for developing countries. Karekezi (2002) sees two major drivers for development of RETs on the continent – the economic burden of oil import and the crises faced by most power utilities in the region – with power rationing and negative consequences for the countries' economies.

Although the interest and investments made in electrifying rural sub-Saharan Africa have been rather low for some decades, the energy issues are making a comeback on the global development agenda in relation to policies of climate change mitigation and adaptation.

[7] CDM is an emissions trading mechanism between developing and industrialized countries that could potentially provide funding for energy projects that reduce carbon emissions. So far, the share of CDM projects in African host countries is about 2% (Unfccc 2012).

The interest in RETs seems to be growing also among African policymakers as it is increasingly seen as a complement and alternative to large-scale energy infrastructure, with the potential of meeting energy needs of the poor rural populations (Karekezi 2002). At the same time, one must not neglect the fact that there are significant challenges to be overcome for any successful development of modern and sustainable energy systems in rural Africa to emerge, as the following discussion will highlight.

2.2.2 Barriers identified in literature

Barriers to rural electrification in sub-Saharan Africa have been identified through reviews of scientific literature and evaluation reports. Table 1 below shows a compilation of barriers found in literature, for rural electrification in general, and off-grid electrification based on RETs specifically. Examples of literature are given for each barrier. I have grouped barriers into *Barriers to RE*, *Barriers to RE resulting in rural development*, *Barriers to off-grid renewable energy systems*, and *Barriers to sustainability in off-grid renewable energy systems*. There are other possible classifications and many barriers are closely related, while some belong in more than one category (see article 2 for an example of a different classification). However, I have not found such an exhaustive list of barriers elsewhere, with references to the literature. The country-specific reports (EdM 2007; MEM 2009) published by domestic actors, which discuss challenges in detail, are not included in Table 1.

Table 1. *Barriers to rural electrification (RE), barriers to RE resulting in rural development, barriers to off-grid renewable energy systems, and barriers to sustainability in off-grid renewable energy systems. These are found in scientific literature and organization reports on RE in sub-Saharan Africa with exemplifying references.*

Barriers to RE	
Scattered population	(Karekezi 2002; Kirubi et al. 2009)
Long distance transmission	(Kirubi et al. 2009)
Lack of generation capacity	(Marandu and Luteganya 2005)
High technical losses	(Ilskog and Kjellström 2008; WB 2009)
Lack of financial capital	(Karekezi and Kimani 2002; Marandu 2002; J. Peters et al. 2009)
Dependency on foreign consultants	(Pigaht and Plas 2009)
Little transfer of skills	(Murphy 2001; Pigaht and Plas 2009)

Privatization of power sectors	(Haanyika 2006; Karekezi and Kimani 2002; WB 2009; Zomers 2003)
Lack of private sector involvement	(Marandu 2002)
High investment and transaction cost	(Bugaje 2006)
High production prices	(Kirubi et al. 2009; WB 2009)
Poverty and low household affordability	(Karekezi 2002; Louw et al. 2008; Madubansi and Shackleton 2006; SEI 1999)
Low tariffs	(Ilskog and Kjellström 2008; Karekezi and Kimani 2002; Marandu and Luteganya 2005; J. Peters et al. 2009)
Inappropriate subsidies	(Ilskog and Kjellström 2008; Kankam and Boon 2009; WE
Low institutional quality (incl corruption)	(Karekezi and Majoro 2002; Mulder and Tembe 2008)
Inappropriate institutional frameworks	(D. F. Barnes 2011; Bugaje 2006; Karekezi and Majoro 2002; Nawaal Gratwick and Eberhard 2008)
Inadequate planning capacity	(Murphy 2001; WB 2009)
Organizational structure and strategies	(Jones and Thompson 1996; WB 2009)
Political control of power sector	(Haanyika 2006; WB 2009; Zomers 2003)
Lack of political interest at national level	(Zomers 2003)
Lack of local participation	(Murphy 2001; Pigaht and Plas 2009)

Barriers to RE resulting in rural development

Poverty and low household affordability	(Karekezi 2002; Louw et al. 2008; Madubansi and Shackleton 2006; SEI 1999)
Connection requires modern housing	(Murphy 2001)
Low reliability of supply	(Ilskog 2011; WB 2009)
Poor rural market and low productive use	(Kankam and Boon 2009; J. Peters et al. 2009)
Insufficient rural financial institutions	(Marandu 2002; Åkesson and Nhate 2006)
Lack of access to tools and machines	(Åkesson and Nhate 2006)
High connection fees and fixed charges	(Karekezi and Kimani 2002)
Lack of complementary investments and cross-sector coordination/collaboration	(Kankam and Boon 2009; J. Peters et al. 2009; Åkesson and Nhate 2006)
Gender issues	(Murphy 2001; Parikh 1995; Winther 2008)
Lack of knowledge about costs of elec.	(Winther 2008; Åkesson and Nhate 2006)
Lack of awareness of economic potential	(J. Peters et al. 2009)
Social settings hinder technology absorption	(Murphy 2001)
Unwillingness of behavioural change	(Murphy 2001; J. Peters et al. 2009)
Lack of local participation	(Karekezi and Kimani 2002; Åkesson and Nhate 2006)
Limited rural infrastructure (roads etc.)	(Kankam and Boon 2009)

Barriers to off-grid renewable energy systems

Lack of global coordination	(Alzola et al. 2009)
Lack of policy support/ political interest	(Karekezi 2002)
Lack of adequate data on energy potentials	(Sheya and J.S. Mushi 2000)
Inappropriate subsidies of conventional fuels	(Kankam and Boon 2009; Lucon et al. 2006; Wilkins 2002)
Regulatory uncertainties and inappropriate policies	(Kankam and Boon 2009; Pigaht and Plas 2009)
High investment and operation cost	(Alzola et al. 2009; Murphy 2001; Holland et al. 2001)
Lack of access to finance	(Ellegård et al. 2004; Pigaht and Plas 2009)
Admin. costs/complexity in small off-grid systems	(Alzola et al. 2009; Brent and Rogers 2010)
Lack of local actors who can disseminate systems	(Murphy 2001)

Barriers to sustainability of off-grid renewable energy systems

Low reliability and capacity in off-grid systems	(Gustavsson 2007; Jacobson 2007; Murphy 2001)
Lack of adequate maintenance	(Ellegård et al. 2004; Kirubi et al. 2009; Murphy 2001)
Lack of local manufacturing of equipment/spare parts	(Sheya and J.S. Mushi 2000)
Difficulty achieving cost recovery	(Alzola et al. 2009; Ilskog et al. 2005; Kirubi et al. 2009)
Lack of local participation and development of local expertise	(Alzola et al. 2009; Pigaht and Plas 2009)
Poor rural market and low productive use	(Gullberg et al. 2005; Jacobson 2007)
Limited rural infrastructure	(Bugaje 2006; Ellegård et al. 2004)
Lack of monitoring procedures	(Alzola et al. 2009)
Theft of systems	(Ellegård et al. 2004)
Low quality products	(Ellegård et al. 2004; Jacobson 2007; Maher et al. 2003)

The list of barriers in Table 1 is too comprehensive to be commented upon in detail here. It should be noticed, however, that many of the barriers found in the literature on RE in sub-Saharan Africa, are entangled or related to one another. It is also important to know that there are diverging views on many issues. The barriers that seem to be widely agreed upon are: high investment costs; problems with political interference in national utilities; the need for cost recovery in projects – and related to that a view that subsidized tariffs are counterproductive; lack of adequate rural financial institutions; rural poverty hindering economic development; and the need for complementary investments and cross-sector coordination.

2.3 Off-grid electrification and renewable energy technologies

The currently slow pace of grid extension makes off-grid systems the only available option in many places in Tanzania and Mozambique. As current use of diesel generators is considered problematic for technical, economical and environmental reasons, there is need for alternative off-grid solutions that can make use of available renewable energy sources. So far, in Tanzania and Mozambique, mainly hydropower and solar photovoltaic (PV) have been utilized. There is a declared intention to better utilize the renewable energy potential, particularly in the context of RE (FUNAE 2007; MEM 2009). In Mozambique, no expansion of large-scale hydropower has taken place since colonial times and pico/micro-hydropower systems for poor rural communities are still at pilot project stage in the region (Maher et al. 2003). At the regional level, the commercial market for solar PV is growing – in Kenya driven by the increased rural use of TV, cell phones and radio among the rural middle class (Jacobson 2007) – and there is a process of technology transfer from more established markets in and outside of Africa. In addition to hydropower and solar PV, some utilized RETs are wind power, and bioenergy (in this region bioenergy is primarily used for heating and fuel, but also for electricity generation in the sugar industry, and in some rare cases for waste-to-energy combustion of agricultural residues or the use of biodiesel in generators) (MEM 2009).

The potential[8] of RET-based electrification is considered to be high in sub-Saharan Africa (Bugaje 2006; WB 2009), and Karekezi (2002) gives a number of reasons for this:

- Renewable energy sources are quite evenly distributed throughout the continent.
- The lack of a well-established energy market for conventional fuels brings the opportunity for investment in RETs without the need for any major system restructuring.
- Investment capital needed for RETs is generally smaller than for conventional fuels, as small/medium-scale technologies and systems can be established and enlarged gradually.
- Decentralized systems are often the least-cost alternative in rural areas of Africa with scattered settlement patterns.

[8] The potential for a RET can, according to Painuly, refer to its technological potential, techno-economic potential or economic potential. See Painuly (2001: 76) for further definitions.

- The number of actors within the energy field has grown, and technical competence is catching up with demand. National and regional networks of actors are increasingly building capacity and spreading knowledge and technology.
- RETs are often technically less advanced than "mature", large-scale conventional energy systems, which makes it easier to provide technical capacity locally.

There has been a lot of debate regarding whether or not RETs are competitive in comparison to fossil fuels (Akella et al. 2009; Chakrabarti and Chakrabarti 2002; Lucon et al. 2006). There are different ways of comparing and counting, and although comparisons are often made with electricity from the national grid (Brent and Rogers 2010), in reality often the only option is a diesel generator (Byrne et al. 2007). Proponents of RETs argue that these technologies usually become competitive when aspects other than installation and running costs are taken into account, such as existing subsidies for grid-based electricity and fossil fuels (Lucon et al. 2006; Wilkins 2002), and costs and benefits of environmental and social impacts – that is an understanding of value that takes energy security, environmental sustainability and economic development into account (Doukas et al. 2008; Lucon et al. 2006; Owen 2006).

There is evidence that micro-scale RETs are suitable for household needs of electricity and can contribute to higher incomes and small business activities, and also, that provision of such energy services and technical support services to rural poor people can be profitable for private companies (Bairiganjan et al. 2010; Chaurey and Kandpal 2010). Wilkins (2002) considers off-grid electrification an important and potentially huge niche market for RETs, and Akella et al. (2009) suggests that RETs promote a diversification of the rural economy. If small-scale RETs replace imported diesel the dependency on imported fuels decreases, which reduces vulnerability related to rise in prices and fuel transport, simultaneously with a strengthening of local production and energy markets (Akella et al. 2009). Further, diesel-based off-grid systems suffer from frequent power blackouts in many countries, due to insufficient maintenance (WB 2008; VPC 2008) and can be major bottlenecks for rural industrial production (VPC 2008).

The prospect for RET-based off-grid RE in sub-Saharan Africa, founded on the progress and constraints of previous implementations, is covered in an extensive literature (Brent and Rogers 2010; Chaurey and Kandpal 2010; Ellegård et al. 2004; Gullberg et al. 2005; Gustavsson 2007; Ilskog et al. 2005; Jacobson 2007; Kirubi et al. 2009; Murphy 2001; Pigaht

and Plas 2009; van der Vleuten et al. 2007; Åkesson and Nhate 2006). Despite success stories like the Kenyan solar PV market, and cogeneration in the sugar industry of Mauritius, the diffusion of RETs has been slow in most African countries and many projects have failed (Kankam and Boon 2009). Barriers identified as hampering diffusion of RETs in sub-Saharan Africa are mainly found at national level of policy, funding and institutional frameworks, but also related to the general lack of rural infrastructure and economy (see Table 1).

The review shows that various dimensions of sustainability must be brought together if challenges are to be understood and addressed. Such studies are now appearing, for example the efforts of Ilskog (Ilskog and Kjellström 2008; Ilskog 2008) to develop a set of sustainability indicators that can be used to evaluate RE projects, and the integrated framework developed by Brent and Kruger (2009), which combines the sustainable livelihoods approach with technology assessment methods.

To conclude this literature review, some gaps of knowledge have been mentioned regarding systematic studies of drivers and barriers for off-grid renewable energy systems in rural African contexts. Primarily, the work presented here fills a gap of knowledge regarding the specific situations in these two countries. When I started working in Tanzania and Mozambique, the focus on drivers and barriers came from a wish to gain a broad understanding of the country-specific challenges of RE, to identify what is seen as prerequisites for RE, and questions of relevance to actors that require more in-depth studies, but also to be open to multiple perspectives on the RE process. Therefore, I contrast the countries to one another, and views of actors with each other and literature. I discuss access to electricity and potential roles of actors involved from different angles. I believe this opens up interesting aspects also for those actors who know the situation of the countries better than I do.

3 Theory

In East and Southern Africa, rural electrification has followed the western model of building large regional systems of power lines. Such systems have been studied in depth and are well-theorized. But the development of small-scale RETs for use in off-grid systems in poor rural areas is less studied and still at an early development stage in the region. The drivers and barriers, and prerequisites, for such systems are very different from the large-scale,

centralized power systems, but does this also mean that such systems require a different theoretical understanding? My short answer is no. This chapter presents the theoretical base of my research[9], how I understand and study the process of rural electrification through the lenses of studies of socio-technical systems, in combination with a user perspective that focus on what can be done with electricity, and the many ways in which people can derive benefits from electricity.

3.1 Development of electric power systems

Technology cannot be separated from the economic and social context in which it evolves, a context which technology in turn helps to shape (Grübler 1998). A number of research traditions[10] have contributed to understanding technological change across various scales of time and space, and the interrelatedness of socio-technical change. What socio-technical approaches have in common is, according to Geels et al. (2008) that they highlight co-evolution of technology and society, multi-dimensionality and complexity of technological change, and multi-actor processes. The theoretical understanding of socio-technical change is highly relevant for, and partly builds on, studies of how countries develop large-scale energy infrastructure.

Rural electrification is a process through which a society goes from depending mainly on available bioenergy resources, to a situation where an increasing part of the population can access and meet (many of) their energy needs by electric power. How does such a transition take place? How does the societal context influence the development pathway of electric systems? What factors enhance or hinder development of large regional power systems?

The development of the extremely large networks of power lines reaching across industrialized countries during the formative years of 1880–1930 has been studied by Hughes (1983). He considered the development of power systems as a history of technology and society – and power systems as cultural artefacts. "Electric power systems embody the physical, intellectual, and symbolical resources of the society that constructs them" (1983: 2). He continues: "In a sense, electric power systems, like so much other technology, are both

[9] I find that, among previous writings, I theoretically come close to the work of Winther (2008) and her 'anthropology of energy', but my questions and focus are empirically different.
[10] Geels et al. (2008) mention sociology, industrial and evolutionary economics and management studies, political science and cultural studies.

causes and effects of social change. Power systems reflect and influence the context, but they also develop an internal dynamic" (1983: 2).

Based on general systems theory, Hughes uses both a broad definition of "system" as interacting components of different kinds, and a more specific definition of a system:

> A system is constituted of related parts or components. These components are connected by a network, or structure (...). The interconnected components of technical systems are often centrally controlled, and usually the limits of the system are established by the extent of this control. Controls are exercised in order to optimize the system's performance and to direct the system toward the achievement of goals. The goal of an electric production system, for example, is to transform available energy supply, or input, into desired output, or demand. Because the components are related by the network of interconnections, the state, or activity, of one component influences the state, or activity, of other components in the system. (1983: 5).

Setting of system boundaries is a difficult task and can be done by different rationales.[11] When Hughes defines the technical system of electric power, he writes: "Electric power systems of the technical kind consist of power generation, transformation, control, and utilization components and power transmission and distribution networks." (1983: 7). But technology is not only artefacts or hardware, but also software, or the knowledge needed to produce and use the artefacts (Grübler 1998). Definitions of a *technological system* include not only the artefacts, but also the network of actors interacting in a specific economic/industrial area, under a particular institutional infrastructure and involved in generation, diffusion and utilization of technology[12] (Carlsson and Stankiewicz 1991: 111).

So how do electric power systems evolve? Hughes uses an overall model of systems evolution, in which electric power systems go through (1) invention and development, (2) technology transfer, (3) system growth, (4) substantial momentum and (5) reaching a state of

[11] System delineation can be thought of as an iterative process, as systems change over time. System boundaries can be defined in relation to the research question, or identified from the data and there are merits and shortcomings with each approach.

[12] Definitions of innovation systems build on this definition of a technological system, and also see actors, networks and institutions as system components. Innovation system studies have lately been more focused on the function of the system than its components, that is, the processes or dynamics of what is actually achieved in the system (Bergek et al. 2008).

planned and evolving regional systems. At the most general level, technology evolves from invention (discovery), to innovation (the first commercial application) and diffusion (widespread replication and growth) (Grübler 1998). Different models of technological development have the S-shaped development curve in common, with time along the x-axis and a performance indicator, e.g. percentage adoption, along the y-axis (see e.g. Grübler 1998: 51; Rogers 2003: 11).

In rural areas of East and Southern Africa, the building of large-scale power systems is based on technology transfer of mature technologies, according to established technical standards and know-how. In comparison, development of small-scale off-grid RETs is at an early stage in the region, and many of these technologies are less mature. The literature on technology transfer offers some insights regarding the conditions under which successful transfer takes place.

3.2 Transfer of renewable energy technologies to new contexts

Anthropologists were among the first to study the importance of local culture for success of technology transfer between societies (Rogers 2003). Apart from Winther's (2008) study of the electrification of Zanzibar, few anthropologists have engaged with electricity. In the field of technology transfer, Wilkins (2002) focuses specifically on diffusion and adoption of small-scale RETs in poor rural areas of the world. Wilkins sees successful technology transfer as a complex process, where not only equipment, but also "the information, skills and know-how which are needed to fund, manufacture, install, operate and maintain the equipment" are transferred (Wilkins 2002: 44). Murphy (2001) has a similar focus but uses the concept "technological capabilities" to define the information and skills – technical, organizational and institutional – that allow technologies to be absorbed incrementally into domestic production systems. Wilkins process of technology transfer also includes adaptation of the technology to local conditions and requirements, that is, mature technologies may also require adaptation to meet specific needs and local conditions.[13]

The innovation and diffusion of RETs has also been theorized by innovation system scholars. Innovation system (IS) studies have empirically studied and theorized socio-

[13] Wilkins (2002) general conclusion is that for new RETs to be successful in rural areas of developing countries, the technology must be adapted to the local context, there must be a market for the service and the price at which the service is delivered must be affordable to the users.

technical transitions to sustainable societies. IS studies explain that 'green' innovations, and particularly renewable energy technologies, face certain challenges related to problems of forming market niches, uncertainties about future markets and regulations and difficulties in competing with existing technologies due to a situation of 'carbon lock-in' (Geels et al. 2008; Unruh 2000). The empirical analyses point to, for example, the importance of early market formation, consistent and stable policy frameworks, and social and political legitimacy for the new technology (Geels et al. 2008). IS studies also emphasize the influence of strategic decisions of particular actors and the importance of entrepreneurs and so-called 'prime movers' (Markard and Truffer 2008).

The resources and aspirations of actors are also crucial in Hughes' analysis. He finds that different actors and organizations are driving development in the different phases, solving critical problems and defining system goals. Two more fields are of interest here, in which actors, organizations and formal and informal institutions are in focus – namely diffusion studies and science and technology studies (STS).[14] The diffusion of innovations is characterized by Rogers (2003), as "essentially a social process in which subjectively perceived information about a new idea is communicated from person to person" (2003: xx). Rogers defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system" (2003: 5). What is crucial for explaining the rate of adoption of a new technology is not the attributes of the technology in itself, but the perceived attributes – for example its relative advantage – and compatibility with existing values, pasts experiences and needs of potential adopters. Rogers also concludes that the structure of a social system and system norms can facilitate or impede the diffusion of innovations.

A similar approach is taken by STS scholars, studying the social construction of technology (SCOT approach) (Pinch and Bijker 1984). The SCOT approach is concerned with how a technology becomes seen as working or not working. The 'workability' of a technology is an inherent property of the technology. Instead, the SCOT-approach suggests that technologies are interpreted differently by different actors and that it is related to what actors see as problems and solutions. Similarly to Rogers, Pinch and Bijker (1984) see the meaning of technology emerge in relation to the social, cultural and political situation of social groups and their norms and values.

[14] Diffusion studies and STS have developed as cross-disciplinary fields with scholars from various fields, but both fields have their strongest base in sociology.

Returning to Wilkins (2002), she identifies key actors, their respective roles in the process and what actions they should take to remove barriers to successful diffusion of RETs in off-grid applications. Even if no single actor can decide the outcome of technological change, the attitudes and actions of more influential actors are key to driving or hindering development of new technologies. Taken together, these perspectives motivate a strong focus on actors, their roles, resources, aspirations and perceptions, in relation to the drivers and barriers to RE and for diffusion of RETs in Tanzania and Mozambique.

3.3 Access to electricity

From the point of view of rural people, the important issue is not the source of supply, but what can be done with the electricity.[15] In the rural context where livelihoods are primarily based on use of natural resources, introduction of electricity can impact people's capabilities to use available assets, but also to generate opportunities for new strategies for making a living. Winther and others, e.g. Karekezi and Majoro (2002), have highlighted how electrification projects, like many other development interventions in society, are often dominated by more powerful actors, and marginalization tends to follow existing social hierarchies based on class, gender, age and ethnicity. Dynamic relations of power within the community and external to it influence interactions between people, and control and access to resources.

Even though only a minority of rural people can afford to connect to the grid or to buy a solar home system, many people gain access through their friends, neighbours and families. Not having direct access does not necessarily mean that you are excluded. The ways in which people get access to electricity are in many ways similar to the ways people access other resources to make a living. The literature on these issues is extensive, and I draw mainly on work in the field of political ecology,[16] research on natural resource management,[17] and theories of property rights and access to resources.[18]

[15] As Winther (2008) points out, it is not the electrical current per se that is of interest to the users, but rather the appliances that make use of it, and the services made available from it. Winther conceptualizes the electrical appliances (e.g. light bulbs) as primary objects and the services (provision of light in the evening) made available as secondary objects.

[16] Political ecology explores the political, economic and ecological dimensions of various environmental issues and has contributed important writings on environmental management, social equality issues and human resource use. For an introduction see e.g. the anthologies by Paulson and Gezon (2005), Rocheleau et al. (1996), and Zimmerer and Bassett (2003). Focusing on factors that shape relationships of power among human groups

The theory of access to resources by Ribot and Peluso (2003) highlights the complexity of resource use. They define access as "the ability to derive benefits from things – including material objects, persons, institutions, and symbols" (Ribot and Peluso 2003: 153). Applying this definition to electricity, I find that access in this context would be defined as the ability to derive benefits from electricity in terms of: (a) being connected to the technical system either *individually* at home/business and getting *direct* benefits from use of electric *appliances*, or (b) having *indirect* access to benefits through somebody else's use (e.g. a neighbour), or *collective* services (education, healthcare, electric mills). The access may be seasonal, regular for a time period of the day or continuous. The definition also includes (c) benefits from *employment* in relation to electrification, e.g. construction works in the project, working with technical service provision, or getting employment in electricity-based productive activities. The ability to derive benefit from (d) *institutions* could include benefitting from formal legal frameworks (e.g. receiving economic compensation for power lines passing one's land) and formalized decision-making, such as being part of the local management committee. But also informal institutions decide who gets access to electricity, such as decisions of where to draw a local grid as to connect local elites. Having electricity in the house and being a member of the management committee also gives (e) *symbolic* benefits and social status.

From this definition it is clear that access to electricity and related benefits can be derived in many ways. It may not be easily quantified, but I think it is more relevant than current definitions based on percentage of people connected to national grids. Ribot and Peluso (2003) focus on the dynamic processes and relationships of access to resources, resulting in an empirical focus on issues of who does or does not get to use what, in what ways and when? For various reasons, people have different abilities to benefit from resources. Their analysis of access involves identifying and mapping the flow of benefits, identifying the mechanisms and underlying power relations by which actors gain access, control the access of others and maintain access to the resource. It is a sophisticated framework and well adapted to poor rural contexts. When I apply it to electricity, it helps me identify the many ways in which people can derive benefits from electricity, and distinguish between mechanisms by which the introduction of a new energy resource has different outcomes for different groups in society. I

in relation to land and resource use, ecological processes and environmental transformations, political ecology has challenged dominant development paradigms and blue-prints.

[17] The sustainable livelihoods approach has been very influential, see e.g. Pound et al. (2003) and Scoones (1998) as well as writings on social-ecological systems (Folke 2006; Ostrom 2009; Peterson 2000).

[18] See for example Juul and Lund (2002).

will now explain how I conceptually relate this definition of access to electricity and related benefits, and the analysis of how actors gain, control and maintain access to resources, to the rich understanding of technology and electricity coming from Hughes (1983), Winther (2008), and socio-technical systems scholars (Bergek et al. 2008; Geels et al. 2008).

3.4 Combining a system perspective with a user perspective

I study the RE process as a dynamic system where the introduction of new technology in a rural society creates new interfaces between technology, people and their societal and natural surroundings. It is often a rather long process before electricity can be introduced in a rural community. In grid extension projects, the planning stage includes a number of activities, such as the political process of priority-making, identification of project area, securing funding and terms of agreements, tendering, technical planning, feasibility studies, risk identification and assessment and agreements with customers. Local people are often involved on a consultant and contractual basis even during planning. Off-grid projects may be initiated by local or external actors and may be more or less formalized. In all cases, there must be actors and factors that drive the process of providing electricity in the community, and the barriers hindering the process need to be overcome (see left-hand side of Figure 1).

Figure 1. A conceptual model of introduction of electricity in a rural community. Development of the technological system in relation to how people access electricity and related benefits.

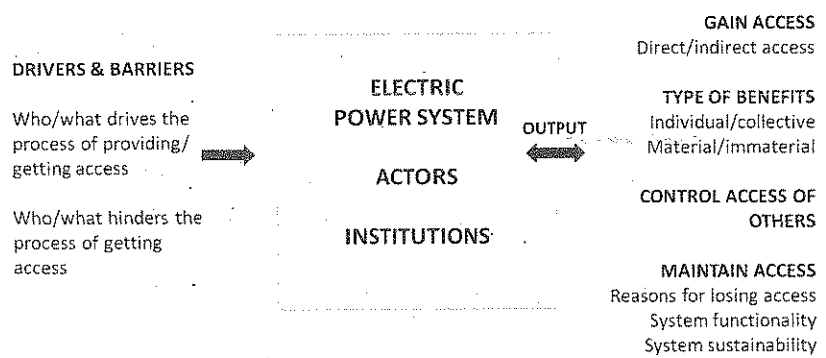

Figure 1 visualizes how I conceptually understand the introduction of electricity in a rural community. Involving more than building of new infrastructure, a technological system develops around the electric power system, with actors (both local and external individuals, groups and organizations) and institutions (formal contracts, management rules and regulations, by-laws etc.) as part of the system (symbolized by the box). Certain characteristics of the electrical power system are linked to specific settings of actors and institutions, for example the scale of the system, if it is on-grid or off-grid, and what energy source(s) is (are) used. Large-scale grid extension projects carried out by the national utility are much the same in all locations, while small-scale off-grid projects come in all sorts of designs. The interactions between the technological system and the local context where the system is introduced are very influential in off-grid projects, but important also in large-scale on-grid electrification. Existing social relations within the community and with the outside, and formal and informal institutions governing resource use, are drawn upon when the conditions for the new system are negotiated.

The system's technical characteristics together with economic and social (and for RETs also environmental) considerations, will result in differing output in terms of capacity, stability, reliability, cost per kWh, cost relative to other alternatives, number of connections and hours of supply. The output is also about what type of access and type of benefits are provided and for whom, when and how. There is a two-way relationship between the technological system and the users, as the performance of the system changes with changes on the user side. This is particularly true for off-grid systems with lower capacity. For example, when the number of connected users grows the load changes and there is a risk of overload during peak times, which may lead to reduced capacity. Also, economic returns might improve with more users, while decision-making can become more complicated with more actors involved. The institutional frameworks and relations between actors direct (more or less successfully) the control of access. New regulations may be needed to control use and avoid overload.

For the users who derive benefits, what matters most is the outcome in terms of meeting of needs, perceived system functionality and sustainable access in a way that improves their well-being. People may fail to maintain access for reasons of economic cost, technical problems that impact stability and reliability of supply, or simply because they perceive that they do not get what they need from the system and therefore decide to disconnect/stop using

the service. Small systems are vulnerable to dissatisfaction among users, especially where the user fees only cover running costs and there are no savings: a system can fail completely if some users stop paying or the system needs repair. Rural users are vulnerable to seasonal lack of cash, which needs to be planned for in the system. In national grids, customers who don't pay are disconnected and some find it impossible to reconnect due to fees that must be paid for reconnection.

It is clear that it is a very dynamic system, which depends on many interrelated factors for continuous functioning. There are also solutions to many of the problems encountered. For sustainability, negative spirals must be avoided, such as overload reducing system capacity, leading unhappy users to stop paying for the service, making it impossible to raise funds for repair, which in turn lead to more users losing access. The goal of transforming available energy supply into desired output is not clear cut, as actors have different needs and desires – that is, the same output is differently appreciated. I believe that this combination of perspectives can help explain why electric power systems that are technically similar, with the same implementing agent, institutional frameworks and the same electricity output, lead to different outcomes for the users and how it feeds back into the system dynamics and influences system sustainability.

Figure 1 represents my understanding of this dynamic system and provides guidance regarding what research questions to ask, what data to gather and what dynamics are of interest. I will develop this further in case studies, but already the combined perspective guides me as how to study the electrification process from multiple perspectives and to reveal agreement, conflicts, differing needs and perceptions of the electrical system and services provided. For me, this conceptual understanding is relevant for both grid extension and off-grid projects. It has not been part of my empirical work so far, because in this thesis I do not look at specific RE projects. Here, the empirical work is limited to trying to understand the type of processes that take place at a societal level and what drivers and barriers there are, related to specific actors, levels and technologies.

3.5 Research questions

Based on reviewed literature and the theoretical discussion, we can now formulate the questions to be answered for the aim to be fulfilled. The first question addresses actors' views on drivers and barriers to RE, and in more detail the lack of private sector involvement and productive uses of electricity, which are emphasized as crucial barriers in previous studies.

The second and third questions reflect the earlier theoretical discussion on the important roles of actors for diffusion of new technologies, but also the understanding that actors have different perceptions of the functioning of technology and related problems and solutions.

1. From the perspective of power sector actors in Tanzania and Mozambique:
    a. What are the drivers and barriers to rural electrification through grid extension or off-grid renewable energy systems?
    b. What are the prospects for private sector actors to take a more active part in rural electrification and development?
    c. How do productive uses of electricity relate to outcomes of rural electrification?
2. To what degree do the perspectives converge or differ when it comes to key challenges for RE and the potential for off-grid RE?
3. Based on actors' perceptions of RETs, what come out as key challenges to be addressed for off-grid renewable energy systems to diffuse successfully?

There are three appended articles, all of which have been submitted to journals. The first article conducts a broad analysis of the power sectors in both countries and identifies drivers and barriers to rural electrification by grid extension and off-grid solutions, as perceived by power sector actors. The second article looks closer at two questions that have gained much attention by scholars: the role for private sector and the importance of productive uses of electricity. Articles 1 and 2 also briefly discuss questions 2 and 3, which are then more fully developed in the discussion chapter of this thesis. The third article deepens the epistemological discussion of this thesis by reflecting on politics and knowledge in natural resource management. The article illustrates a methodological approach to studies of management of resources and environmental change, which mirrors the theoretical understanding of how actors interpret situations differently, based on their interest, values and needs.

All research questions are answered in the discussion chapter, building on findings in articles 1 and 2. I also draw on the theoretical discussion for my reflection on the picture that emerges from our interviews with actors, readings and experiences from the countries.

4 Methodology and method

In this chapter, I present my methodological approach, how I understand my role as a researcher in relation to questions of epistemology and ontology, and choice of scale of observation. I discuss how claims of knowledge and relations of power emerge in processes – in which I as a researcher become involved – of societal, technological and environmental change. The second part of the chapter presents the methods used to conduct the empirical studies. Article 3 provides an in-depth theoretical discussion on these matters, and illustrates empirically why researchers should reflect upon them.

4.1 Epistemology and ontology

My approach to science is based on the philosophical debates, following the work of Kuhn (Kuhn 1962/1970), in sociology of science and feminist critiques of science that have created an awareness of the plurality of knowledge systems, and the normative underpinnings in how we do science (B. Barnes and Bloor 1982, 27; Haraway 1991). Science is, as Mendelsohn (1977) says, a social activity. Haraway (1991) uses the concept of 'situated knowledges', to explain how all knowledge is partial and linked to the contexts in which it is created. Social scientists have engaged with natural and engineering sciences and 'deconstructed' key concepts and objects of analysis. For example, the field of STS is, according to Sal Restivo (1995), strongly based on the constructivist paradigm[19] and sees technology as fundamentally social. There are important insights coming from the constructivist paradigm, but in my view some social science scholars take deconstruction too far. I believe that this tendency to see everything as 'socially constructed' is partly because some have not done away with the (false) dualistic thinking that sees nature and society, matter and mind, as opposites.

In the interdisciplinary fields of environmental science, rural development and socio-technical systems many paradigms meet. My own approach to research includes an assumption that crossing disciplinary boundaries, and to work transdisciplinary, i.e. to also engage with actors outside the universities, actors from public and private sector and civil society (Hirsch Hadorn et al. 2008), is necessary for solving important societal problems, and for studying complex phenomena at the interface of society/technology/nature. My work is based on the following principles: (1) to be problem-oriented and explicit on the normative underpinnings of my work, e.g. that I try to contribute to ecological sustainability, social

[19] Kuhn introduced the concept of 'paradigm' which we can understand as the worldview of the scientist, including a number of general theories and values. Kuhn saw the paradigm as a prerequisite to perception itself.

justice and wellbeing for people, (2) to use a dynamic systems perspective as a platform for communication between disciplines and a common framework of understanding and (3) to work, when possible, with mixed methods and multi-scale assessments.

4.1.1 Scale of observation and knowledge scales

Article 3 further explores the epistemological dimension of science, and argues that the choice of observational scale has political implications. I use the concept of 'scale' to refer to time, space or quantity, something that can be measured. Based on the conceptual discussion on scale and scale mismatch, article 3 develops the concept of 'knowledge scales' one step further.

The observational scale, i.e. the temporal, spatial or quantitative dimensions used by scientists to measure and study the world, may be deliberately chosen by scientists to highlight specific features, while at other times it is for practical or logistical reasons (Levin 1992), but it may also be taken for granted. The choice of scale mirrors the knowledge, culture and priorities of the observer, and it influences what can be seen and the conclusions made (Cumming et al. 2006; Gibson et al. 2000; O'Flaherty et al. 2008; Rangan and Kull 2009). When we observe the world as scientists, we necessarily do so on a limited range of scales, so our perceptions of events will be limited. To some extent this is evident, but actors are often unaware of their own and others' implicit assumptions. Awareness of the political implications of scale choices have led to the use of multi-scale assessments, to increase the credibility and relevance of findings.

Observational scale is part of a chosen research design, but has relevance also in everyday life. Transdisciplinary science (Hirsch Hadorn et al. 2008) tries to overcome the mismatch between knowledge production in academia and knowledge needed to solve societal problems, and often finds that people have different worldviews and knowledge systems. As I work in foreign countries, I often find myself in situations where I have to reflect on my own partial perspective of the world. Quite often, I experience misunderstandings and problems in communication that are due to a mismatch between my own and other people's knowledge bases. I use the concept of *scales of knowledge*, to refer to the temporal and spatial extent and character of knowledge held by individuals and collectives in society (not to confuse with the knowledge per se).

4.1.2 Multi-scale assessments

As a way to deal with the limitations and biases imposed by the scale of observation, large environmental assessments such as the Millennium Ecosystem Assessment, apply multi-scale assessments and cross-scale studies. According to the Millennium Ecosystem Assessment report on multi-scale assessments, "an effective assessment of ecosystems or human well-being cannot be conducted at single temporal or spatial scales" (MA 2005, 23). The motivation behind this statement is that single scales are too limited and risk misinterpreting results. In relation to actors and groups in society, one can see that scale of observation has political dimensions and that it becomes part of a process where power relations emerge.

> The choice of the spatial or temporal scale for an assessment is politically laden, since it may intentionally or unintentionally privilege certain groups. The selection of assessment scale with its associated level of detail implicitly favors particular systems of knowledge, types of information, and modes of expression over others. (MA 2005, 24).

For this reason, Lebel (2006) argues that all actors involved in assessment processes should make their scale choices transparent to achieve legitimacy through a shared understanding of scope and assumptions. This is a good principle for all research that engages with important and complex societal challenges.

4.1.3 Situated knowledges and triangulation

The recognition that our knowledge is situated and partial also underlies my focus on perceptions of actors. When studying complex processes of societal and environmental change, rather than looking for what is true and who is right (although that is quite often a very relevant thing to do), we can see actors' perceptions of events as partial stories, reflecting the underlying scales of knowledge, and actors' values, needs and interests. In forest management, the forest has multiple meanings to actors involved. The same can be said for electricity: actors have different needs, values and interests influencing how they react to its introduction (Winther 2008). It is thus not surprising, that, when actors discuss the potential and functionality of a specific electric power system, they can have very different opinions regarding its characteristics. This approach could for example be used to compare the

functioning of a micro-hydropower plant in a rural community from the perspectives of the local technician responsible for running the plant, a visiting hydropower expert from a Nordic country, and people with electricity at home in the village. While the visiting expert is likely to judge system performance as rather poor according to his or her experience and technical training, the local technician with in-depth knowledge of the system, may consider the system as working rather well as long as problems encountered are possible to solve. The preferred output is one that balances capacity and load, adapts to seasonal water flows and stays within budget. From the local villager's point of view, preferred output is one that meets specific needs and expectations, allows for activities at certain hours of the day and over the year, and minimizes cost. Diverging views and lack of coherence is, rather than a methodological problem, an interesting reflection of underlying assumptions and in itself an object of study.

In the result chapter and in article 3, a method used to explore diverging perceptions is presented: triangulation for divergence (Nightingale 2003, 2009). What is commonly referred to as triangulation of data is a key method for validation of results, i.e. cross-validation or comparison of data from different sources. There is also the approach of triangulation for complementarity (e.g. Gagnon and Berteaux 2009; Huntington et al. 2004). All three approaches are helpful for analysis of perceptions of various actors, and for contrasting different data sources, such as interviews with documents and observations. Triangulation for validation is, for example, used by Nightingale (2003) for a quantitative analysis of changes in forest cover. This data set is then contrasted (triangulation for divergence) with a qualitative analysis of people's perceptions of changes in forest cover over the same time period – revealing interesting differences in interpretation and new questions being asked. Complementarity as an approach is used by Gagnon and Berteaux (Gagnon and Berteaux 2009) to integrate traditional ecological knowledge with scientific knowledge, and thereby improve the knowledge base.

4.2 Conducting the study

The empirical contribution of this thesis is presented in articles 1 and 2. These articles are based on literature studies, an interview study undertaken together with colleagues in Tanzania and Mozambique in January to March 2010, and interviews with three Swedish experts in 2011.

The study presented in article 1, on drivers and barriers to RE, has been guided by the study design proposed by Painuly (2001), and included a literature survey, interviews with power sector actors, and site visit observations. Through the literature survey, we identified a list of barriers, which were sorted into barrier categories (see article 1). It became clear that our analysis needed to include all sorts of aspects, including aspects that were beyond our expertise. Therefore we chose to work with qualitative, semi-structured interviews that asked open-ended questions facilitated by an interview guide. Each interview is also adapted to the professional experience and role of the respondent (Mikkelsen 2005). Through the literature review, the lack of private sector involvement and the importance of productive uses of electricity (the topic for article 2) came out as crucial issues, which were therefore included among topics to investigate.

4.2.1 Selection of respondents and interview topics

The study of drivers and barriers was carried out in 2011 and includes 16 interviews with government officials, international donors, technical consultants and the civil society organization TaTEDO. For the study on productive uses and the role of private sector, three interviews were excluded but three new interviews were made in 2011, thereby the study includes 16 interviews. In total 19 interviews have been made with African actors. Respondents were selected on the basis of their influence in and experience of RE processes, and it was our colleagues at the universities of both countries that provided many of the contacts. We also asked in interviews, which actors are influential and important to talk to. Due to time limitations and for practical reasons, we could not meet all the actors we wanted to interview. Wilkins (2002) provides a list of key actors in RE, which includes: policymakers, legal and regulatory bodies, development agencies (international donors), utilities, consultants, academic institutions, NGOs, community groups, recipients and users of technology – all of which we have met with – and financiers (banks), manufacturers, suppliers, developers and installers, that we have not interviewed.

The studies partly differ in interview topics, the analysis of drivers and barriers explored, social, technical and economic aspects of RE, off-grid and RETs: (1) current state of the electricity infrastructure in rural areas, (2) RE strategies (including capacities of both own and other organizations), roles and relations between actors, (3) institutional, social and economic drivers and barriers to RE, (4) potential for off-grid and renewable energy

technologies, (5) local participation in electrification processes, and (6) impact of electricity on people's lives. For the study of productive uses and private sector, the following topics were added: (7) the importance of different (non-specified) energy loads for successful outcome of RE, (8) the importance of productive electricity uses, and (9) the involvement of the private sector in the RE market.

As suggested by Painuly (2001) we also visited operating off-grid systems using solar, wind, diesel generators and small-scale hydro to complement the interviews. At each site discussions were held with involved actors (entrepreneurs, management staff and local users). These visits provided valuable understanding, but the limited data is not included in the analysis.

4.2.2 Coding and analysis

Interviews were recorded (unless it was considered inappropriate), transcribed and analysed by content analysis, based on a scheme of analysis defined beforehand (Mikkelsen 2005). The analysis revealed drivers and barriers specific to the context that had not been emphasized in previous literature. The empirical analysis of the specific context has informed and given substance to my theoretical understanding of system dynamics. Each context is unique and lessons from one case cannot simply be generalized to another context, but in-depth empirical understanding provides a base for asking relevant questions in other cases. After transcription, each interview was coded, using Atlas.ti software, and codes agreed upon between my colleague and me.[20] We used a scheme of analysis with predefined themes and used it to sort codes into code families, but new codes and themes also emerged as we worked with the interviews. The material has been scrutinized by both of us, separately and together, and on multiple occasions, compiled in various ways according to specific themes, codes or respondents.

Some methodological weaknesses should be pointed out. Firstly, the analysis is limited in scope in terms of both the number of respondents and the time allocated to each interview. Strictly, the analysis mainly reflects what actors found important or relevant at a specific point in time, even though the respondents are very knowledgeable in their field. However, semi-structured interviews allow for respondents to reflect on their own answers and bring up additional aspects that they find important. The respondents were not presented with a list of

[20] The other colleague who worked in the field with us did not participate in coding and analysis.

predefined drivers and barriers, and it is likely that actors would agree to more factors working as drivers and barriers than they themselves brought up. The list of drivers and barriers should therefore not be seen as complete. The next step is to arrange a stakeholder workshop and present our results to power sector actors in both countries. That will offer an opportunity for in-depth discussion on the list of drivers and barriers, and provide better understanding of the degree to which actors' perceptions converge or differ in this respect.

Secondly, there is always a risk of misunderstandings as regards language. Inconsistencies are addressed through triangulation of findings, but only some facts can be triangulated; differing views and perceptions are seen as part of the results. Possible biases in interviews as well as the concepts of reliability and validity are discussed at length in the literature for this type of qualitative analysis (Mikkelsen 2005). In this study, trustworthiness of results is sought by two researchers scrutinizing the material in the search for inconsistencies, and comparing findings to existing literature.

4.2.3 Interviews with external experts

When the results for articles 1 and 2 were compiled, they were discussed with three external experts with substantial experience of the power sectors in Tanzania and Mozambique. These Swedish experts reviewed the draft manuscript of article 1, and then subsequent interviews were held with each expert for further input. This provided a different perspective on the topics (also the topics of article 2) and in-depth discussions, which we contrasted with the other interviews and literature. This helped us to take the analysis one step further.

5 Results

5.1 Article 1 – drivers and barriers to rural electrification

The first appended article has the title *Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off-grid and renewable energy technologies.* The study was undertaken and is co-authored together with my colleague Linus Hammar. It is an empirical contribution to the literature on rural electrification in sub-Saharan Africa. The aim is to identify, from the perspective of power sector actors in Mozambique and Tanzania, specific drivers and barriers to RE through (1) grid extension and (2) off-grid renewable energy systems.

The analysis identifies drivers and barriers that are: (a) general for the region; (b) country specific; (c) specific for national or local level, or actors involved; and (d) technology specific. The result largely corresponds to what has been identified by previous studies, but there are also some factors not previously mentioned, and some not much emphasized before, that come out as important country-specific constraints.

It was found that the main drivers in both countries are political priorities and development policies. The RE strategies are laid out by ministries and government utilities, supported by international donors who push for RE and power sector reforms. Bottom-up demand for electricity services is also a driver, although less significant. The countries have chosen different development paths: Tanzania has recently carried out a power sector reform, including debundling of the national utility, establishment of a rural energy agency (REA) and encouragement of the private sector, including the introduction of standardized small power purchase agreements, working as off-grid feed-in tariffs for small power producers. Mozambique has chosen not to encourage private sector investment or to debundle the national utility, which is expected to remain the only actor for grid extension.

Tanzania and Mozambique face the same challenges of large geographical distances, low population density and rural poverty, working as barriers to grid extension. Traditional building techniques also come up as a technical barrier in grid extension projects, a barrier that has been mentioned by Murphy (2001) but not emphasized. Further, the results show that both countries experience institutional and organizational weaknesses impeding the performance of national utilities. The lack of coordination, planning capacity and enough staff are perceived as important barriers, particularly in Tanzania, where the utility has failed to use large amounts of available funding. The problems associated with donor dependency also come out as important constraints for both countries. This has not yet been discussed in detail in the RE literature. The role of donors in relation to domestic actors is ambiguous and has come out both as a driver (when providing funds and pushing for reforms) and a barrier (by adding to the work loads of already pressed staff in government, agencies and utilities). According to utility staff in Tanzania, donor-funded projects sometimes subsidize the connection fees, which results in more connections but also leads customers to complain in government-funded projects, if there are no subsidies. The same conflict applies to the compensation levels (for property loss) that are lower in government-funded projects than in donor projects. The use of subsidies can also create another type of barrier. By some actors,

subsidized tariffs are considered to be very problematic, as they tend to make RE economically unviable and hinder private sector involvement.

Although most actors recognize off-grid systems and renewable energy as a necessary complement to grid extension, specific barriers to these systems are related to young organizations responsible for its implementation and to guilt-by-association with dysfunctional diesel-based off-grid systems. Actors also relate off-grid to problems of maintenance and lack of entrepreneurship, but have different perceptions regarding specific barriers of RETs. In Tanzania, the newly introduced feed-in tariff may become an important driver for new actors to enter into off-grid RE. There are no such incentives in Mozambique, but there is an ongoing process of decentralization that may, if successful, empower the districts to take an active part in small-scale off-grid RE for productive uses.

5.2 Article 2 – productive use and private sector involvement

The second article is also an empirical contribution, co-authored with Linus Hammar and Sverker Molander. It has the title *Productive use and private sector in rural electrification of Mozambique and Tanzania*. In this study, power sector actors in Tanzania and Mozambique were interviewed on their perspectives regarding productive use, private sector involvement and off-grid solutions in the RE undertakings of their respective countries. The results were also discussed with three Swedish experts. The aim is to reveal how these important matters for successful RE are perceived by policymakers and implementers of RE in respective country, and to contrast actors' perceptions to the experts' views and earlier research.

The article identifies a stronger emphasis on social development goals in Mozambique, while Tanzanian actors have a more pronounced focus on economic development. Productive uses of electricity are seen as the most important loads for successful RE, by most actors, but Mozambican actors also stress administrative/official buildings and public services. The actors reported a high potential for increased agricultural production and manufacturing in both countries, but also described a poor rural market with very few industries. The results do not support the previous suggestion made by Mulder and Tembe (2008), that rural industries (in their case a cotton factory) are generically available 'anchors' for RE in the region. Instead, small-scale rural production and business activities – such as mills, pumps for irrigation, mechanical workshops and poultry farming – are seen as having the largest development potential. With electricity, there are also direct benefits from income generation

activities at the micro-scale, i.e. at household level. Actors in both countries report low levels of productive use, and relate this to lack of rural infrastructure and markets. It is suggested by many actors that complementary investments and better coordination between sectors are needed. Actors suggest that RE projects would benefit from a broader rural development perspective, but say it is not really happening.

The article illustrates how the private sector can play multiple roles in RE processes: as producers and/or consumers of electricity, and as buyers or providers of electricity-related services. However, in discussions of the role of the private sector in RE, most attention is given to private sector engagement in generation, transmission and distribution. It is suggested that a focus on how to enhance the capabilities of private actors in their roles as productive users and service providers would be beneficial. So far, the private sector has not been much involved in RE, and Mozambican actors do not see any reason for the situation to change. In Tanzania, there is hope of a shift, and for the private sector to start taking an active role. The major change relates to the power sector reform, establishment of REA, and economic incentives for off-grid generation. However, interviewed actors described a situation where local investors lack financial and organizational capacity to start projects, and larger investors have little interest in the rural energy market, because of low expectations on profits and limited experience of power sector business. In Mozambique, the private sector is virtually absent from the power sector according to the domestic actors, partly due to inexpensive large-scale hydropower and partly for lack of promotion by the government.

At micro-scale, off-grid RETs such as solar PV and micro/pico hydropower can reduce cost, generate cash and improve affordability. Households have important roles to play both in generating their own electricity, using it productively and selling electricity services. There is varying interest in off-grid renewable energy systems, ranging from enthusiasm to scepticism. Of potential RETs, small-scale hydropower is considered a viable and suitable alternative for productive uses, while solar PV is appreciated for its benefits at household level, but not seen as a good alternative for productive uses requiring higher output.

5.3 Article 3 – power and knowledge in natural resource management

The third appended article has the title *Mismatch between scales of knowledge in Nepalese forestry – epistemology, power and policy implications* and is co-authored with Andrea Nightingale. It aims to interrogate the problem of cross-scale processes and scale mismatch,

taking the case of forestry, and the limits of observation and interpretation are framed as a discussion about knowledge scales and scale of observation. The conceptual discussion has been accounted for in the methodology section. Based on the empirical work by Nightingale on community forestry in Nepal, the article illustrates how actors' understanding of the forest is based on different needs, interests and values, but also how knowledge is derived from different temporal and spatial scales. As a result, actors interpret both the forest and the rationale of forest management through specific, and often conflicting, frames.

In Nepalese community-based forestry, the district authorities promote 'expert knowledge' to local people with an underlying assumption that ordinary villagers are 'backward' and need to be 'sensitized' to proper forest management and climate change. Forest officials see monoculture stands for timber as the main resource, and base their expert recommendations on generalized scientific knowledge extracted from other geographical and timescales external to Nepal, whereas local people's knowledges about the forest spans multiple time frames, based on people's life-long relation to it, the daily and seasonal harvesting of various forest resources and the oral knowledge and symbolic meaning traded from older generations – as well as their interactions with forestry officials. For those local people who depend on the forest for their livelihoods, there are multiple resources, places and values of interest. The case study reveals a mismatch between actors' interests and goals, and their understanding of the forest.

Further, local elites make knowledge claims to assert control over forest resources, such that literate, high caste, usually male members – who do not work in the forest – use their superior abilities to read, interpret and 'understand' management documents (a symbol of expert knowledge) to assert their right to control management. Meanwhile, the knowledge of those local people who regularly work in and depend on the forest – illiterate, usually lower caste and female members – is marginalized. The outcomes are ecosystem change, a redefinition of the forest as a source of timber rather than a multi-use forest for local livelihoods and places of meaning, gradual disappearance of local knowledges, and changes in people's access to the forest and forest resources.

The Nepalese case illustrates how acknowledging multiple and divergent stories has policy implications. Ambitions to include local knowledge in negotiations around climate change policies and programmes like REDD+ are likely to ignore the multiple scales of knowledge within communities, seeing partial and political claims to knowledge by elites as

representative of local needs and interests. Taking scale politics and mismatch between knowledge scales into account requires a different organization of the decision-making process, one which can allow open dialogue between actors without striving for a single dominant story as output. The negotiation process does not necessarily become more equal, but more transparent regarding the trade-offs at stake.

6 Discussion

Going back to the overall aim of the thesis, the discussion has revolved around country-specific drivers and barriers, and prerequisites, to rural electrification in general, and off-grid electrification using renewable energy technologies in particular. The results for each article have been presented, and I will now discuss the empirical results so as to answer the research questions.

From the perspective of power sector actors in Tanzania and Mozambique: What are the drivers and barriers to rural electrification through grid extension or off-grid renewable energy systems? What are the prospects for private sector actors to take a more active part in rural electrification and development? How do productive uses of electricity relate to outcomes of rural electrification?

From the analysis of drivers and barriers (article 1), and actor's views on private sector engagement and productive uses of electricity (article 2), a pretty clear picture emerges regarding what are perceived as major drivers and barriers to grid extension. Importantly, drivers and barriers strongly relate to the roles of international, national and local actors in planning and implementation. In both countries, the main driver at national level is political ambition to develop the rural areas and alleviate poverty. In Mozambique, the focus lies primarily on social development, while hope for economic benefits are more pronounced in Tanzania, where the power sector has moved towards commercialization. Demand for electricity is expected to grow faster than supply in both countries. Bottom-up drivers such as initiatives by local actors also exist, but more so in Tanzania where civil society is more active than in Mozambique.

The major barrier to higher pace of grid extension is, according to domestic actors, lack of funds. This view has generated some debate regarding Tanzania, where one actor points to the fact that the domestic actors did not use more than 14% of available funds for energy

projects in 2008–2009 (MEM 2009). The external actors agree that RE is costly, but rather emphasize institutional and organizational weaknesses as the major barriers in Tanzania. One reason why RE is considered so costly is the low rate of return on investment due to the low affordability of consumers and the lack of industry. The use of subsidies works as both a driver and barrier. It is considered an important driver, and a necessity, when being used to overcome initial costs, such as for capital investment and subsidized connection fees. The use of subsidized (social) tariffs as a pro-poor policy for small consumers, however, is considered counterproductive by Tanzanian actors. The government utility Tanesco runs at a loss, selling electricity at tariffs below production cost. According to the World Bank, it is a general problem in sub-Saharan Africa that residential, commercial and industrial customers do not pay full cost-recovery prices, although the situation is worse in countries relying on diesel-based power generation system (WB 2009). At the same time, some Tanzanian actors refer to studies[21] showing that the better-off rural elite can afford higher, commercially viable tariffs. A gradual increase in tariffs would improve the financial viability of RE and the money could be invested in better service and more connections. The view that current subsidies primarily benefit higher-income groups and should be removed is shared by the World Bank (WB 2009). Some actors also see the low tariffs in Tanzania as a barrier to private sector engagement. In contrast to Tanzania, the Mozambican actors did not bring up the question of subsidies in the discussion. There, the discussion about tariffs concerned the 'Cahora Bassa effect', with comparatively cheap electricity supply from large-scale hydro, which the private sector considers it is unable to compete with.

Many actors, including the donors themselves, consider donor dependency to be a crucial barrier. It has not been given much attention in previous studies, but in our interviews, the role of donors comes out as ambiguous and important. Donors push for RE and provide major parts of the budget, but dependency on external funding impacts the budgeting and planning process negatively, as government development plans develop the character of wish-lists. Some actors direct critique at donors for not coordinating with one another, creating unnecessarily heavy workloads for domestic actors. There are no signs of decreasing dependency on donor funding for RE, and the countries need the external money. From a research point of view, and emphasized by the external experts, donor funding comes with time constraints that endorse short-term thinking, while experience from other countries

[21] An example comes from Zambia where Ellegård et al. (2004) found high willingness to pay for electricity from solar PV systems and in the study by Ilskog et al. (2005) on an off-grid system in Tanzania.

shows that RE is a long-term investment that takes decades to implement even in the wealthiest countries. The interviewed donors are also limited by the policies decided by governments in their home countries regarding what kind of projects can be supported and how to measure and report achievement of goals.

The private sector can play multiple roles in RE processes: as producers and/or consumers of electricity, and as buyers or providers of electricity-related services. Some cogeneration industries are both generating their own electricity, and exporting excess electricity to the main grid, if connected (Otieno and Awange 2006). There are examples from the region of rural industries being 'anchor projects' or key customers enhancing the economic potential of RE (Mulder and Tembe 2008). Our interviews show, however, that in contrast to literature, actors do not think that there is enough rural industry to provide an economic base for RE. Rather, the economic development potential is considered to be found in small-scale productive uses of electricity and related business activities.

The view on productive uses of electricity is somewhat contradictory. The dominating experience of actors is, despite hopes of RE leading to economic development and poverty alleviation, that the economic results fail to come. Grid extension has a positive impact on household economy and small-scale income-generating activities, but little happens above that level. Other factors impede a more substantial economic development, for example lack of rural markets and communication infrastructure, lack of investment capital, entrepreneurship and business skills. In Mozambique, there is awareness that RE has been supply-driven rather than demand-driven, and that a strategy focusing on productive uses as the primary focus is needed (EdM 2007). The importance of productive uses of electricity for RE to result in economic development is widely agreed upon. However, RE projects rarely include mechanisms to ensure that such development takes place. The findings of this study give a potential explanation, namely that the discussion on the role of private sector has focused primarily on participation in generation, transmission or distribution. Less attention has been given to the private sector as customer and service provider – roles that could be strengthened.

To enhance productive uses of electricity, RE projects need to be extended beyond what is now the implementation stage, and include specific measures to enhance actors' abilities to make use of electricity, for a variety of actors and productive activities from micro- to large-scale. Encouraging the private sector as consumer further implies a focus on increased quality

of power supply and customer services so that production can develop. This brings us back to the question of integrated development. Most actors (including government staff and donors) and earlier assessments and research (EdM 2007; J. Peters et al. 2009; Ranganathan 1993; Åkesson and Nhate 2006) emphasize the importance of integrated development, but still many RE projects are carried out without coordination with other development sectors and efforts. This contradictory situation leads me to ask: what is stopping actors from working according to best practice and their own insights?

A full answer to this question lies outside the scope of this study, and would, I believe, require deeper understanding of the culture of organizations involved in funding, planning and implementation. However, one aspect of organizational culture is how sharing of information and learning takes place.[22] Theories of diffusion of innovation (Rogers 2003) provide some guidance on what types of questions need to be asked: What processes for learning and integrating new knowledge are put in place? At the sector level: What channels exist for power sector actors to communicate new ideas and technological innovations? Are there common objectives and norms that enhance sharing of information and diffusion of innovations? There is also the complex question of how dependency on external funding impacts organizational culture, the diffusion of innovation, and possibilities and motivation for long-term thinking and coordinated activities among domestic actors.

The empirical work of this thesis shows that both countries face barriers related to weak institutions and organizations, for example lack of human capital at ministerial and utility level, in terms of not enough staff, and circumstances that hinder staff from full performance. Many actors perceive the top-down management in the sectors to cause problems of inefficiency and corruption. Responsible organizations also struggle with difficulties in planning and coordination. It is difficult to say what is cause and effect, but clearly, addressing the challenges lies beyond the ability of any single actor. These are questions that I would like to gain a better understanding of, because I can see that the institutional and organizational weaknesses are issues of long-term importance.

Until now, development of the power sectors in the region has been based mainly on transfer of large-scale electric power system technology, based on a standard model from

[22] This discussion was left out of article 1 due to lack of space, but the interviews indicated that important information is not always transferred between different divisions in the same organization and that competence lies with individual staff rather than at group level. If individuals change position or quit the organization, the knowledge may be lost to the division/organization.

industrialized countries. Due to lack of domestic human capital, the countries have relied on international consultants. The process that Wilkins defines as technology transfer (see section 3.2) – which includes transfer of skills and know-how to a degree that domestic actors feel ownership of the entire process – has still to take place. Grid extension is based largely on industrial-country-perspective, while technology transfer, according to Wilkins, includes an adaption of the technology to the local conditions. As I see it, such adaption requires a shift of perspective. For example, our interviews show how traditional huts built from grass and mud are not considered for connection in grid extension projects in Tanzania. In Mozambique, on the other hand, there are examples of technical solutions so as to also connect traditional houses, resulting in higher connection rates. With a shift of perspective, traditional building techniques can be taken as the starting point, instead of being seen as an obstacle. With such an approach, RE projects in rural Africa would apply technical standards that match local realities, and engineering solutions could take a broader perspective on providing rural people with access to electricity and related benefits. It would require redefinition of goals in RE projects, shifting from a focus on connection rates to a broad array of benefits and possible ways in which access can be provided.

To what degree do the perspectives converge or differ when it comes to key challenges for RE and the potential for off-grid RE? Based on actors' perceptions of RETs, what come out as key challenges to be addressed for off-grid renewable energy systems to diffuse successfully?

There is general agreement on the challenges facing the power sectors of both countries regarding the difficulty of providing the rural populations with modern energy services and access to electricity from the main grid within the coming decades. Lack of enough funds within the sector and dependency on donor financing are considered to be crucial issues by most actors involved, but some – especially external experts, donors and consultants – actors stress organizational weaknesses, top-down management and low institutional quality rather than lack of funds. Some issues reflect diverging perspectives between the countries, for example critique against use of subsidies in Tanzania and the low expectations for/interest in private sector involvement in RE in Mozambique. The focus on economic aspects of RE is stronger in Tanzania, while in Mozambique more actors refer to social benefits. There is general agreement in both countries, somewhat contradictory, on the need for productive uses

of electricity, integrated development and cross-sector coordination, but still this rarely takes place in practice.

For off-grid electrification using RETs, the actors' perceptions of drivers and barriers are less clearly formulated. Although full grid coverage is currently seen as the goal by most actors, a couple of respondents suggest that demand is so small in remote areas that it can be met with solar PV systems.[23] Currently, the number of actors in the field working to promote RETs is small, and at national level the interest in RETs for off-grid RE is rather weak, with only a few actors showing enthusiasm. Off-grid RE is still seen as an exception, and not expected to contribute substantially to improving access rates because most rural people cannot afford to buy a solar home system. But some actors express divergent views, and see large potential in using available renewable energy sources. One actor strongly believes the introduction of the off-grid feed-in tariff in Tanzania will boost private sector involvement. There are positive experiences, for example from Rwanda, of private sector involvement in micro-hydropower development (Pigaht and Plas 2009). As RETs are at a very early development stage in the region, attitudes can change quickly. For example, at the time of interviews, among the Mozambican actors only Funae showed interest in solar PV technologies, but a process is now initiated to build a solar PV factory in the country as to supply the regional market. It is likely that attitudes towards these (in this context) new technologies will change concurrently with growing evidence of their applicability (or not) in these specific contexts.

As grid extension represents the dominant technology, there is need for supporting policies for off-grid RETs, which encourage bottom-up initiatives as a complement to top-down implementation. What policies could enhance development of a RET cluster in the region? Innovation system studies argue that generic policy issues are of little relevance in the specific case. An informed answer demands a more thorough analysis. Bergek et al. (2008) propose a combined structural and functional analysis for identification of key policy issues in emerging innovation systems. For the RET cluster to strengthen in the region, efforts can be directed at supporting key actors and processes[24] of the innovation system. Lessons from

[23] Based on what the evolution of technological systems and examples from other fields, e.g. communication infrastructure teach us, we should not preclude the possibility of future decentralized energy infrastructure making extremely expensive full grid coverage unnecessary, also where there is higher demand.

[24] The processes that should be strengthened in an innovation system are: (1) knowledge development and diffusion, (2) influence on the direction of search (3) entrepreneurial experimentation, (4) market formation, (5) legitimation, (6) resource mobilization, and (7) development of positive externalities (Bergek et al. 2008).

other countries show that policy-makers should use a variety of technology-specific policy instruments and support technologies to develop in parallel[25] (Geels et al 2008).

The responsible government organizations could take strategic roles in development of an RET-cluster in the countries. These organizations could work to facilitate activities and coordinate networks for promotion of RETs, and identify the main barriers now blocking development. Based on what I have learned so far, I see the need for off-grid RE to include investment in productive activities and packages of capacity training, supporting local initiatives and entrepreneurship. Politicians need to focus on how to strengthen rural market formation – and not only for cash crops – for without markets for their products rural people have no incentive for increasing productivity.

The success of solar home systems in Kenya is partly due to the development of a network of rural actors, providing necessary technical support. There is much to learn from other countries, and there are multiple models for service delivery. One barrier now hindering the spread of small-scale RETs is lack of support infrastructure (for example access to micro-loans, equipment, maintenance, local technicians, retailers, recycling systems and educational programmes). Off-grid systems require other measures than centralized grids, in the sense that much managerial competence must be available locally. The educational aspect of building technical, business and management capacity locally requires substantial efforts by many actors over a long time period. However, the benefits of investment in development *after* introduction of electricity would probably be immediate, especially if directed towards maximizing productive activities supporting rural markets.

Finally, the theoretical contribution of this thesis is the work of bridging between two areas of research: the interrelatedness of social and technological change, and the dynamics of social relations of power and people's resource use. I seek to combine a system perspective on introduction of electricity in rural communities with a user perspective that can identify the mechanisms whereby individuals, groups and organizations control and access electricity and related benefits. In the theory chapter, I have visualized how I conceptually relate the technological system to the outcomes of electrification for various users, depending partly on people's abilities to derive benefit from the process. For that aim, I have applied the theory of access by Ribot and Peluso (2003) to electricity, which as far as I know, has not been done

[25] As many new ideas and inventions fail to take off from development to diffusion, aiming for diversity of technologies and solutions is always a good guideline for policy-makers.

before. The definition of access to electricity makes visible the indirect access and benefits (including the symbolic and institutional aspects) that are not captured in terms of connection rates. Being able to connect does not necessarily mean that people can derive much benefit from electricity, satisfy their energy needs or that they will be able to maintain access over a longer time period. The discussion highlights the fact that someone is controlling the access of others, and this is also true for access to other resources (land, machinery, financial capital etc.) needed for people to really make use of electricity.

I conceptually relate the type of technological system to questions such as: who gets access, access to what, when and how; do actors perceive the system as functional, why/why not, and is it sustainable in the sense that access can be maintained? A successful outcome should not only provide electricity, but should also match output with needs, and generate benefits that can be maintained and strengthened over time. Also, this conceptualization illustrates that the same technological system can be perceived as functional by some actors, while leaving other actors unhappy, and excluding some from access.

7 Conclusions

This thesis has the overall aim of understanding how power sector actors perceive country-specific drivers and barriers, and prerequisites, to rural electrification in Tanzania and Mozambique. There are three appended articles, two empirical studies that explore drivers and barriers to RE through extension of national grids and off-grid electrification using renewable energy technologies, and how actors view the importance of productive uses of electricity and the role of private sector in RE; and one article discussing the methodological points of departure. There is also a theoretical aim of the thesis – to bridge between two fields of research and conceptually combine a socio-technical system perspective on the introduction of electricity in rural communities with an user perspective.

The results show that Tanzania and Mozambique face similar challenges related to geographical and socioeconomic conditions, such as large distance, lack of communication and energy infrastructure in large parts of the countries, and very rudimentary rural industry and economy. The countries also face similar financial constraints where major parts of energy sector budgets come from foreign donors. The power sectors are centralized and controlled top-down, with the national utilities as main actors. But there are also differences

between the countries: while Tanzania has undertaken power sector reforms and gradual commercialization, and now encourages private sector actors, Mozambique has recently decided to not undertake further restructuring of the sector, and does not provide incentives for private sector (WB 2007). There may still be a possibility of new actors entering RE, but at local level as a result of ongoing decentralization of district planning. This difference in approach opens the way for a very interesting future comparison between two countries that share many other characteristics.

From the analysis of drivers and barriers (article 1), and actors' views on private sector engagement and productive uses of electricity (article 2), a pretty clear picture emerges regarding what are perceived as major drivers and barriers to grid extension. Importantly, drivers and barriers strongly relate to the roles of international, national and local actors in planning and implementation. The main driver at national level is political ambition to develop the rural areas and alleviate poverty. However, the implementing organizations face many financial, technical, institutional and organizational barriers – some of which have been highlighted in earlier studies and some not previously emphasized. For example, it is found that traditional building techniques are considered a problem in grid extension projects in Tanzania but not always in Mozambique. The role of donors is ambiguous because the large involvement of international donors works as an important driver for RE, but also as a barrier with regards to difficulties in funding, planning, conflicts related to subsidized connections and increased workload for domestic actors.

It is also found that the role of private sector has, in Tanzania and Mozambique, so far been discussed mainly in terms of private generation, transmission and distribution, but a broader discussion could focus on the private sector as customer and productive user of electricity, and provider of electricity-related services. The interviewed actors perceive the largest economic potential to be found in small-scale productive uses of electricity, such as agriculture, mills and mechanical workshops, and at household level where access to electricity helps improve incomes through micro-scale business and replacing expensive fuels. However, large-scale grid extension projects have paid little attention to what happens after electricity is provided, and to possibilities for enhancing the capacities of local actors to make full use of development potentials. Although there is a broad consensus that integrated rural development and cross-sector coordination are needed, it does not take place in practice.

The review of previous literature has resulted in an exhaustive list of barriers to RE and off-grid renewable energy systems, which provides a good guide to the research field. Together with the systematic study of drivers and barriers, as perceived by power sector actors in Mozambique and Tanzania, the thesis provides a good base for understanding the challenges for grid extension and off-grid systems, including the globally wished-for increased use of renewable energy technologies. It suggests a conceptualization that links the technological systems to the local context, through an assessment of system functioning taking technical, social, economic and environmental aspects, and the perspectives of actors, into account. System output is related to perceived functioning and the multiple ways in which rural populations can gain, control and maintain access to electricity and related benefits. Importantly, the thesis looks at rural electrification through theoretical glasses that encourage a shift in perspective and the use of multiple viewpoints. It thereby provides a base for creative solutions for providing rural people with access to electricity in a way that gives immediate benefits, but also contributes to a better life in the long-term perspective.

7.1 The way forward

The empirical work presented in this thesis will be further discussed in stakeholder workshops in Tanzania and Mozambique, so as to enhance the sharing of knowledge and critical reflection together with power sector actors. The main focus is to undertake case studies of existing off-grid projects in the region, using the methodological approach of multi-scale assessment and triangulation for divergence. The next step for me is to continue ongoing case studies of two diesel-based mini-grids, and two micro-scale hydropower systems in Tanzania. The studies will be based on the theoretical work presented in this thesis, and use multiple data sources and methods. I will interview actors with different roles in the project: the financiers, implementers, local managers, technicians and users as well as non-users, thereby different perspectives on system functionality will be explored. On-site observation of the technical system design and technical evaluation (through documentation and interviews with technicians) of the system operation will be contrasted with what comes out in interviews regarding actors' perceptions of benefits, functionality, problems, possible solutions and meeting of needs. The analysis will explore how actors experienced the electrification process, what they see as drivers and barriers, how they understand the roles and relations between actors, and their own participation in the process. The analysis will finally map the

mechanisms by which various actors gain, control and maintain access to electricity and related benefits (including access to other resources).

My work will also follow a parallel track, together with colleagues, of investigating the opportunities for RETs for off-grid applications to develop and diffuse in the region. Coming studies will discuss the functionality of specific RETs with actors at local level, so as to understand what problems actors associate with each technology and what are perceived as acceptable solutions.[26] As integrated development efforts and productive uses of electricity are necessary for RE to lead to economic growth, the research efforts of my colleagues and me will include an assessment of potential market formation for RETs in Tanzania for the purposes of modern energy services for the poor, and small-scale productive uses of electricity.

[26] A Masters student has already carried out such an analysis for solar PV and small-scale hydro with national-level actors and that work will be complemented by interviews with local level actors.

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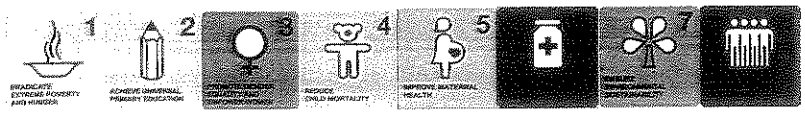
Appendix. The energy dimension of the Millennium Development Goals



Goal 1: To eradicate extreme poverty and hunger: Access to electricity and other modern energy services for heating and cooling/ light/ mechanical power/ transport can greatly improve agricultural output, the taking care of and storage of food, and food preparation. With electricity, the benefits include for example water pumps and irrigation, fridges and freezers, machines for processing agricultural products, pasteurization of milk products, ovens, electrical cookers, water heaters, and kitchen appliances. With electricity some types of animal production such as poultry breeding can greatly improve.

Goal 2: Achieve universal primary education: Access to light, video, radio and television are crucial for improved educational services, and increase both quality and quantity of education, by offering better teaching and learning conditions to teachers and their students. Schools that use efficient stoves save fuel cost and energy services create opportunities to carry out productive activities and raise incomes.

Goal 3: Promote gender equality and empower women: Access to electricity and modern energy services in rural Africa is of large importance to women, primarily by cost saving, and reduced effort and time spent on heavy work tasks. The drudgery of collecting firewood and water eases. More girls are sent to school. Electricity for mills, water pumps, light indoors and outdoors improve working conditions and security. TV, mobile phones and radio are much appreciated for information and entertainment. Existing gender relations impact women's access to new energy services but gender relations also change with introduction of electricity. There is a correlation between access to TV and family planning, and lowered birth rates. Education for women is correlated to decreased infant mortality and number of births (Sen 1999).

Goal 4 and 5: Reduce child mortality and *Improve maternal health:* Electricity at dispensaries improves health care in general and maternal and child care in particular. Light at night during deliveries, refrigeration of vaccines and medicines, sterilization of equipment, access to clean water and communication technologies, improve survival rates for mothers and children. In the home environment, efficient stoves improve indoor air quality and reduce respiratory diseases that are especially common among women and children.

Goal 6: combat HIV/AIDS, malaria and other diseases: Improved health care, access to TV and radio are crucial for successful prevention and treatment of many diseases. Information campaigns, communication technologies, access to clean drinking water, improved sanitation, healthcare and nutritional status decrease infection and mortality rates.

Goal 7: Ensure environmental sustainability: With electricity and modern cooking services the pressure on forests decreases. Carbon emission decrease as less wood and charcoal is burnt and light bulbs replaces kerosene. However, consumption levels tend to increase as a result of higher income levels, but in poor rural areas that is both needed and positive. Replacement of diesel generators with solar PV systems and small scale hydro is part of getting away from fossil fuel dependency. Clean and efficient energy services are crucial for long term economic development and decreasing population growth in rural Africa.

Goal 8: Global partnership for development: The global South needs access to technologies developed in industrialized countries. The current lack of energy infrastructure offers a possibility to avoid the industrialized world's' lock-in of fossil-fuel based energy systems (Unruh 2000), and instead leap-frog directly to environmentally sound, appropriate, sustainable and commercially proven technologies (Wilkins 2002). This requires a global partnership for transfer of technology, know-how, and funding, based on an understanding that technologies need to be appropriate and adapted to specific local contexts of receiving countries. Providing partnerships between North-South and South-South countries is very important and urgent because at the current pace of progress, in sub-Saharan Africa millions of people will not access modern energy services within their lifetime.

The examples given above are based on own experience from East and Southern Africa and some key references (UNDP 2005; Wilkins 2002; Winther 2008)

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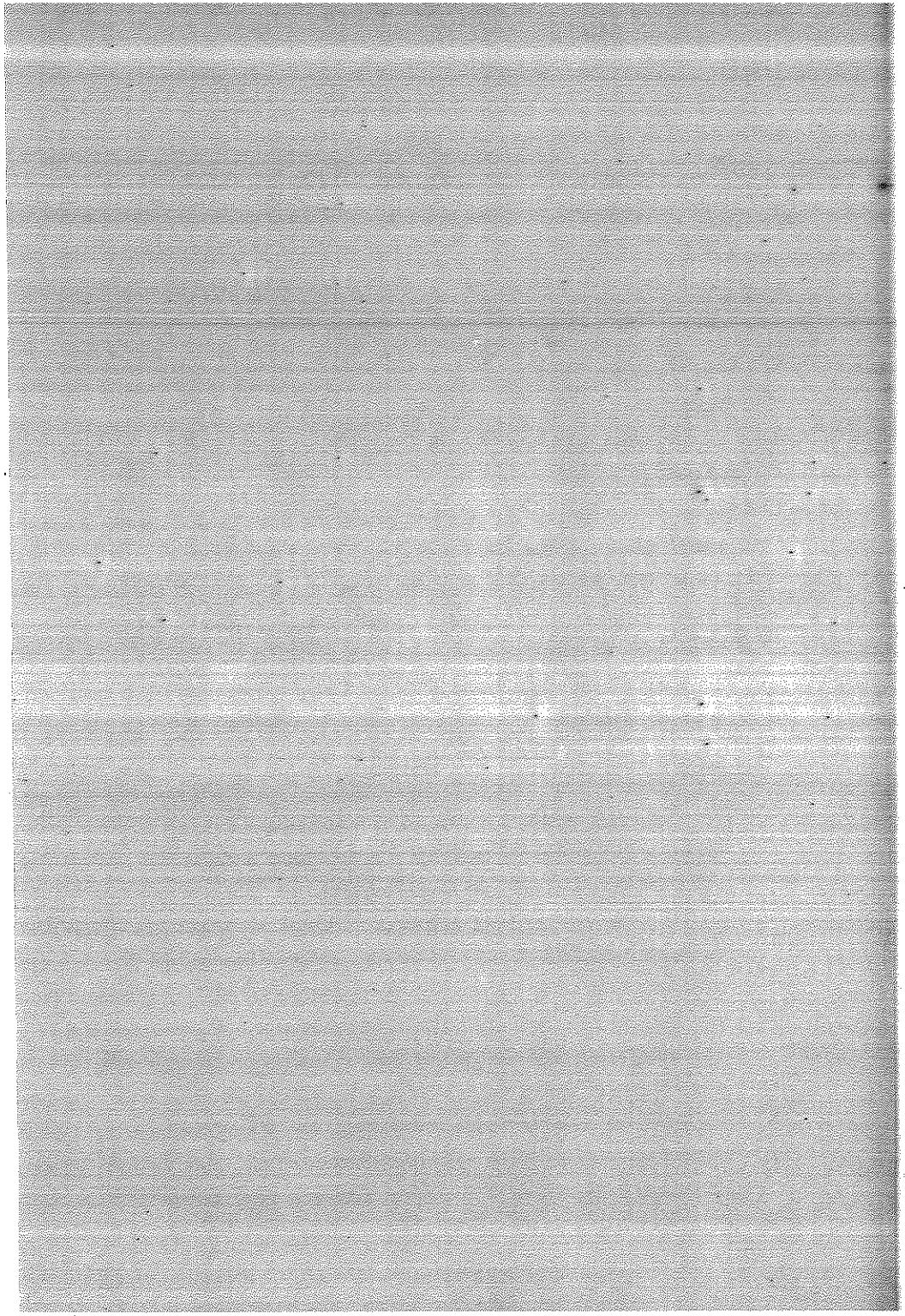
Paper 1



Drivers and barriers to rural electrification in Tanzania and Mozambique – grid-extension, off-grid, and renewable energy technologies

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Mozambique and Tanzania are countries with very low rural electrification (RE) rates as far less than 5% of the rural population use electricity. Despite efforts to extend the national grid in rural areas, most remote areas will not be reached within the foreseeable future. Off-grid (decentralized) electricity grids are seen as a complement and forerunner to the national grid, making electricity available many years in advance and creating demand and a customer base. Renewable energy sources are plentiful in the region and may be particularly useful for off-grid systems. The countries' power sectors are undergoing interesting changes with potential to speed up the pace of RE. However, there are significant barriers to effective RE by grid-extension and off-grid installations.

In this study, the specific drivers and barriers for RE in Mozambique and Tanzania are explored across a spectrum of involved actors. By qualitative methodology, drivers and barriers were first identified through literature survey, then data was collected both in semi-structured interviews carried out with power sector actors from national to local level and in visits to off-grid electricity users in Tanzania and Mozambique during eight weeks in 2010. Findings illustrate generic, country-specific, and renewable-energy-technology-specific drivers and barriers to grid and off-grid rural electrification, as perceived by different power sector actors. Results were validated and discussed with three external experts. Drivers and barriers strongly relate to the roles of national and local actors in planning and implementation. The main drivers are political ambitions based on expected growth of demand, but bottom-up drivers such as local initiatives by industries or churches also exist. The barriers are related to lack of access to human capital, to difficulties in planning and donor dependency, to low rural markets and little interest from private sector, and to more straightforward technical matters such as difficulties with installing electric equipment in traditional buildings. Although off-grid systems and renewable energy are recognized by the actors, specific barriers to these systems are related to young organizations responsible for its implementation and to guilt-by-association with dysfunctional diesel-based off-grid systems.

Keywords: *Rural Electrification, Off-grid Systems, Renewable Energy, Africa, Drivers and Barriers*

1 Introduction

There is little doubt that access to and use of electricity is a benefit to people, not only in the already electricity-dependent world but also in developing areas. While electricity may not bring development on its own it is a highly desired commodity and a prerequisite to economic development in long term perspective [1-3]. In the first industrial countries electrification was initiated in the 1880s and was completed only decades after World War II – a huge effort backed by powerful institutions and publicly funded [4]. It should be kept in mind that, in any country, power distribution in rural areas is an infrastructure assignment carrying huge expense. The challenge is now to provide modern energy services also in emerging economies with different institutional, cultural, and financial conditions. One such region is sub-Saharan Africa, where the electrification level still is minute – particularly in rural areas. In Africa and elsewhere, rural electrification (RE) has largely been the responsibility of the public sector, which in the African context often implies influence from foreign donors. In comparison to the rest of the world, sub-Saharan Africa lags behind [5]. Lack of electricity services constrains urgently needed socioeconomic development and the almost total dependency on bio-energy carries large social and environmental cost, being both a cause and an effect of rural poverty. Despite substantial efforts at extending national power grids, the electrification rate in rural areas has barely kept up with population growth, leaving the RE level hovering at a few percent [5, 6]. The neighboring countries of Tanzania and Mozambique are two such African countries where the pace of RE must increase. As our study will show, they face similar challenges but also differ in terms of factors that specifically enhance or hinder efficient RE.

Tanzania's electricity generation relies primarily on hydropower and natural gas, complemented by imported oil and co-generation from agro-industry [7]. The power sector is dominated by the public utility TANESCO (Tanzania Electric Supply Company Limited). In 2008, the total power generation capacity was 1100 MW. The transmission grid reaches only part of the country, and large areas, particularly the sparsely populated western and southern regions, are still beyond reach. Here, district capitals and other important centers are supplied by diesel generators. The Tanzanian RE level is estimated to be 2–3% [6, 7].

The public utility EdM (Electricidade de Moçambique) dominates the power sector of Mozambique. Electricity is almost exclusively supplied by the 2075 MW hydropower station Cahora Bassa, situated in the north-western part of the country. In addition to Cahora Bassa,

there are only a few smaller hydropower stations and a back-up coal power station. Most electricity from Cahora Bassa is exported to neighboring countries, but transmission lines reach main cities and supply many towns along the line. The Mozambican RE level is not well established but is probably in the order of 2–5%, based on provincial statistics [8]. Due to the long distances, transmission losses are significant and the power supply becomes fragile at the outskirts of the grid. Numerous diesel generators have been allocated to supply smaller and remote districts.

Traditionally, RE has solely been regarded as a public undertaking to be implemented by national utilities, and the private sectors of Tanzania and Mozambique have hardly been involved. However, power sector reforms have lately addressed the encouragement of private sector actors in RE [9, 10]. The rural customer base is weak, and large geographical distances make grid-extension particularly expensive. At current pace, it is unlikely that the national grids can be extended sufficiently to provide the majority of the rural population with electricity within a foreseeable future. Thus, off-grid electrification, i.e. small decentralized electric grids or autonomous generation, is an important means of supplying remote areas without having to invest in expensive transmission [11]. Off-grid systems may be a more viable option for electrification of remote locations [12, 13].

Using off-grid electrification is not just a temporary solution, but in many cases it is necessary if particular rural communities are to have electricity within the coming decades. Off-grid systems in Tanzania and Mozambique are most often powered by diesel generators and dependent on fuel transport for their operation. Thus, off-grid has a higher running cost per Wh than grid-connected systems, which in turn opens the way for the use of small-scale renewable energy technologies (RETs). This RET-based complement to traditional RE has lately been recognized within the World Bank [5].

The potential of RET-based electrification is high in sub-Saharan Africa [13, 14] and thus far mainly hydropower and solar photovoltaic (PV) have been utilized. There is a declared intention to better utilize this renewable energy potential in both Mozambique and Tanzania, particularly in the context of RE [15, 16]. In addition to hydropower and solar PV some utilized RETs are wind power, geothermal energy, and bio energy (in this region bio energy is primarily used for heating and fuel, but also for electricity generation in the sugar industry, and in some rare cases for waste-to-energy combustion of agricultural residues or the use of biodiesel in generators). The prospects for RET-based off-grid RE are covered in an extensive pan-African literature based on the progress and constraints of previous implementations [17-29].

The combination of high abundance of renewable energy sources and the aim of mitigating global climate change makes the use of RETs in off-grid electrification an increasingly attractive option, at least in theory. However, the rural energy transition process is not unproblematic and, as we will present, several barriers have previously been identified. With the exception of Painuly [30]and Wilkins [31] few studies take a systematic approach to drivers and barriers and much more attention is generally given to barriers (constraints) than to drivers, to grid-extension than to off-grid systems, and to national level than to local.

The concepts of 'drivers' and 'barriers' are commonly used by actors in the field, to signify factors that enhance or hinder the wished-for development. Following Wilkins [31], barriers can be defined as any technical, economic, institutional,[1] organizational, political, social, or environmental factor impeding the deployment of a new technology. Barriers tend to be interrelated and therefore it is difficult to isolate the impact of one single barrier. Drivers signify any technical, economic, institutional, organizational, political, social, or environmental factor that enhances the deployment of a new technology. We base our analysis of drivers and barriers on the analytical framework by Painuly [30].

Much experience of successful RE is derived from Asia and Latin America, but the understanding of prevailing drivers and barriers on these continents may not be directly transferrable to the context of the poorest African countries [33]. On the basis of previous research, the aim of this study is therefore to identify the specific drivers and barriers to effective RE through (1) grid-extension and (2) off-grid renewable energy systems, in Mozambique and Tanzania, as perceived by those who are operational – the power sector actors. Drivers and barriers at different levels are distinguished (e.g. international versus national or local; generic versus technology-specific) and the findings are contrasted to existing literature.

2 Method

Data collection was conducted in Tanzania and Mozambique in January to March 2010 by qualitative methodology, following the study design proposed by Painuly [30], including

[1] In this article, institutions refer to both formal (e.g. laws, policies, regulations) and informal (e.g. values and norms, traditions, and 'common sense') institutions shaping and constraining human behavior. Institutions can be thought of as 'rules of the game' and different from organizations and their structures [32] B.G. Peters, Institutional theory in political science: the "new institutionalism", Continuum, London, 1999. Wilkins use of the concept of institutions is slightly different [31] G. Wilkins, Technology transfer for renewable energy. Overcoming barriers in developing countries, Earthscan Publications Ltd, London, 2002.

literature survey, interviews with power sector actors, and site visit observations. The literature survey [author cite] exposed six RE barrier categories, relating to: institutions and actors performance; economy and finance; social dimensions; technical system and its management; technology diffusion and adaption; and rural infrastructure. The subsequent actor interviews covered seven themes that included social, technical, and economic aspects of RE, off-grid, and RETs: (1) current state of the electricity infrastructure in rural areas; (2) RE strategies (including capacities of both own and other organizations), roles, and relations between actors; (3) institutional, social, and economic drivers and barriers to RE; (4) productive uses of electricity; (5) potential for off-grid and renewable energy technologies; (6) local participation in electrification processes; and (7) impact of electricity on people's lives. Sixteen interviews were carried out with government officials, international donors, technical consultants, and the civil society organization TaTEDO. The respondents were selected on the basis of their influence in and experience of RE processes.

The interviews were semi-structured, i.e. asking open-ended questions facilitated by an interview guide, taking professional experience into consideration when framing the questions [34]. Interviews were recorded, transcribed, and analyzed by content analysis, combining a deductive and inductive approach to identifying drivers and barriers in an iterative process [34].

As suggested by Painuly [30] we visited operating off-grid systems using solar, wind, diesel generators, and small-scale hydro to complement the interviews. At each site discussions were held with involved actors (entrepreneurs, management staff, and local users). These visits provided valuable understanding but the limited data is not included in the analysis.

Some methodological weaknesses should be pointed out. Firstly, the analysis is limited in scope both in terms of the number of respondents and time allocated to each interview. Strictly, the analysis reflects what actors found important or relevant at a specific point in time even though the respondents are very knowledgeable in their field. However, semi-structured interviews allow for respondents to reflect on their own answers and bring up additional aspects that they find important. Secondly, there is always a risk of misunderstandings as regards language. Inconsistencies are addressed through triangulation of findings, but only some facts can be triangulated, differing views and perceptions are seen as part of the results. Possible biases in interviews, the concepts of reliability and validity, are discussed at length in the literature for this type of qualitative analysis [34]. In this study, trustworthiness of results is sought by two researchers scrutinizing the material, searching for

inconsistencies, and comparing findings to existing literature. Importantly, we have also discussed the results with three external experts[2] with in-depth knowledge about RE in Mozambique and Tanzania. These experts reviewed the draft manuscript and a subsequent interview was held with each expert for further input (referred to as personal communication below).

3 Results and discussion

3.1 Power sector actors and their roles in driving rural electrification

The power sectors of Tanzania and Mozambique have historically been very centralized and top-down controlled by ministries and governments. For some years now, there have been some interesting changes underway which may lead to new actors entering the power sectors and to changes in the sector structure and dynamics. As the analysis will clearly show, both drivers and barriers are strongly related to the roles taken by involved actors, their organizational capacity, and coordination between them. In this section, the roles of power sector actors are described in terms of how they contribute to RE development, starting with policy at national level, followed by local initiatives, local demand, and other drivers. Table 1 gives a compiled summary of perceived drivers for RE.

According to interviews, the main driver for RE in both Tanzania and Mozambique is political priorities. This result is not surprising as governmental campaigns and programs play a major role in RE in most countries, e.g. [5, 24, 35, 36]. The political priorities are in turn based on ambitions of rural development. Electricity's importance for better healthcare and education is frequently mentioned and EdM staff further see electrification as means of slowing down urbanization and lowering birth rates in rural areas. In both countries, the use of subsidies and pro-poor policies are regarded as drivers increasing the connection rate in rural areas, which is also confirmed by [29]. According to Åkesson (pers. comm.), no rural customers would be able to afford the tariffs if private actors were to run off-grid systems without subsidies.

Until now, focus has been mainly on grid-extension, but according to the Mozambican donor and Consultant B, there is a growing political interest also for RETs and off-grid electrification among donors and politicians. Directed donor support is considered an

[2] The expert for Mozambique is Gunilla Åkesson, Växjö University, Sweden, and the experts for Tanzania are Elisabeth Ilskog, KTH Royal Institute of Technology, Sweden, and Therése Hindman Persson, Schneider Electric, Sweden.

important driver for RE in both countries. International donors provide the major part of the energy budgets and have been pushing for reforms. Some actors also mention that influential politicians push for electrification of their districts and home communities, especially in times of elections.

Table 1. *Identified drivers (D) to RE extracted from actor interviews. Tanzania: 1=TANESCO, 2=REA, 3=TaTEDO, 4=Donor, 5=Consultant A. Mozambique: 6=EdM, 7=FUNAE, 8=Donor, 9=Consultant B, 10=Consultant C. Number of interviews with each organization: i–iii.*

Identified driver	Source									
	1	2	3	4	5	6	7	8	9	10
	iii	*ii*	*i*	*i*	*i*	*iii*	*ii*	*i*	*i*	*i*
Policy and poverty mitigation ambitions										
Governmental policies	D	D	D	D	D	D	D	D		D
New legislation	D	D								
Use of subsidies or pro-poor policy	D	D		D		D	D			D
Promotion by REA/FUNAE		D	D	D				D		
Political election campaigns	D					D			D	
Donor push/support			D	D	D			D	D	
Pushing from individuals in gov. agencies			*		D					D
Promotion of renewable energy globally				D					D	
Local initiatives										
Local entrepreneurship	D			D		D			D	D
Churches		D			D					
Industry installing own systems	D	D		D		D				D
Grass-root organizing	D	D		D		D	D			
Local demand										
Increasing demand (industry, households)	D	D	D			D	D	D		D
Productive uses drive RE	D		D			D				
Off-grid RE creates demand for grid ext.					D					D
Other										
High cost of grid drives off-grid	D	D								
Need of increased sustainability in grid						D		D		

In both countries, the power sectors are centralized and dominated by the ministries and government utilities. Still there are differences in sector structure and legal frameworks between the countries. In Tanzania, TANESCO is the main actor for grid-extension projects, following government policies as laid out in a distribution master plan. The main policy is to electrify all districts by starting with their headquarters. After headquarters, villages are electrified along the distribution line. An energy sector reform has taken place during the past decade, leading to the enactment of the Electricity Act in 2008 [16, 37] which is considered a driver for RE. Donors were actively involved in the energy sector reform process, providing financial, organizational, and legal assistance. The important changes after the reform are that private sector is now encouraged to take an active role and standardized small power purchase agreements, working as off-grid feed-in tariffs for small power producers, have been introduced [38]. This may turn out to be of importance. The encouragement of private sector involvement is considered a driver, but in 2010 little private investment in RE had taken place. The reform included sector restructuring, and regulatory oversight of the tariff system is now ensured by EWURA (Energy and Water Utilities Regulatory Authority). Furthermore, a new agency, the Rural Energy Agency (REA), was established and became operational in 2007, with responsibility for coordination and facilitation of RE (both grid-extension and off-grid systems). REA facilitates RE by supporting applicants with grants for organizational capacity building and for capital investment. In addition to scaling up RE, the ambition is to increase the use of RETs. REA also lobbies donors for better financial support to local investors. Most respondents expect that REA will become an increasingly important actor for driving RE. When asked about the policy and legal framework, all interviewed actors expressed their content with the outcomes of the Tanzanian reform process.

In Mozambique, the national electricity company EdM is the governmental utility responsible for RE, conducting both planning and implementation. Restructuring has been suggested by the World Bank, but this process was slowed down after strategic analyses [10]. The Ministry of Energy and EdM outline grid-extension and new generation, and the recently formed regulatory agency CNELEC (initiated 2006) monitors the performance. The provincial directorates, and to some degree the districts, are also involved in planning. So far, EdM has been almost the only actor in RE and there has been a focus on grid-extension. According to the interviewed donor, EdM is ambitious and well-performing. EdM's strategy is to electrify rural centers with administration, schools, hospitals, industry, and business. The focus on poverty alleviation is strong. There is a new Energy Policy from 2009, and an action plan, but according to the donor it has been more of a wish-list because implementation

ultimately depends on external funding. Current development is based on the Distribution Master Plan from 2004 [8]. The power sector was opened to private investment in 1997 [8], but so far, it has not played a significant role.

Regarding off-grid projects, the main Mozambican actor is the public institution FUNAE (National Fund for Rural Electrification), founded in 1997 and strongly supported by donors [15]. In practice, FUNAE is responsible for rural off-grid electrification; it installs off-grid installations (mainly diesel generators and solar PV systems) in district headquarters, schools, and clinics, according to planning by central government and provincial directorates. Through their projects they implement off-grid projects and build some capacity in local communities.

In the two countries, some RE is also driven by local actors, e.g. local politicians and entrepreneurs. The reform process in Tanzania is an important step towards a more dynamic sector with more actors, and the feed-in tariff has now (2011) had some positive impact on the number of privately funded off-grid projects, according to Hindman Persson (pers. comm.). Local Tanzanian actors who engage in off-grid RE projects are church organizations, entrepreneurs and small industry, international and domestic NGOs, and local authorities. The churches are often considered as actively driving RE by implementing their own, small-scale projects to power rural hospitals and communities. Civil society is weaker in Mozambique and we have not encountered the same importance of church organizations or NGOs in the Mozambican power sector as in that of Tanzania. Nevertheless, a few local entrepreneurs and small industries sell electricity to the grid, or install off-grid systems; also in Mozambique. The number of small producers may improve over the coming decade, according to Åkesson (pers. comm.), since Mozambique has started a process of decentralization of both state administration and planning. This may potentially also affect the power sector. Furthermore, there are district development funds that can be used in off-grid electrification for productive uses. A few local entrepreneurs have taken over power distribution to run it commercially (Åkesson, pers. comm.). Such development, with entering of new actors, can make the Mozambican power sector more dynamic.

Another driver for RE is the increasing local electricity demand. In Mozambique, EdM and the donor both report an urgent need for new generation to meet the demand from industry in urban areas and to allow for growth of productive electricity uses in rural areas. In Tanzania, both TANESCO and REA regard the high costs of grid-extension as a driver for off-grid solutions. According to Consultant A, it is necessary to seriously develop off-grid RE if the political goals are to be achieved. According to some respondents, electricity generates positive feedback once it is provided. For example, TaTEDO says that electricity may boost

local productive electricity uses such as agro-processing, and REA reports that access to electricity reduces energy expenditure, thereby improving household budgets. A positive aspect of off-grid systems, brought up by Consultant C, is increased familiarity with, and demand for, electricity, which becomes a driver for grid-extension.

3.2 Barriers to rural electrification by grid-extension

Tanzania and Mozambique face some common barriers to RE that are due to a combination of geographical, financial, political, and social factors. Table 2 gives a summary of all barriers, or constraints, to RE that were indicated by the respondents. The barriers to grid-extension are further explained below, starting with a combination of factors that make RE particularly challenging for both countries, then moving on to financial problems, lack of private sector involvement, and institutional and organizational barriers.

Electrifying rural areas is a major long-term investment and low national incomes constrain grid-extension RE in many African countries [14]. Lack of capital makes RE dependent on international funding. In both Tanzania and Mozambique, actors perceive RE as being restricted by poverty-related issues such as lack of funds and donor dependency, in combination with rural poverty (weak customer base of households and industry). The role of donors is ambiguous. Several donors drive RE but, according to Hindman Persson (pers. comm.), they are not well-coordinated. This results in Tanzanian REA and TANESCO spending unnecessary amounts of time and effort on meetings and reporting. In Mozambique, the donor recalls how earlier lack of communication between donors led to misunderstandings, but the situation improved with regular donor meetings. There is also skepticism towards the donor push for privatization of the power sector; from the RE perspective this is considered unwise (Consultant B, Ilskog, and Åkesson pers. comm., [9, 39]).

Extending the grid means a very long-term payback period and in comparison to many other developing countries population density in the region is low and settlements are scattered. Transmission over long distances becomes a geographical barrier and results in high costs per connection, as reported by several actors. As the rural economy is rudimentary the majority of households cannot pay the connection cost, which equates to months of income for many households. The same barrier has been identified by, for example, [40] and [1].

Table 2. Identified barriers (B) to successful RE extracted from actor interviews. Tanzania: 1=TANESCO, 2=REA, 3=TaTEDO, 4=Donor, 5=Consultant A. Mozambique: 6=EdM, 7=FUNAE, 8=Donor, 9=Consultant B, 10=Consultant C. Number of interviews per actor: i–iii.

Identified barrier	1	2	3	4	5	6	7	8	9	10
	iii	*ii*	*i*	*i*	*i*	*iii*	*ii*	*i*	*i*	*i*
Weak institutions and organizations										
Low institutional quality				B	B			B		B
Lack of private sector involvement		B		B		B		B		B
Top-down management in energy sector			B	B	B	B			B	
Lack of human capital				B		B		B	B	
Inadequate planning capacity	B			B	B			B		
Lack of co-investments (rural develop.)					B					
Incompatible donor policies		B			B					
Economy and finance										
High costs of diesel	B		B			B	B		B	B
Donor dependency				B	B	B		B	B	
Low productive use and income generation	B					B		B	B	B
Lack of funds	B	B		B	B			B		
Tariff system and connection fees		B		B	B					
Subsidies	B	B		B						
Insufficient rural financial institutions		B		B						
Admin. costs in small off-grid systems									B	
Compensation (in land acquisition)	B									
Lack of consistency between RE projects	B									
Social dimensions										
Poverty and low household affordability	B	B	B	B	B	B				B
Lack of local engagement/capacity		B			B		B			
Change of mind among costumers							B	B	B	
Problems in local participation and theft								B		B

Gender issues			B							
Technical system and local management										
Weak maintenance culture			B		B				B	B
Low generation capacity					B	B		B		B
Low access to required materials	B					B	B			
Lack of access to skilled personnel		B							B	B
Low capacity of solar PV systems					B		B			
Technology diffusion and adaption										
Cultural mindset		B	B			B			B	
Lack of local entrepreneurship					B	B				
Rural infrastructure										
Scattered population	B				B	B	B	B		
Long-distance transmission						B			B	B
Nature reserves and national parks				B	B	B				
Traditional houses (electricity prohibited)				B	B					
Seasonal draughts/cyclones				B					B	
Limited rural infrastructure (roads etc.)					B					

Another problem is that traditional building techniques make the houses unsuitable for electrification according to technical standards. In Tanzania, traditional houses built of mud and grass are not considered for connection. According to Consultant A, this means that only about 10% of the rural population can both afford connection and have houses where electricity can be installed. However, Åkesson (pers. comm.) reports that traditional houses have been electrified in Mozambique, using more secure (and expensive) connections.

The problem for poor potential customers to cover connection fees, or take economic risks in general, is well known but is nonetheless an important barrier [24, 26]. In response, government and donor projects use subsidies and differentiated tariffs with subsidized rates for the lowest users to increase connection rates. Despite the low tariffs, most people cannot afford it, according to interviewed actors. According to Ilskog and Hindman Persson (pers. comm.), those rural customers that currently connect to the grid could also afford higher commercially viable tariffs. Hindman Persson argues that the problem is rather the cash flow, to be solved with suitable payment systems. A gradual increase in tariffs could improve the

financial outlook for the power sectors, but according to Ilskog, raising the tariffs is a politically sensitive issue. Also, there are examples of grid and off-grid projects without subsidies where customers can still afford to pay [29, 41]. The use of differentiated tariffs with reduced fees for the smallest users has another downside as, according to Consultant A, the threshold value keeps the consumption at minimum level.

The use of subsidized tariffs makes power generation rather unattractive for private investment. According to Consultant A, the production cost for grid electricity in Tanzania is almost twice the current tariff (which is politically decided), so distribution is a constant loss and TANESCO cannot cover its operational costs. Subsidies can thus be a double-edged sword [24, 42] working as both driver and barrier. TANESCO staff recall how the subsidized connection costs in donor projects lead rural customers to be obstructive towards other, government funded, projects where they are required to pay full connection cost. There are also complaints over low compensation for loss of property (e.g. farm land) along power lines, because donor-driven projects pay higher compensation than government RE projects.

There are no formal barriers stopping the private sector from entering RE, but at the time of the interviews (2010) most actors argued that they couldn't see why private investors would want to engage in RE, the main reason being the lack of profit – rural areas are of little interest to private investors. However, Hindman Persson (pers. comm.) disagrees, arguing that the private sector will soon play an important role in Tanzania, especially on the generation side. In Mozambique, EdM and Consultant C note that private actors cannot possibly compete with the low prices of hydropower electricity from Cahora Bassa. FUNAE adds that privately generated electricity cannot be sold without permit and there are no incentives for industry to supply nearby communities with electricity. Another Mozambican problem, which historically has affected privately managed grids, is the occurrence of cyclones along the coast. Power infrastructure is easily damaged or destroyed in the strong winds, and investments are thus impeded.

The slow pace of RE is also associated with institutional and organizational barriers, as previously argued by [23, 43-45]. The top-down structure is considered a problem in both countries and by all three external experts. According to Åkesson (pers. comm.), lack of local participation in planning, results in electrification of less suitable areas, and inefficient use of resources. From the perspective of donors and consultants, there are problems at national level, involving low institutional quality (in terms of corruption, in both countries, and inefficient legal frameworks in Mozambique) and organizational barriers such as lack of human capital, and insufficient project coordination and planning. For example, most

respondents consider TANESCO and EdM to have good capacity and staff, but employees are few and the wages are low which, according to Consultant A, results in staff doing side-jobs.

According to Consultant A, most projects in the master plan for distribution in Tanzania are still waiting because of unrealistic time-planning and slow implementation. According to this actor, the problem is an inefficient top-down structure, rather than lack of funds. In fact, only a minor part (14%) of available funds for energy projects in 2008–2009 were disbursed [16]. In Tanzania, the reform process is seen as positive, and according to Hindman Persson (pers. comm.), involved as consultant in the reform process and drafting of the new Electricity Act, the formal institutional frameworks are now basically in place. She considers lack of human capital as the crucial issue. A barrier related to the top-down structure is the lack of intermediate level between the national and local political levels, according to Consultant A and TaTEDO. The strong influence from national level actors makes it hard for small actors to drive electrification, both grid-extension and off-grid.

3.3 Barriers to off-grid electrification

Off-grid systems are regarded as necessary to complement grid-extension, and there are many possible system designs and energy sources. In these countries, off-grid normally means diesel generators and it is the problems with diesel generators that come first to mind when off-grid is mentioned. Diesel systems are very common but all respondents agree that they are inadequately managed and too expensive. The interviews indicate that, to some extent, this has been a barrier to development of other off-grid solutions based on RETs through guilt-by-association. When discussing other off-grid solutions, several economic, social, and technical barriers come out as important, some of which are technology-specific.

Barriers to hydropower are opposition to exploitation of protected areas, seasonal draughts, and the high costs of planning for small hydro. Hydro is also geographically restricted. However, it is still regarded as a good alternative and the technology is appreciated for its high capacity. In Tanzania the potential exploitation of new hydropower resources, including micro-scale, was particularly advocated by Consultant A who also stressed that the gas lobby operates as a barrier to at least large-scale hydropower expansion. Also in Mozambique micro hydropower has gained enthusiastic support from actors. The interest in wind power was low in both countries, with skepticism related to costs and fluctuations. Solar PV is used in both countries and is promoted by, for example, FUNAE, REA, and donors. However, it is referred to as being expensive and unsuitable for productive use due to low

capacity. The same issues have been raised by [19, 21]. Positive attitudes to RETs are expressed more in Tanzania than in Mozambique. The actors' reflections on RETs for productive uses will be further developed in a forthcoming paper.

A challenge for all off-grid projects is, according to REA and in line with previous findings [26, 40], that local people lack enough finance and know-how to initiate projects. REA grants only provide 30% of total investment cost; the rest has to be supplied by the applicant or found elsewhere. REA thus advocates improved incentives for private initiatives. Despite the existence of feed-in tariffs for off-grid electrification [38], additional incentives such as improved banking arrangements are suggested by several actors. The lack of local financial institutions is an important barrier that has also been identified in previous studies from the region [37, 46]. REA also raises the issue of current donor criteria which don't match local capacities, making it hard for rural entrepreneurs to get funding.

Tanzanian Consultant A argues that both grid-extension and off-grid RE are hindered by lack of local entrepreneurship and underdeveloped maintenance culture. Also Consultants B and C in Mozambique regard underdeveloped maintenance culture as a major problem for off-grid systems. EdM and FUNAE staffs report cultural mindsets, lack of commercial initiatives, and weak organizational capacity as barriers at local level. FUNAE reports difficulties in acquiring supplies and spare parts. In addition, rudimentary infrastructure makes communication difficult. TaTEDO's experience is that off-grid projects have problems with costs and bad management, and sometimes traditional thinking and gender issues. But also, many off-grid projects fail after some years, impeding overall reliability. It can be concluded that maintenance issues are major constraints, as previously shown by, for example, [14]. According to TaTEDO, the solution lies in securing good management and income generating productive use of electricity.

4 Main findings

Provision of modern energy services is necessary for socioeconomic development of rural areas in developing countries. In Tanzania and Mozambique, the pace of RE has been slow and the large majority of rural people still lack access to electricity, despite the wide recognition that electricity services substantially improve well-being and development. The pace of RE must speed up. This study addresses factors that drive and hinder RE from the perspective of energy-sector actors in Tanzania and Mozambique. The result largely corresponds to what has been identified by previous studies, but there are also some factors

not previously mentioned, and some not much emphasized before, that come out as important country-specific constraints.

It was found that the main drivers in both countries are political priorities and development policies. The RE strategies are laid out by ministries and government utilities, supported by international donors who push for RE and power sector reforms. Bottom-up demand for electricity services is another driver, although less significant. The countries have chosen different development paths: Tanzania has recently carried out a power sector reform including debundling of Tanesco, establishment of a rural energy agency, and encouragement of the private sector. While the private sector is expected to contribute more to generation, none of the interviewed actors believes that the private sector will engage in grid-extension, which is seen as economically unprofitable. Mozambique has chosen not to encourage private sector investment or to debundle EdM, which is expected to remain the only actor for grid-extension. Regarding off-grid RE, FUNAE is the main actor, but the ongoing process of decentralization, if successful, may empower the districts to take an active part in small-scale off-grid RE for productive uses.

Grid-extension is expected to remain a public sector investment and, for the pace to speed up, the national utilities must improve their RE performance, which might include further attention to off-grid solutions. The results show that both countries experience institutional and organizational weaknesses. The lack of coordination, planning capacity, and enough staff are perceived as important barriers, particularly in Tanzania, where TANESCO has failed to use large amounts of available funding. Overcoming institutional and organizational barriers is a complex matter, and we do not pretend to have the answers. However, attending to the lack of human capital requires proactive and long-term investments in educational systems and organizational capacity building.

In this context, the problems associated with donor dependency, and how this affects budgeting and implementation, come out as important constraints for both countries. This has not yet been discussed in detail in the RE literature. The role of donors is ambiguous in that they push for RE and provide major parts of the budget, but they could spare time and work for domestic actors if they were better synchronized and aligned in terms of standards, reporting, and evaluation systems. Donors could also facilitate civil society actors to apply for donor funding, as suggested by REA.

There is another issue related to donor dependency that comes out as a challenge: the use of subsidies working as both driver and barrier to RE. In Tanzania, donors have used subsidized connection fees, resulting in more connections. Donors also compensate more

generously for property loss. This creates discontent among rural customers in government-funded grid-extension projects, where customers are expected to pay full price, and compensation levels are lower. However, the most appropriate solution is not evident.

There are different opinions about subsidized tariffs, but there appears to be a consensus about the need for and desirability of subsidies for capital investment. The poor rural market is a major barrier, but subsidized tariffs for households are considered counterproductive by some actors, as the better-off minority now connecting can afford higher, commercially viable tariffs. A gradual increase in tariffs would improve the financial viability of RE and the money could be invested in better service and more connections.

RE connection rate would further benefit from taking traditional building techniques as a starting point, instead of regarding it as an obstacle. This is an important barrier, mentioned by Murphy [26] but not previously emphasized. RE projects in rural Africa should apply technical standards that match local reality; with engineering solutions, all buildings could be electrified instead of just a fraction.

From the study, we conclude that there is political recognition that off-grid systems are necessary to complement grid-extension, but the responsible agencies are yet to become fully operational. We see the need for encouraging bottom-up initiatives to complement the top-down implementation. With the off-grid feed-in tariff there is now an opportunity for the private sector and civil society in Tanzania to play a bigger role in RE. Mozambique has had few local initiatives so far, but if the national level supports the districts, they could become actors in off-grid RE.

Currently, dysfunctional diesel generators create skepticism towards off-grid systems. Back-up diesel generators will continue to play a role in the future, but other off-grid solutions are urgently needed. Although full grid coverage is currently seen as the goal, technological developments in other fields, e.g. communication infrastructure, should remind us of the possibility of future decentralized energy infrastructure making full grid coverage unnecessary. Appropriate RETs could contribute to expansion of off-grid RE, but the interest among several actors is halfhearted. Still, interest seems to be growing, and current RET pilot projects might change attitudes if successful. Important barriers to overcome relate to maintenance culture and lack of entrepreneurship. Earlier research has emphasized the need for RE to be integrated with, and complemented by, other investments in infrastructure, social services, local finance institutions, and education [1, 29, 35, 46]. Political and economic incentives for thorough rural development are required. For example, REA and FUNAE could take strategic roles in encouraging and supporting local initiatives and entrepreneurship, and

facilitating the spread of small-scale RETs by building support infrastructure for equipment, maintenance, local technicians, retailers, recycling systems, and educational programs. In a long-term perspective this could provide building blocks for domestic production of some RET systems. Interestingly, the government in Mozambique has now secured loans and launched a tender for a large solar PV factory, scheduled to supply domestic demand [47]. Such development, if successful, may contribute to overcoming the barriers related to access to materials and knowledgeable technicians.

Finally, it should be remembered that RE takes decades to implement even in the wealthiest countries; due to strong political ambitions, donor support, and an accumulating experience among actors, the numbers of customers are increasing fast in both studied countries and EdM is both extending national grid and connecting urban costumers at a high rate.

The social benefits of RE are clear and there is a long-term aspect of importance: with electricity services only in urban areas, the difference between urban people who can access the new technologies and the rural people who cannot, increases. Such a development may induce political tensions and increased income gaps.

The methodological weaknesses of the study are primarily related to time constraints, and a follow-up on sector development over the coming years would improve the credibility of the findings. However, the results have been validated by, and further discussed with, three Swedish experts with in-depth experience of the power sectors. Being the first study to systematically target drivers and barriers as perceived by power sector actors in Mozambique and Tanzania it provides a good base for understanding the challenges for grid-extension and off-grid systems, including the globally wished-for increased use of renewable energy technologies.

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Paper 2

Productive use and private sector in rural electrification of Mozambique and Tanzania

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Under the right conditions rural electrification both provides social benefits and boosts the economy of underprivileged areas of developing countries. During the last century rural electrification was carried out all over the world, with sub-Saharan Africa lagging behind. In economic terms Tanzania and Mozambique are currently among the least developed in the world, and despite substantial efforts they still have rural electrification (RE) levels below 5%. As both countries are developing fast this number has to improve if not enormous gaps between city and countryside, the middle class and the poor are to emerge. Experiences from other countries provide valuable lessons regarding successful and unsuccessful policies, but each country has its own specific conditions to which policy must be adapted. In this study, 16 power sector actors in Tanzania and Mozambique were interviewed on their perspectives regarding productive use, private sector involvement and off-grid solutions in the RE undertakings of their respective countries. The results were then discussed with three Swedish RE researchers. The aim is to reveal how these important matters for successful RE are perceived by policymakers and implementers of RE in respective country, and to contrast actors' perceptions to the experts' views and earlier research.

The findings indicate that the importance of productive use is well understood but not sufficiently targeted in RE projects. There is potential for RE to boost rural production, but lack of rural infrastructure, entrepreneurship skills and access to financial capital, together with underdeveloped rural markets, hinder economic development. The weak rural economy and high investment costs explain the low interest, so far, among private sector actors to engage in RE. There are, however, some signs that this situation may change in Tanzania in the coming years. Tanzania now provides incentives for off-grid power generation, which may attract private sector to invest in renewable energy technologies. Overall, but more pronounced in Tanzania, renewable energy off-grid systems are slowly winning ground as an interesting alternative to grid-extension. There are multiple roles for private sector to play in RE processes. It is suggested that, at this time, it may be more effective to engage private sector on the consumer side of rural electrification than on the supply side. Supporting private actors as productive users of electricity aligns well with what comes out as a prerequisite to successful RE – to integrate RE into other rural development undertakings and to improve cross-sector collaboration.

Keywords: *Rural Electrification, Productive use, Private sector, Off-grid systems, Africa*

1. Introduction

Current lack of access to electric power in rural sub-Saharan Africa hinders socioeconomic development. Where access to electricity is provided, there have been substantial social benefits – related to lighting (Davis 1998, Gustavsson 2007b), education (Ellegård et al. 2004, WB 2008, Daka and Ballet 2011), health (Spalding-Fecher 2005), leisure (Ellegård et al. 2004, WB 2008) and security (WB 2008) – but evidence for enhanced economic development from rural electrification (RE) is weak (Barnes and Binswanger 1986, Foley 1992, WB 2008). To boost RE under the impediments of weak rural markets and a growing global energy crisis is an enormous challenge.

Hindsight assessments of RE strategies and projects have repeatedly concluded that productive use of electricity, i.e. electricity used directly for income-generating activities such as agricultural production, refining of tradable goods and commerce, is an indispensible component for RE to boost economic development in rural areas (Ranganathan 1993, Holland et al. 2001, Peters et al. 2009). Hence, there is a growing awareness that the link between RE and economic development must be reinforced. Where productive uses of electricity are facilitated by complementary services such as improved infrastructure and business assistance, access to electricity may increase business opportunities, ability-to-pay and demand for electricity – eventually leading to structural change of communities (Muldet and Tembe 2008). However, contrary to expectations productive use of electricity is often very limited in RE projects (Wamukonya and Davis 2001, Ilskog and Kjellström 2008, WB 2008, Peters et al. 2009). A review by Brew-Hammond and Kemausuor (2009) concludes that "efforts which succeed in integrating productive uses and income generation activities into energy access initiatives, whether based on conventional fuels or renewable energy, may well turn out to be the deciding factor if the dream of energy for all in sub-Saharan Africa is to become a reality in the foreseeable future" (s 83).

The road to most effective RE in developing countries is not straightforward and this study targets possible improvements of the process in Tanzania and Mozambique. While the opinions of scholars and international actors such as the World Bank are important, the perceptions among those involved in the daily RE work are decisive. It is individual actors who take part in developing and interpreting policies, learn from project outcomes, and carry out the detailed planning and field implementation.

In this study, 16 power sector actors in Tanzania and Mozambique were interviewed on their perspectives regarding productive use, private sector involvement and off-grid solutions in the RE undertakings of their respective countries. The results were then discussed with three Swedish RE researchers with experience of work in the two African countries in order to get additional perspectives and minimize the risk of misinterpretations. The aim is to reveal how these important matters for successful RE are perceived by policymakers and implementers of RE in respective country, and to contrast actors' perceptions to the experts' views and earlier research.

The paper first provides a background on important RE issues along with an introduction to the power sectors of two studied countries. Method and interview results are presented,

followed by a discussion on each covered topic. Lastly, the findings are summarized in a conclusion and some suggestions are given for particular issues of concern.

2: RE history and strategies

Historically, national or private utilities have been the main actors for building electricity infrastructure in generation, transmission and distribution (Hughes 1984). In sub-Saharan Africa, electrification was initiated during colonization but was often limited to main cities and industries. Since independence, the extension of national grids into rural areas has often been slow and in most sub-Saharan African countries, electricity generation and coverage of electric grids are deeply underdeveloped (Karekezi et al. 2004). For any country, providing electric grids in rural areas is a massive and expensive undertaking, and developing countries are therefore dependent on financial assistance from donors and financial institutions, such as the World Bank.

In Tanzania and Mozambique, the power sectors have been controlled by the states, and the private sector has largely been absent. International institutions and donors provide the bulk of funding and are hence very influential with respect to budgets for RE. In the 1980–90s, the World Bank strategy on RE lending shifted from sector support towards promotion of energy sector reforms, with increased focus on economic efficiency and strong emphasis on private sector involvement (Weisser 2004, WB 2008). In short, emphasis on the economic aspects has increased at the cost of the social aspects (equity, public services, 'electricity for all'). The World Bank scheme has been persuasive and most developing countries have now undertaken, or are undertaking, corresponding energy sector reforms. Following suit, Tanzania and Mozambique have introduced energy sector reforms during the last two decades, including commercialization and market liberalization. Although there is no universal answer to the outcome of these reforms the policy has been widely criticized (Karekezi and Kimani 2002, Wamukonya 2003, Karekezi and Kimani 2004, Weisser 2004). In essence, the criticism is related to the low interest of the private sector to getting involved in RE, due to weak rural markets, and the general failure of reforms to provide RE benefits for the poorest. These shortcomings on poverty reduction have correspondingly been recognized in the impact evaluation report published by the World Bank (2008).

Further, the World Bank evaluation report states that future investments in African electric power infrastructure and efficiency have to be massive, and that off-grid (decentralized) solutions may be justified as complements to grid extension in order to ensure the inclusion of remote areas (WB 2008). The report suggests that renewable energy technologies (RETs) should be more involved and that particular support for productive use should be included in the schemes for RE projects. The option of off-grid RE supplied by small-scale RETs is not new to the discussion (Murphy 2001, Brent and Kruger 2009, Kirubi et al. 2009) but may be controversial in economic and efficiency-related terms because such solutions may incur higher costs and reduced power quality in comparison to main grid extension. Despite this, it is suggested that micro-scale RETs are suitable for household needs for electricity and can contribute to higher incomes and small business activities (Chakrabarti and Chakrabarti

2002), and also that providing such services to rural poor people can be profitable for private companies (Bairiganjan et al. 2010).

3. Productive use of electricity

Productive use of electricity takes place over a range of scales. Due to the very limited rural industry in Tanzania and Mozambique, even small- and micro-scale economic activities are significant for the rural economy. There is evidence of RE generating increased income for existing micro-scale businesses, mainly due to lighting and extended working hours but it also creates new business opportunities (WB 2008, Kirubi et al. 2009). Here, productive use at the micro scale refers to household-level business activities, such as charging of mobile phones, TV shows, hairdressers, selling of food and cold drinks. Small- and medium-scale economic activities within agriculture, communication services, manufacturing, fishery and forestry may also benefit from electricity. Some examples are irrigation of cropland (Fan et al. 2000), dehusking/milling, carpentry, repair shops and lighting in dairy and poultry farms (Barnes and Binswanger 1986, Kirubi et al. 2009). Large-scale economic activities that may be found in rural areas are industries such as cotton factories and mines.

The private sector can play multiple roles in RE processes: as producers and/or consumers of electricity and as buyers or providers of electricity-related services. Large-scale industries have functioned as important 'anchoring' consumers for RE, that is large electricity users that establish inter-sectorial linkages and initiate trickling down effects so that RE spurs economic development throughout communities (Mulder and Tembe 2008). However, these large industry and manufacturing need power of high capacity and high quality, but unfortunately, blackouts and power rationing are common phenomena in many developing countries, incurring costs associated with production stops and damage to equipment. Since grid-supplied power is unreliable, own generators are often used as backup, despite connection to the main grid (WB 2008, VPC 2008). On the production side some co-generation industries, like sugar cane plantations, produce electricity through combustion of residual products and may even export excess electricity to the main grid, if connected (Otieno and Awange 2006). Furthermore, in the absence of grid electricity, smaller rural industries, wealthier farms, and workshops may use their own electricity production, relying on expensive diesel generators.

Access to reliable energy services can result in productive use of electricity, as long as there is access to both raw material and markets (Wilkins 2002). Raw material might be provided from the many natural resources of the continent and not least agriculture, which has a great potential in sub-Saharan Africa (Sanchez et al. 2009). But also transport infrastructure is necessary to trade the goods. Adequate financial institutions is another prerequisite that must be available to producers at all levels. Furthermore, electric appliances for refining and in some places irrigation need be locally available. And last but not least, there must be an awareness of the potential of electric power. As concluded by Kankam and Boon (2009) on the evaluation of RE projects in Ghana: "The absence of other rural infrastructure and markets that complement energy use for small and micro enterprises' growth and development tends to negatively impact job creation opportunities" (p 217).

It has often been expected that access to electricity will spur production and lead to industrial development of rural areas, but this has rarely been shown for sub-Saharan Africa. Where national grids have been extended, the productive uses have been mainly micro- and small-scale, while medium-scale activities and creation of employment opportunities have not taken off. One example provided by Åkesson and Nhate (2006), showed that electrification of Ribáuè and Iapala in Mozambique stimulated agriculture and commerce, and increased purchasing power in the district, but generated less employment than expected, and mainly within informal and self-employed commercial activities. Development of productive uses was hindered by lack of local banks, lack of access to credit, tools and machinery, and markets for products. Therefore, just providing electricity to a new location does not necessarily mean that economic development will improve.

As in the case of Ribáuè and Iapala, it has been argued that these shortcomings on productive use in RE may be strongly related to the lack of complementary services (Pearce and Webb 1987, Ranganathan 1993, Holland et al. 2001, Åkesson and Nhate 2006). 'Complementary services', in this respect, is synonymous with co-development of different sectors, and hence is an issue of coordinated activities among a number of actors.

In short, electric power may have the potential to increase profits from local production and may be a prerequisite – but not enough – for economic development in rural areas. Integration with, or at least parallel development of, other sectors and services seems to be an important aspect.

4. Off-grid RE and productive use

Off-grid RE, that is rural electrification based on independent isolated systems, is a complement to national grid extension. From a longer time perspective, off-grid is often regarded as a temporary solution because large interconnected grids with a multitude of supply sources have technical advantages related to power quality, and can utilize the generated energy more effectively (no excess power) (Kaundinya et al. 2009). However, given the current pace of grid extension in countries like Tanzania and Mozambique, many areas are unlikely to gain access to the grid for another 50 years. In this context off-grid systems should be regarded not as temporary solutions but as the only available option for RE in many remote areas. So far, off-grid systems have primarily been based on diesel generators, which carry high costs as a consequence of fuel transport and currently increased fuel prices. Further, diesel-based off-grid systems suffer from frequent power blackouts in many countries, due to insufficient maintenance (WB 2008, VPC 2008) and can be major bottlenecks for rural industrial production (VPC 2008). A given alternative to diesel-based off-grid RE is to utilize RETs.

Geographically dispersed settlements and high abundance of renewable energy resources make RETs a particularly promising option for African RE, although there are challenges to overcome (Bugaje 2006, Brew-Hammond and Kemausuor 2009). Documented outcomes of off-grid systems based on RETs have been both encouraging and disappointing; successful African examples include micro-hydro programmes (Maher et al. 2003, Pigaht and van der Plas 2009), and solar PV projects, which have at least resulted in social benefits (Ellegård et

al. 2004, Bugaje 2006, Gustavsson 2007a, b) and micro-scale productive uses (WB 2008). Although electrification by RET-based off-grid systems is more expensive per connected costumer in comparison to grid extension (Brent and Rogers 2010), it might still be justified in order not to leave remote areas behind in the RE process. Moreover, technical development is making RETs increasingly competitive (WB 2008). Where water streams are available even pico-hydro (<5 kW) systems can be cost-effective (Maher et al. 2003). Being expensive or not, only a minority of rural people can afford connection or a stand-alone-system. For the less affluent majority, access to electricity is possible mainly through public or collective services which generate long-term economic benefits derived from better health and education.

5. RE and power sectors in Tanzania and Mozambique

Accurate figures for RE levels[1] are difficult to derive, and estimates depend on which definition of 'rural' is being used – which rarely is clearly stated when RE numbers are presented. The World Bank (2008) reported RE levels of 1.6% and 1.1% for Tanzania and Mozambique, respectively (data from 2003–2004). A Tanzanian household budget survey from 2007 estimated the RE level to be 2–3% (REA 2011). Electricity access was between 2.2 and 8.2% for a sample of Mozambican provinces (including both towns and countryside) in 2005 (EdM 2007). With RE levels in this order of magnitude and the great majority of the population living in rural areas, both countries are among the least electrified in the world.

5.1 The Tanzanian power sector

Tanzanian power generation is based on hydropower and natural gas (the latter supplied from the private company Songas), with some contributions from agro-industry cogeneration (Otieno and Awange 2006). The off-grid systems are based mostly on diesel generators, although a few RET-based systems have been installed along with a growing number of private solar home systems. Before the energy sector reforms, the public utility Tanesco (Tanzania Electric Supply Company) was responsible for RE. As part of the reform, the power market was opened up and measures were taken to attract private sector involvement. The responsibility for RE then shifted to the Rural Energy Agency (REA, operational in 2007) which is operating under the Ministry of Energy and Minerals (MEM). REA aims to facilitate RE through financial support (up to 30%) of RE projects, to enhance private sector involvement, and to increase the use of RETs. Thus far (2010), however, interest from the private sector has been limited and most funding has entered Tanesco-driven RE projects.

Tanesco carries out RE by following a master plan which prioritizes electrification of district capitals. Both grid extension and off-grid projects are undertaken, although the former alternative is favoured. Along the transmission lines, villages meeting economic development-oriented criteria are electrified. Tanesco tariffs are negotiated through the Energy and Water Utilities Regulatory Authority (EWURA), which also negotiates the price of electricity sold by small private producers to the Tanesco grid, including a recent (2009) feed-in tariff for Tanesco connected off-grid systems that aims to attract private producers in rural areas. The purchase tariff offered to small private producers is based on Tanesco's own costs, using existing diesel generators, and is consequently much higher (about a factor of three) for electricity sold to off-grid systems in comparison to electricity sold to the Tanesco main grid (EWURA 2011a, b). In addition to the undertakings of Tanesco, off-grid RE in Tanzania is carried out by non-governmental organizations (NGOs), churches, and project-funding donors (all of which can access the feed-in tariff in case they sell to Tanesco). The financial contribution from donors to the energy sector is fundamental, and international consultancies play an important role in planning, both at the strategic and the project level.

[1] Proportion of population with direct access to electricity

5.2 The Mozambican power sector

Most of Mozambique's electricity infrastructure was destroyed during the civil war, which ended in 1992. Since then, the public power utility EdM (Electricidade de Moçambique) has undertaken massive grid extensions (Amado 2009). The main power source in Mozambique is the Cahora Bassa hydropower dam situated in the far mid-west part of the country. The almost 2 GW capacity of Cahora Bassa far exceeds domestic demand and much power is exported to neighbouring countries through long-term contracts. There are few other power stations in Mozambique, although there are plans for expansion of hydropower. In addition, substantial coal reserves have been found in the same geographical area as Cahora Bassa (Tete province). As the available power is geographically concentrated, a diversification of power generation locations is sought (EdM 2007).

Although the market was opened to private companies in 1997, as part of the energy sector reform (EdM 2007), the private sector is virtually absent in the power sector, particularly so in RE. EdM focuses on grid-extension and has almost reached the current master plan priority of electrifying all district capitals (some of which are supplied by off-grid systems). The governmental foundation Funae (Fundo de Energia, initiated in 1997), operating under the Ministry of Energy, has the objective of improving access to energy in rural and urban areas, including the promotion of private sector involvement and increased use of RETs (FUNAE 2007). In practice, Funae is responsible for off-grid electrification which is mainly carried out by supplying solar PV systems and diesel generators to remote areas, following directions from central and regional authorities.

Mozambique has few NGOs involved in the power sector but, just as in Tanzania, donors and international consultancies play an important role.

6. Method

On two separate occasions in 2010 and 2011, one or two researchers carried out interviews with energy sector actors in Tanzania and Mozambique. In addition to the interviews, some of the electrification projects that had been referred to by the actors were visited in the field in order to make personal observations.

Three Swedish experts[2] on RE in Tanzania and Mozambique were interviewed in 2011. Before these interviews, the experts read a less detailed draft with preliminary results, which was then referred to and commented upon during interviews. This material was treated as a separate data set.

The interviews held in Tanzania and Mozambique were semi-structured with open-ended questions. This means that the respondents (actors) were asked questions that were predetermined by topic and content but not by precise phrasing, with the option of follow-up questions on relevant matters (Mikkelsen 2005). The questions regarded six topics: RE strategies; which energy loads were considered particularly important for successful outcome of RE; the importance of productive electricity uses; the involvement of the private sector in the RE market; the importance of off-grid solutions for RE; and the opinions on utilizing RETs. RETs were only covered at a generic level, in the sense that general opinions on RET technologies were sought for, but each possible RET was not discussed with each respondent.

Where the interview topics were not familiar to, or within the responsibility of, the interviewed actor, the discussion moved on to the next topic. Most interviews took 50–70 min and were held in English, with the assistance of Portuguese-speaking interpreters when needed.

Interviews were recorded, transcribed and analysed through content analysis methodology (Mikkelsen 2005). In a few cases recordings were substituted by notes. Content analysis provides an iterative process, where content categories are based on predefined themes of interest (deductive analysis), and sub-categories may emerge from the material (inductive analysis).

The interviews held with Swedish RE experts were likewise semi-structured, recorded, and analysed by content analysis. In this article, the discussion relating to importance of productive use of electricity, and the role of the private sector, is presented. As the experts both gave their own views and commented upon views of others, and as they have an outsider's perspective on the RE process, this material is presented under separate headings in the result section.

The interview-based approach made it possible to access the core of RE decision-makers in the two countries, but the method also implies some weaknesses. Although several of the most influential policy-making and implementing actors were included, the study does not cover the opinions of the political top level, banks or private companies other than consultancies and a few firms that were visited in the field. Further, interviews only reflect what the actors found important at a specific point in time, influenced by the interview situation. Also, interpreting between languages and the discomfort of not speaking in one's mother tongue implies that some information and nuances inevitably are lost. To some degree, misinterpretations are prevented by scrutinizing the interview material in an iterative process and by the procedure of involving external experts with country-specific expertise who have read through and commented on the results.

[2] The consulted expert for Mozambique is Gunilla Åkesson, Växjö University, Sweden, who has undertaken several studies of RE projects in Mozambique. The experts on RE in Tanzania are Elisabeth Ilskog, Royal Institute of Technology, Sweden, who wrote her PhD Thesis on RE in the country, and Therése Hindman Persson, Schneider Electric, Sweden who has worked as a consultant during power sector reforms in Tanzania.

6.1. Power sector actors

The interviewed actors were selected on the basis of their professional position, with the ambition to interview representatives from the most important organizations in RE policy-making and implementing (authorities, agencies, utilities, consultancies, donors and NGOs). Sixteen actors within eleven organizations were interviewed (see Table 1).

Table 1. Interviewed actors, organizations and roles in their respective organization.

The table include the following Tanzanian organizations and actors: the Ministry of Energy (MEM); the Tanesco power utility (Tanesco); the Tanzanian rural energy agency (REA); the Energy and Water Utilities Regulatory Authority (EWURA); a foreign donor agency (Donor); a local NGO involved in rural energy (NGO); and a foreign power sector consultancy (Consultancy A). The Mozambican organizations and actors were: Electricidade de Moçambique (EdM); the Mozambican rural energy agency (Funae); and two foreign power sector consultancies (Consultancy B and C).

	Actor	Organization/division	Role in organization	Category
Tanzania	MEM	Ministry	Commissioner	Policy-maker
	Tanesco-A	Power utility: distribution	Manager	Policy-maker
	Tanesco-B	Power utility: distribution	Director	Policy-maker
	Tanesco-C	Power utility: research	Research manager	Policy-maker
	REA	Rural energy agency	Director	Policy-maker
	EWURA	Regulatory authority	Manager	Policy-maker
	NGO	Energy-related development	Manager	Implementer
	Donor	Energy sector support	Program officer	Policy-maker
	Consultancy-A	Power consultancy	Manager	Implementer
Mozambique	EdM-A	Power utility: generation	Director	Implementer
	EdM-B	Power utility: remote province	Director	Policy-maker
	EdM-C	Power utility: remote province	Director	Policy-maker
	EdM-D	Power utility: distribution	Director	Policy-maker
	Funae	Rural energy agency	Manager	Implementer
	Consultancy-B	Power consultancy	Manager	Implementer
	Consultancy-C	Power consultancy	Manager	Implementer

The number of actors exceeds the number of organizations because separate divisions and provincial head offices within large power utilities were considered different actors. Moreover, some actors were represented by more than one respondent during the interview. The authors were assisted by colleagues from the University of Dar es Salaam and the Universidade Eduardo Mondlane in the identification of appropriate actors to be part of the study. The full details of interviewees are undisclosed, to avoid personal exposure. As a brief indicator of professional responsibility, the actors were categorized either as policy-makers (involved in central planning) or implementers (involved in field surveying or detailed planning of implementation). For some actors, the borders between these categories are vague. For example, consultants are employed both to perform detailed planning in field and to develop strategic planning documents.

7. Results

7.1. Views on the role of productive use of electricity in RE

In both countries, the RE strategy is outlined in power distribution master plans which direct rural electrification towards district capitals, and emphasizes potential for productive electricity use as an important selection criterion of where to extend the grid. When asked about the operational RE strategies, that is the actual thinking and doing in RE planning and implementation, all responding actors in Tanzania emphasized economic-growth-related aspects, including the selection of areas with productive use loads. Social – equity-based – aspects of RE were only mentioned by MEM, REA and EWURA – none of them involved in ground-level implementation. In Mozambique, social and economic aspects were equally emphasized as important when planning for grid-extension. The actors who did not emphasize economic-growth-related aspects were those engaged in RE in the most remote areas (EdM-C and Funae). As an illustration of the difference between central and remote Mozambican provinces EdM-A, operating from the capital Maputo, explained:

> What we [EdM] electrify is, for example, a cashew factory or some cotton processing factories ... we visit a district and see the potential, then we prioritize.

while EdM-C, operating from a remote province of the same country, stated that:

> Large consumers are not the main purpose, the village is the priority ... the motivation is to increase quality of life for rural people.

When asked about which loads are most important for successful RE, all Tanzanian actors pointed out productive use loads (see Table 2) as important if RE is to lead to socioeconomic development of the rural areas.

Table 2.

Tanzanian and Mozambican actors' opinions on which loads that are most important for successful outcomes of RE projects. Four types of load were mentioned in interviews. They have been categorized as productive uses, public services, households and village administration.

	Actor	Productive uses [a]	Public services [b]	Households	Village administration
Tanzania	MEM	●			
	Tanesco-A	●			
	Tanesco-B	●			
	Tanesco-C	●		●	
	REA	●		●	
	EWURA [c]	-	-	-	-
	NGO	●			
	Donor	●			
	Consultancy-A	●			
Mozambique	EdM-A	●	●		●
	EdM-B	●			
	EdM-C		●		
	EdM-D	●			
	Funae	●	●		●
	Consultancy-B	●			
	Consultancy-C	●	●		●

[a] industries, mills, irrigation, manufacturing, fish markets, business and tourism
[b] health centres, schools, public lighting and wells
[c] the interview did not cover the topic

Other than productive use, loads were only mentioned by two Tanzanian actors (Tanesco-C and REA). This should not be interpreted as if other loads are not valued – after all, RE undertakings strive to connect communities, but doubtless the incorporation of productive use loads is considered particularly important for success. As framed by REA:

> [What is important is] first and foremost the load for productive use, since we know that productive use is the most important component that can provide [higher] standard of living for the rural people. The livelihood of rural people cannot be increased by only using electricity for lighting ... So, first and foremost, [electricity] for productive use, and secondly also for households.

The perceptions on most important loads were more diverse in Mozambique. Most actors mentioned productive uses, but public services and administrative buildings were given more importance than in Tanzania. The attention to both productive use and social aspects can be exemplified by EdM-B:

> The purpose is to connect [households], but EdM also need to sell electricity so we look for industries, mills and production. But the main purpose is the people and not to find industries.

EdM-C, responsible for RE in one of the most remote Mozambican provinces, did not mention productive use among the most important loads for successful RE. The interviewee explained that although large industry would be prioritized, most productive use of electricity is too small to make a difference for the economy (of the power utility) and is hence not considered particularly important.

Rural industry was perceived as very rare or virtually absent by all interviewed actors in both countries, but small-scale agro-processing and manufacturing workshops were considered fairly common. Since transmission, substations and even distribution lines are costly, small-scale production cannot motivate grid extension from the financial perspective of a power utility (Mulder and Tembe 2008). This may lead to discouragement of small electricity-dependent production units situated outside towns. One example is a Mozambican farmer that was visited in the area of EdM-C's responsibility. The farm relied on electricity for freezers and the property was a few hundred metres from the distribution line, but the entity was denied connection unless the farmer covered the full cost himself. Instead, the farmer continued to run his business on an autonomous and self-constructed producer gas system.

Grain mills and small-scale businesses may have substantial impact on the local economy in a rural context where most people are without access to electricity. Electrification of these small production units was understood as important by several actors. For example, Funae who is implementing remote area RE based on diesel generators and solar PV systems underscored the importance of small-scale productive use in RE and remarked that the low capacity of PV does little for productive use loads:

> What needs to be known is that, what is very important to us is productive use, and solar PV has a big limitation; that is the big problem.

It can be concluded that productive use is considered important among most actors. Results also indicate that social aspects are more explicitly associated with successful RE projects among Mozambican actors. Moreover, an important note is that some actors were of the opinion that access to electricity is a strong catalyst to development: if electricity is provided, development will improve. Tanzanian MEM explained:

> I believe that there are many entrepreneurs in the rural areas, but they cannot do anything without power. They cannot have milling machines, only a few can afford diesel generators. You cannot have lumber workshops and such things if you don't have electricity. So, I want to look beyond what is on the ground when I provide power ... for a long time we have looked at electricity as a luxury, but no, it is a necessity for development.

Mozambican EdM-A recalled a conversation with the African Development Bank:

> They said 'no we cannot bring electricity to this place, there is no demand'. I said, 'no, the demand is already there, if you bring electricity then you will see what will happen, they will buy lamps, fridges, they will improve.'

What was most enthusiastically depicted was the 'large potential for agricultural production' in not-yet-electrified areas, to be boosted into growth once electricity is provided. However, not all actors are as positive about the prospects for RE to result in economic development.

7.2. Factors hindering productive use of electricity

In interviews, a number of factors come out as currently hindering productive uses of electricity and economic development in areas where electricity is provided. The visits to various RE projects and production units in both countries, made it clear that there is a general lack of markets for agricultural products. For example, farmers may all grow the same crops at the same time without having efficient procedures for export. This creates marketing problems for consumer products, which seasonally flood the local market and lower the prices. This problem, which is believed to be generic for the region, is related to lack of market infrastructure and co-development.

The Mozambican actors EdM-A and Funae mentioned the importance of complementary services in arguing that provision of electric appliances or micro-finance institutions are important supplements to RE – although it is only occasionally provided in practice. The Tanzanian Consultancy-A argued that the lack of complementary services and particularly lack of cross-sectorial planning is a major impediment to economic development. The Tanzanian NGO reported that it strives to integrate energy with other development issues in order to engage local politicians and officials in energy projects. All four actors who raised the issue of complementary services are implementers of RE, with long experience of working in the field. When policy-making actors were asked about complementary services as a follow-up question, Tanzanian MEM established that there is little coordination between the endeavours of different sectors:

> No, everyone is running on his own. It [co-development] is a good idea but at the moment there is no coordination.

The regulatory authority EWURA confirmed that there is currently a lack of coordination between Ministries and rural development actors, but noted that there have been discussions with REA regarding extending the agency's responsibility from RE to a more comprehensive rural planning. Reference was made to Zimbabwe, where financial assistance for small-scale investments is offered to new rural electricity consumers. In Mozambique, EdM-D (director of power distribution) referred to the coordination of rural development projects controlled by a governmental cabinet. It was explained that all external funding received by Mozambique

has to pass through the cabinet, which directs the resources and strives to coordinate projects on infrastructure, agriculture, water, health, communication and electrification. This indicates that there is coordination at higher level although this was never mentioned by the interviewed actors working at lower levels.

7.2.1 External experts' reflections on productive use in RE

According to Ilskog, not enough attention has been given to what happens after electricity is introduced. As opposed to the experience of some of the actors she argues that just electrifying an area does not produce much development. There is generally some development of micro- and small-scale businesses, but the level of productive use is very low, and for the poor majority there is little change. For development to take off there should be investments to enhance productive uses, market development and generation of local employment. Donors need to look beyond their connection targets, and take responsibility for what happens after implementation. With reference to the economic and social depression that took place in Zanzibar during to the blackouts in recent years (Ilskog 2011), she thinks that actors need to handle the economic vulnerability that comes with dependency on stable electricity supply. The transition to a rural economy based on electricity-dependent activities must also include developing proper back-up systems, or the cost of blackouts can be detrimental.

Hindman Persson also emphasizes the importance of stable electricity supply. For RE to result in economic growth, the industries must be given access to high quality supply. Unreliable supply is devastating for any industry. Hindman Persson argues that access to electricity quickly increases micro- and small-scale business activities and income for their owners. But actors should be more open to various models for delivering the same service (electricity), both in terms of ownership and management arrangements, models that could vary between communities and regions.

Based on her work in Mozambique (Åkesson and Nhate 2006), Åkesson concludes that RE has positive effects on local incomes and business, but also that people use electricity mostly for basic household needs. She stresses the need for integrated development initiatives, so as to achieve positive synergies and maximize the benefits from RE. Grid-extension projects could integrate off-grid solutions and modern cooking technologies, and should be coordinated with other sectors right from the planning stage.

7.3 Views on private sector involvement in RE

The private sector not only uses electricity but may also plays a role in contributing to RE by engaging in generation, transmission or distribution. The energy sector reforms have made all levels of the power market legally available for the private sector in both Tanzania and Mozambique. But general criticism among scholars has warned of low interest by the private sector in taking any responsibility for RE (Wamukonya 2003, Karekezi and Kimani 2004, Haanyika 2008). Regarding the actors' views on private sector involvement the result comes out different for the two countries (see Table 3).

Table 3. Tanzanian and Mozambican actors' reflections on private sector (PS) involvement in RE (power generation, transmission and distribution). Actors also give examples of private sector involvement.

	Actor	Private sector (PS) involvement	Examples
Tanzania	MEM	PS is encouraged; PS has large potential; PS involvement is low	Songas and a few cogenerating industries and small private producers
	Tanesco-A	PS is involved; PS has large potential	Cogenerating industries sell to main grid, or by using own grids
	Tanesco-B	PS is involved	Songas and cogenerating industries sell to main grid
	Tanesco-C	PS is encouraged; cogeneration is a research focus area	Cogenerating industries sell to main grid, small private producers sell to neighbours
	REA	PS is encouraged; PS has large potential	Cogenerating industries sell to main grid, the church provides some distribution
	EWURA	PS is encouraged; PS involvement is low; PS interest is low	Songas and a few small private producers
	NGO [a]	—	—
	Donor	PS is encouraged; PS involvement is low	A few private producers and churches
	Consultancy-A	PS interest is low; competition with the gas industry is not encouraged	
Mozambique	EdM-A	PS involvement is low; there is no incentive for PS	A few cogenerating industries sell to neighbouring villages
	EdM-B	PS involvement is low	
	EdM-C	PS involvement is low	A gas company and a coal mine sell electricity, but not in our province
	EdM-D	PS involvement is low	
	Funae	PS involvement is low; there is no incentive for PS	
	Consultancy-B	PS involvement is low; there is no incentive for PS	Few cogenerating industries; gas and railway companies have not succeeded
	Consultancy-C	PS involvement is low; there is no incentive for PS	Cogenerating industries sell during excess periods

[a] the interview did not cover the topic

In Tanzania, measures have been taken to encourage private sector involvement; REA has been created and a feed-in tariff for small private producers in off-grid systems has been established by EWURA (EWURA 2011b). Several actors found that the private sector was encouraged to get involved in generation and RE. MEM, Tanesco-A and REA all stated that there is a large potential for private sector contributions, particularly in power generation. In addition to the large natural gas company, Songas, which is an important power supplier at national level, cogenerating agro-industries were the most common examples mentioned among private sector actors. These industries produce electricity to supply their own needs in production, and sell surplus electricity or heat to nearby communities. Small private producers and civil society actors such as churches, which are running micro-hydro generators and distribute power through own mini-grids, were also mentioned. These producers mainly focus on collective social services and households. No Tanzanian actor, however, perceived the private sector to hitherto have played an important role for RE. EWURA noted that the financial institutions' low interest in the energy sector is an important factor that inhibits small private investors:

> Most financial institutions don't have good experience from the energy sector; they don't even show up when invited to meetings; it is not their interest.

To solve this problem, MEM and the World Bank have recently allocated credits of USD 23 million to facilitate loans to small private producers in Tanzania.

Regarding power distribution, Consultancy-A mentioned several barriers to private sector involvement, including unviable RE markets (distribution), low experience of entrepreneurship among local actors and unreliable tariffs due to political involvement. Consultancy-A:

> The only interest private investors may have is generation, not distribution. There is no one who can run distribution; it has been tried out [but it failed], it is impossible. And no one is interested in rural electrification on private basis; it can never be viable.

The Tanzanian Donor acknowledged the importance of both subsidizing government-led RE and making credits available for private RE incentives. However, Consultancy-A noted that the donors' policies do not allow for supporting the private sector, and that donors hence cannot contribute to the wished-for development in this aspect.

Also, Mozambican actors considered private sector involvement to be very limited at the moment and, in contrast to Tanzania, there was no belief that the private sector will become important for RE. It was explained that the low interest in private involvement in the power sector is strongly associated with the very low tariffs resulting from inexpensive large-scale hydropower generation. This phenomenon, where inexpensive hydropower inhibits the private sector from being involved in electrification, was referred to as the 'Cahora Bassa effect'.

Inexpensive hydropower seems to be one strong reason for the virtual monopoly of EdM, another reason being the low ability to pay in rural areas. The Mozambican power sector has been commercialized but the government has declined World Bank proposals for a horizontal restructuring of EdM and improved incentives for private sector, arguing that such policies have not shown successful in other parts of Africa (WB 2007). Consultancy-C explained his views on the issue:

> Only the capital, and possibly some other bigger cities, may be of interest [for private sector involvement]. The energy sector reform came 50 years too early, commercialization is unwise since it is so expensive to build infrastructure.

But could there still be a role to play for private generation in off-grid RE? Mozambican actors explained that experience has shown how higher tariffs used in private off-grid systems have been difficult to defend among customers because the price difference compared to main grid tariffs becomes too large (even where main grid access is far from available). In addition, there is long-term insecurity as prices will be immediately dumped if the main grid should be extended to the area. Obviously, private generation in areas close to main grid becomes very risky.

In summary, even though Tanzania has encouraged private sector involvement in RE and the expectations on the private sector are much higher among interviewed actors in this country, it was fully agreed among interviewed actors in both countries that the private sector is currently not much involved in RE as other than potential consumers and self-supplying producers.

7.2.1 External experts' reflections on private sector involvement in RE

Both Åkesson and Ilskog are sceptical of the donor-driven trend of privatization in RE, arguing that large-scale commercialized RE would require much higher tariffs than rural customers could afford – to build electricity infrastructure is an incredibly costly long-term investment and private sector engagement cannot be expected within the foreseeable future. Ilskog believes that private sector would possibly engage more in power generation if the state would secure purchase tariffs through long-term contracts. Also, small-scale systems require less capital investment, and private actors could engage in providing off-grid RE. Positive examples are found in Zambia, where private companies lease solar home systems to households. Based on her own studies, Ilskog concludes that private sector actors are more efficient than government utilities when it comes to connecting new customers and adapting to local needs. However, small private companies driven by individual entrepreneurs are particularly vulnerable to external circumstances.

Hindman Persson has a more enthusiastic opinion of the role of the private sector in RE. She disagrees with the general view that the private sector is unable or unwilling to play a role in RE. She considers commercialized RE fully possible and that it is already taking place. She argues that in Tanzania, the main constraints and uncertainties have been removed with the new electricity act and the feed-in tariff. Before that, the slow negotiation of power purchase

agreements was the main barrier which stopped many small projects. This situation has now improved. She sees good opportunities for private actors to engage in small- and medium-scale RE projects, particularly in off-grid projects. The slow process of tender is a barrier that still remains, and much would be gained if it could it be simplified. For large-scale projects, there are international investors with interest in African markets and natural resources.

A reason why RE has been so costly in Tanzania is the subsidized tariffs, which are even below the cost of power production. Hindman Persson believes that cost-reflective tariffs are necessary and will open for more private sector engagement. Still, the prevailing expectations of short pay-back periods for private investments are not realistic considering the size of investment and long life-time of large electric power systems.

7.4. Views on off-grid electrification

The role of off-grid systems in providing electricity access in rural areas was discussed during interviews. Among interviewed actors, the Tanzanian NGO and Funae in Mozambique are implementing small- and micro-scale off-grid solutions, particularly solar lanterns, solar home systems and diesel generators. In Tanzania, churches have been active in installing micro- and small-scale hydropower plants, and the NGO mentioned a few small wind-power projects. It was also reported that mines, cogenerating industries, and a railroad company have undertaken off-grid RE at a few locations. Among Tanzanian actors off-grid RE was considered important by the NGO, and by MEM and REA, who all have more or less of a responsibility of promoting off-grid. The Tanesco actors simply regarded off-grid as a costly but necessary part of RE without giving the issue much reflection. The Donor and Consultancy-A associated off-grid RE with complications concerning organizational capacity and low ability to pay.

Also the Mozambican consultancies regarded off-grid electrification as a rather peripheral part of RE, although Consultancy-B saw benefits of letting rural people get used to electricity, prior to getting connected to the main grid. EdM-B and EdM-C, who are responsible for electrification in remote provinces of Mozambique, regarded off-grid RE as necessary for reaching out to rural communities – but they both declared that off-grid is the responsibility of Funae. Their main experience of off-grid comes from situations where EdM has had to take over existing, but not well functioning, off-grid generators from district-level actors and Funae. EdM-D, who has an overarching responsibility for RE in Mozambique, clearly stated that off-grid is the wrong way of using available resources. EdM-D showed little interest in remote area electrification on the whole, and argued that few people live under conditions where off-grid can be justified. Contrary to that, EdM-A, with long experience of implementing RE, was rather enthusiastic about the potential for off-grid solutions:

> There is one thing that has fascinated me: off-grid electrification … You can do it with mini- and micro-hydro, I think this is the future for Mozambique, we have a lot of rivers.

The opinion that off-grid should be based on RETs to be successful was repeated by several actors in both countries. When deductively analysing the actors' reflections on diesel

generators, it was found that none had referred to these systems in positive terms (although it was often understood as necessary); most actors brought up diesel generators as a problem. The mentioned setbacks with diesel were high running costs and difficulties with maintenance of large generators. EdM-A explained how diesel-based off-grid generation is far too expensive for economic viability. EdM-D simply declared:

> I don't want to listen to diesel more in my life.

Although RET-based off-grid was clearly preferred among actors, the actual trust in RET systems other than mini/micro-hydro was not very high. Almost all actors regarded hydropower as having high or very high potential and as being suitable for productive use. Also, solar PV was considered valuable, but several actors also associated solar PV with high costs and restricted usefulness as it can hardly support productive use beyond the micro level; use of machinery requires a higher capacity factor than provided by small-scale solar PV systems. Larger installations are currently rarely considered in this context, due to its capital cost. This has also been noted in previous studies (Holland et al. 2001, Jacobson 2007). Wind power was regarded with scepticism in Mozambique but more positively so in Tanzania, which may be related to current plans for a large wind power plant in central parts of the country (Ng'wanakilala 2010). Overall, the Tanzanian actors appeared more open-minded to RETs than the Mozambicans.

In summary, off-grid RE is considered problematic as it is often based on diesel generators, which are expensive and sometimes hard to maintain. Tanzanian actors seems to acknowledge the necessity of off-grid RE to a higher level than their Mozambican colleagues, and the potential of RET is recognized. Partly, this may be due to the successful use of RET-based off-grid systems initiated by several churches. Both off-grid and RET are less familiar and less appreciated among Mozambican actors, and the issue is in practice handed over to Funae alone. In both countries, however, there are actors who advocate an increased use of RETs and particularly small-scale hydro.

7.3.1 External experts' reflections on off-grid electrification

According to all three experts, off-grid solutions are necessary if RE is to be completed within the foreseeable future – a wide range of solutions are needed. Based on her experience, Ilskog thinks off-grid RE can be economically viable in terms of running costs. What is important is to make sure always to have people who can manage the systems properly, as corruption and mismanagement are common problems. Hindman Persson notes that there are many examples of off-grid projects in African countries that are viable, although some initial support may be necessary. Åkesson regards maintenance and access to financial capital for local actors as the most important issues for off-grid. Currently, Mozambican banks are not interested in supporting entrepreneurs to engage in small-scale RE.

8. Discussion

8.1 Boosting rural production by co-development

The overarching RE strategy is similar in both countries, including electrification of district capitals and using economic development or production units as selection criteria for connection of villages along the power lines. During interviews, Mozambican actors stressed social and economic aspects equally, which may indicate a difference between countries, as Tanzanian actors showed a strong focus on economic potential in their operational strategies. However, the difference may also reflect the poverty in the Mozambican rural districts.

The actors reported a high potential for increased agricultural production and manufacturing in both countries, but also described a poor rural market with very few industries. The results do not support the previous suggestion made by Mulder and Tembe (2008), that larger rural industries – securing high power consumption, increasing production and creation of jobs – are generically available 'anchors' for RE in the investigated countries. Instead, it is most probably the small-scale rural production that has the development potential. For electricity to be used in production, and for the utility to secure that their service becomes integrated into the local economy, it is the small productive activities that should be connected. This is in line with the growing anticipation of small-scale agricultural production as the vehicle for the 'African Green Revolution', as opposed to large farms (Sanchez et al. 2009). If you provide smallholders' agriculture, fisheries and forestry with the means of refining their goods, the local economy will likely improve.

Such small-scale productive activities were considered very important among the actors, particularly so in Tanzania. The benefits of incorporating small production units in RE strategies have been stressed before (Barnes and Binswanger 1986, Holland et al. 2001, Brew-Hammond and Kemausuor 2009). However, for this rural production to blossom, and to spur economic development, complementary services and coordination between different segments of rural development are very important (Pearce and Webb 1987, Ranganathan 1993, Holland et al. 2001, Kankam and Boon 2009). Although this importance of complementary services has also been shown for neighbouring Kenya (Kirubi et al. 2009) and might be no news to the actors involved, the two studied countries need improvements. Micro-credits are rarely available, and particularly Tanzanian actors noted that lack of coordination between sectors is problematic. The importance of complementary services is emphasized in the Mozambican "low-cost rural electrification plan" (EdM 2007), but still the issue received little attention among interviewed actors.

It is concluded that RE strategies would likely benefit from really implementing the broader rural development perspective. That is, co-development across sectors including development of micro-finance institutions, progressive agriculture policies and infrastructure for transport and communication.

8.2 Contributions from the private sector

In Tanzania, the main responsibility for promoting RE has been moved from the public utility Tanesco to the agency REA. In its role as facilitator, REA does not carry out RE projects itself but strives to attract other actors to engage, mainly through financial support. However,

in the absence of private investors most support has hitherto gone to Tanesco. Previous research indicates that there is sufficient local technical and managerial capability for independent power producers and distributors to develop in Tanzania, and that the lack of appropriate local financial institutions has been the major constraining factor (Marandu 2002). As was pointed out, with the improved conditions provided by REA (investment subsidies) and EWURA (off-grid feed-in tariffs) both civil society and private power producers are now expected to engage in off-grid RE. However, interviewed actors described a situation where local investors lack financial and organizational capacity to start projects, and larger investors have little interest in the rural energy market, because of low expectations on profits and limited experience of power sector businesses. Haanyika (2008) described a similar dilemma from Zambia, where the opening of power sector to private companies and efforts to attract private sector involvement in RE produced little response and left the public utility to do all the work, just as before the reform. In Mozambique, the private sector is virtually absent from the power sector according to the actors, partly as a consequence of the 'Cahora Bassa effect' with very inexpensive large-scale hydropower and partly due to lack of promotion by the government. The Mozambican government has been intentionally careful as it has postponed the World Bank suggestions on seeking private participation in the state-owned utility EdM (WB 2007). As noted by Wamukonya (2003), it may not be effective to rely on private sector investments at this early stage of electrification in general and RE in particular. There are other sectors where private investors may have quicker returns.

When considering private sector involvement, one must differentiate between project types (main grid or off-grid), scales of activity (large, medium, small or micro-scale) and the separate roles of power producer and consumer. In Tanzania, the gas industry and cogenerating agro-industry provides some large-scale generation (Otieno and Awange 2006). The potential for increasing the contributions from cogeneration, where the company is both supplier and consumer, has previously been stressed by Barnes (2007). Expansion of cogeneration is a valuable opportunity for both countries because both agriculture and forestry have development potential. It can be worthwhile to consider co-generation plants as possible local development hubs, provided that they have the capacity to generate and sell surplus electricity. At small and medium scale, the private sector can be encouraged in its role as a productive electricity consumer, and in delivering technical services to small and micro-scale users of electric appliances. On the micro-scale, households in remote areas may play an important role in using RETs to generate their own electricity and selling its services (Gustavsson 2007b, Svensson and Farina 2010).

When considering how the private sector, other than large-scale, can contribute to RE in poor areas, it seems that actors have primarily focused on the supply side. We suggest that it is rather in its role as a consumer that private sector can transfers supplied electricity into economic growth and increased purchasing power. For such development to take place, from our perspective, RE projects need to be extended beyond the implementation stage and include measures to enhance local actors' abilities to productively make use of electricity. This requires integration between ministries and areas of development, and specific measures to target different actors and productive activities at every scale. Moreover, supplied power has to be of good quality if it is to be used in production (WB 2008, VPC 2008).

8.3 Powering off-grid systems with renewable energy

Rural populations are scattered, and off-grid RE is the only option if many small communities are to gain access to electricity in a nearby future. This even includes villages in the vicinity of transmission lines because substations are expensive. Among the interviewed actors, off-grid RE is a recognized part of remote area electrification in both countries, used in order to fulfil the strategy of electrifying district capitals. But current use of diesel-based off-grid systems was clearly regarded as problematic among actors, and Funae and REA are now promoting alternatives based on RETs.

RET-based off-grid systems were enthusiastically promoted by some actors while others were sceptical. Policy-making actors in Tanzania expressed great expectations on these systems as a means of combating the low RE levels. By contrast, the most influential actor in Mozambique, EdM-D, was also the most sceptical.

Throughout discussions with the actors, small/micro-scale hydropower was seen as the most well-favoured of RETs. This technology is old and well-known, and the power output is predictable. Experiences from neighbouring Kenya show that even pico-hydro systems with capacity of only a few kW can be cost-effective (Maher et al. 2003). Yet almost none of the many small rivers and streams in Mozambique have been utilized so far. In Tanzania, the technology is sporadically used by some churches. Interestingly, these church initiatives were referred to by several of the interviewed actors, despite their being very small and insignificant from a national perspective. Even though these systems are rarely fully independent (they have received support from international donors), the enthusiasm among RE actors indicates that such off-grid initiatives are warmly welcomed.

Many actors also regarded solar PV as a technology of high potential, but its limitations in respect to productive use, other than at household-level, were remarked. It should be noted though, that solar PV systems in the range of 1–25 kW have been shown to successfully increase rural production and development in other parts of the world (Chakrabarti and Chakrabarti 2002).

In Tanzania the economic incentives for off-grid systems are now substantial. Electricity that is sold to Tanesco's off-grid systems is purchased at a fixed price calculated on the cost of the alternative energy source, which is diesel. Hence the purchase price is about three times as high as electricity sold to Tanesco's main grid, based on hydropower and gas (EWURA 2011a, b). This way, RETs stand a chance of becoming an economically competitive alternative in rural areas of Tanzania. As this feed-in incentive is new, evaluation will have to wait.

The results indicate a stronger belief in RET-based off-grid systems in Tanzania than in Mozambique, which is likely related to the 'Cahora Bassa effect'. Nonetheless, the undertakings of Funae are growing, and a solar PV factory for domestic supply of the technology is under establishment (AEA 2011).

9. Conclusions

This study is based on interviews with power sector actors in two of the poorest countries in the world – Tanzania and Mozambique. Three themes were addressed, the importance of productive use of electricity, private sector involvement in RE, and off-grid solutions in the RE undertakings of their respective countries. The results were then discussed with three Swedish RE researchers. The aim is to reveal how these important matters for successful RE are perceived by policymakers and implementers of RE in respective country, and to contrast actors' perceptions to the experts' views and earlier research.

Productive use of electricity is understood as highly important, but is not straightforwardly encouraged due to the poor rural markets and limited coordination between electrification strategies and other rural development. Some actors ask for a stronger focus in RE projects on the development of economic activities, such as small-scale agriculture. In contrast to Mozambique, Tanzania has taken measures to get the private sector involved in the power sector and RE – but actors in both countries perceive the private sector to be little involved at the moment, and there is a risk of putting unrealistic faith in getting help from the private sector. The interest from private investors to be involved in RE is low due to poor markets, low tariffs and difficulties of getting funding from banks. Recent subsidies and feed-in tariffs for off-grid generation in Tanzania may, however, result in more private actors engaging in power generation.

It is suggested by the authors that more attention should be given to the private sector in its role as productive electricity consumer and provider of energy-related services. Investments can be directed towards productive electricity use in rural agriculture and suchlike; both (i) by supplying the means for increased production and refining among smallholders and (ii) by investments in large-scale units such as processing factories, particularly those that can provide electricity by co-generation. Increasing the economic return on power infrastructure investments will increase the political incentives for further RE developments.

Furthermore, the study shows that almost all actors have a negative experience of diesel generators – which is liable to develop into a negative opinion of off-grid electrification in general. However, some actors are enthusiastic about the opportunities of off-grid systems based on renewable energy, more so in Tanzania than in Mozambique. Solar PV is appreciated for its benefits at household level, but not seen as a good alternative for productive uses requiring higher output. Hydropower is the preferred option among renewable energy technologies, as it is well-known and can be used productively.

In conclusion, the study indicates that policy-makers and donors should give increased attention to co-development oriented RE strategies, support private sector actors in their multiple roles in RE, as producers, consumers and service deliverers, without relying too much on private sector investments in RE. The study also indicates support for better utilizing the potential of small-scale RETs for off-grid systems in remote regions.

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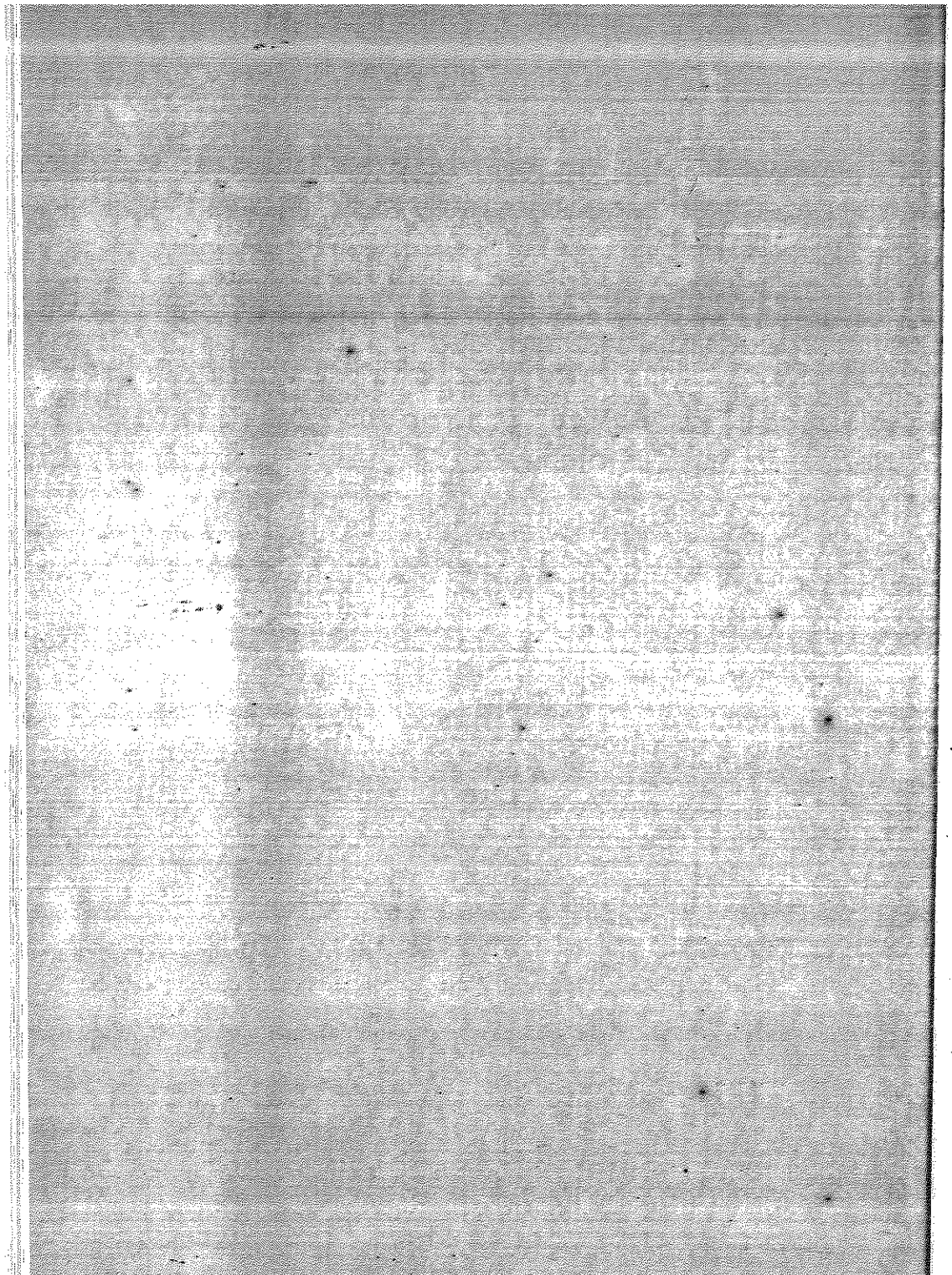
Paper 3



Mismatch between scales of knowledge in Nepalese forestry – epistemology, power and policy implications

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The importance of scale dynamics and scale mismatches for outcomes of natural resource management has been widely discussed. In this article we argue that the choice of observational scale, i.e. the temporal, spatial or quantitative dimensions used by scientists to measure and study the world, has policy implications and is part of how power is exercised in natural resource management. We reveal how there are multiple positions within local knowledge systems and how these positions emerge through people's use of and relations to the forest, animated by a dynamic interaction between the natural environment and power relations such as gender, literacy and caste. The Nepalese case is a concrete example of how power and scales of knowledge are being coproduced in community forestry, at the interface of material and symbolic practices in use of forest resources, and in contestations of social-political relations based on work, gender, caste and literacy skills. Further, the article reflects upon the epistemological approach, the use of mixed methods and multiple observational scales. We present a methodological approach using triangulation for divergence, enabling researchers and practitioners involved in natural resource management to explore the gaps and silences between data sets.

1. Introduction

The need to tackle global challenges at the society-environment interface has brought with it concerns over the complex interface between ecological, social and political processes across various temporal and spatial scales. (Cash et al. 2006, Cumming et al. 2006, Termeer et al. 2010). Yet scale is not simply a problem of resolution or extent. Rather, a fundamental problem for natural resource management (NRM) is that the resource in question can be understood differently depending on the temporal and spatial scales of observation. The choice of scale mirrors the knowledge culture and priorities of the observer, it influences what can be seen and the conclusions made, and therefore scale itself requires scrutiny (Gibson et

al. 2000, Cumming et al. 2006, O'Flaherty et al. 2008, Rangan and Kull 2009). In this paper we argue that the choice of observational scale, i.e. the temporal, spatial or quantitative dimensions used by scientists to measure and study the world, has policy implications and is part of how power is exercised in natural resource management. In the following case study, we illustrate the ways that different temporal and spatial scales of knowledge become part of the emergence of power and ecological change in the social-ecological systems of Nepalese forestry. We reveal how there are multiple positions within local knowledge systems and how these positions emerge through people's use of and relations to the forest, animated by a dynamic interaction between the natural environment and power relations such as gender, literacy and caste.

This article thus aims to interrogate: (1) the problem of cross-scale processes and scale mismatch, taking the case of forestry and (2) the limits of observation and interpretation, framed as a discussion about knowledge scales and scale of observation. Knowledge scales/scales of knowledge we define as the temporal and spatial extent and character of knowledge held by individuals and collectives. We do so through a case study of community forestry in Nepal, illustrating how actors' understanding of the forest is based on: a.) different needs, interests and values, and also b.) knowledge derived from different temporal and spatial scales. As a result, actors interpret both the forest and the rationale of forest management through specific, and often conflicting, frames. We argue that disparate scales of knowledge are an important 'scale mismatch', which together with scale politics, lead to conflicts in Nepalese forest management. We demonstrate how such mismatches can be illuminated through the use of mixed methods that both a.) employ multiple observational scales and b.) allow triangulation for divergence, that can reveal the silences and gaps between data sets and give equal weight to different knowledge systems.

Our discussion of scale concepts takes place in the context of society-nature interactions, or social-ecological systems (SES) and in relation to the management of natural resources. Forestry in Nepal is home to scale mismatches between social, ecological and political processes. But it is also an arena for conflicts between and within different knowledge systems, with important implications for policy. To support our argument, we critically review different conceptualizations of scale, cross-scale processes and scale mismatch, and then engage an epistemological dimension – the mismatch between scales of knowledge. A focus on scales of knowledge helps us understand conflicts between actors in Nepalese

forestry. This is the realm where scientific and local knowledge systems meet on unequal footing. As many scholars are well aware, the choice of observational scale is not neutral. The political implications of scale choices have led to use of multi-scale assessments, to increase the credibility and relevance of findings. Building on these discussions, we present a methodological approach to triangulation that helps to explore mismatch between scales of knowledge in the Nepalese case.

2. Cross-scale dynamics and forestry

Scale has been conceptualized in many disciplines (e.g. Peterson and Parker 1998, Gibson et al. 2000, Manson 2008, Rangan and Kull 2009, Termeer et al. 2010), and has long been considered a fundamental problem in ecological science. Understanding processes that occur on different scales of space, time, and organizational complexity, is crucial both in theoretical and applied ecology (Levin 1992). O'Neill and King (1998) define scale as physical dimensions of observed entities and phenomena (see also Reid et al. 2006), which is usually recorded as a quantity (e.g. spatial extent and temporal duration) and involves (or at least implies) measurement and measurement units. 'Cross-scale studies' tend to either take both temporal and spatial scales into account (MA 2005), or study the interactions between ecological and social processes (Cash et al. 2006, Cumming et al. 2006). Clearly these are two quite distinct agendas, and point to the diversity of issues that can be subsumed under 'questions of scale'.

In order to understand how scale mismatch emerges in natural resource management, we need to recognize that in ecology, scale is different from the concept of level. The latter refers to level of organization in a hierarchical system, characterized by the rate of a process. Level of organization is therefore a relative characterization of system organization, or as Allen (1998) calls it, "definitional", i.e. relationships that derive from definitions employed by the observer. The rate of a process that defines a specific level also has a temporal and spatial scale over which that process operates (O'Neill and King 1998), resulting in confusion when the concepts of scale and level are used interchangeably.

Confusion may also stem from conceptual differences between disciplines, such as when the temporal rates of processes at various levels in social hierarchies are not necessarily ordered like rates in ecological hierarchies. In ecology, higher levels have slower rates and lower levels have faster rates of change (i.e. cellular processes vs. those of an organism as a whole)

(Wilbanks 2006), while in social systems, governments may rise and fall over weeks, months, years or decades. To avoid misunderstandings, we maintain that scale is preferably used to refer to time, space or quantity, something that can be measured, or the "spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objects and processes" (Gibson et al. 2000, 219).

Empirical and cross-disciplinary studies of social-ecological systems (SES) have broadened the understanding of scale concepts, and there are now a number of uses and definitions, complementing the traditional temporal and spatial scales, such as institutional, jurisdictional, knowledge, and management scales (for a review see Termeer et al. 2010). Different applications are partly due to different epistemological positions, ranging from realist to constructionist perspectives (Manson 2008). We find these broader applications of the scale concept interesting, so the point here is not to say which one is 'best', but we are cautious of the conflation of disparate ideas that can result. Following our understanding of scale, we refer to jurisdictional scales as the spatial extent of a jurisdiction (the area under jurisdiction) but also include its size, in terms of number of people; while level we use to refer to organizational levels of jurisdiction, e.g. national authorities, courts, municipalities etcetera.

Of particular importance for our argument about knowledge scales, is the mismatch that occurs when the scales of ecological and societal processes do not coincide (MA 2005, O'Brien 2011). The literature on SES has contributed much to our understanding of cross-level and cross-scale dynamics and scale mismatches (Peterson and Parker 1998, Zimmerer 2000, Cash et al. 2006, Cumming et al. 2006, Folke 2006, Ostrom 2009, van Lieshout et al. 2011). As Cummings et. al. (2006, 16) elaborate, "scale mismatches occur when the scale of environmental variation and the scale of the social organization responsible for management are aligned in such a way that one or more functions of the social-ecological system are disrupted, inefficiencies occur, and/or important components of the system are lost". Forestry starkly reveals a number of scale mismatches. The slow growth of a forest and diverse forest ecosystem requires time spans longer than human life-spans. Meanwhile, our societies and economies generally prioritize immediate needs and short-term gains, whereas monitoring forest change requires the ability to measure slow changes and delays in impacts. There is also often mismatch between the spatial distribution of forest ecosystems and the political and jurisdictional areas of forest management and use. Cross-level interactions and multiple uses of forest resources add to the complexity.

But our point here is that the problem of scale mismatch in forestry goes deeper than this. There is a more subtle, but equally important dimension of scale-mismatch that affects the frames for negotiation, rationality and goals in NRM. It is the epistemological dimension – what may be called knowledge scales – that relates to knowledge, worldview and scale of observation. In natural resource management, the resource in focus can be understood differently depending on the viewpoint of the observer. To some extent this is evident, but actors are often unaware of their own and others' implicit assumptions. As our case will illustrate, different scales of knowledge interact with contestations of power in Nepalese forestry, shaping actors' perceptions.

In the special feature in Ecology and Society on "Crossing scales and disciplines to achieve forest sustainability", it is argued, that it is necessary to understand not only "cultural differences between local communities and broader-scale society, but also the scales of perception and differences in the depth and character of knowledge associated with stakeholders at these different social levels" (Papaik et al. 2008, 32-33). In our Nepalese case, we can see that the temporal and spatial scales of local knowledges differ both within communities and from the 'expert' knowledge that forestry officials promote. While much has been written on the relation between science and other knowledge systems, we would like to bring into focus the heterogeneity of so called local traditional knowledge as well as the differing scales of knowledge *within* local communities - resulting in unconscious mismatches between knowledge scales, communication problems, lack of legitimacy, and some local knowledge being ignored or down valued.

Scales of observation and partial knowledge

From an epistemological point of view, scale of observation is about the limits of knowledge. When we observe the environment, we necessarily do so within a limited range of scales; therefore, our perceptions of events will be limited. The choice of observational scale mirrors the knowledge culture and priorities of the scientist, it influences what can be seen and the conclusions made (O'Flaherty et al. 2008, Rangan and Kull 2009, Buizer et al. 2011). It may be deliberately chosen by scientists to highlight specific features, while at other times it is for practical or logistical reasons (Levin 1992), but it may also be taken for granted – but regardless, the choice of scale has implications. Philosophical debates on epistemology have created an awareness of the plurality of knowledge systems and the impossibility of "context-free or super-cultural norms of rationality" (Barnes and Bloor 1982, 27). The contributions

from sociology of science, feminist critiques of science (Haraway 1991), the works of Kuhn (Kuhn 1962/1970) and Foucault (1980) among others have created debates for reflexivity on and acknowledgement of the normative underpinnings in how we do science.

Social scientists have engaged with these issues through the of 'politics of scale' (Buizer et al. 2011), showing how actors exert power through "shifting the agendas or shaping the contexts in which knowledge is organized or decisions are made" (Lebel 2006, 37). According to Rangan and Kull (2008), the preconceived ideas held by social and natural scientists on ecological change influence the delineation of a system, which plays a crucial role in determining the outcome of change. They see scale as the *means* by which ecological change becomes political. According to them, scale is produced to explain or argue for or against the processes and outcomes of ecological change in words like transformation, degradation or evolution, good, bad, alien, invasive, native, or benign.

In ecology, scale of observation has also received much critical attention. Ecologists often talk about the 'characteristic' scale of ecosystem processes and services, i.e. the typical extent or duration over which processes have their impact (MA 2005), this should not be taken as saying that there is a correct scale of observation (O'Neill and King 1998, Cash et al. 2006, Termeer et al. 2010). As Levin (Levin 1992, 1947) writes, "... the problem is not to chose the correct scale of description, but rather to recognize that change is taking place on many scales at the same time, and that it is the interaction among phenomena on different scales that must occupy our attention". Generally, diverse processes are likely to be important on different scales, and ecologists need ways to integrate them. O'Neill and King (1998, 6) write, "if you move far enough across scale, the dominant processes change. It is not just that things get bigger or smaller, but the phenomena themselves change. Unstable systems now seem stable. Bottom-up control turns into top-down control". Moving between scales is a trade-off between detail of variation and statistical predictability. According to Levin (1992), this makes it clear that there are no natural levels of description, although some scales are more appropriate to study phenomena than others. This is a crucial point, and we adhere to the idea that some scales are more appropriate than others for scientific study of phenomena, however, we also argue that scientists need to reflect upon the policy implications of their scale choices.

To a certain extent, differing scales of knowledge help explain conflicts between how disparate knowledge systems understand socio-ecological processes. Here, scales of

knowledge refers to the spatial and temporal character of that knowledge, not to be confused the knowledge content *per se*, or with the organizational level at which stakeholders holding that knowledge are active.

A knowledge system has been defined as a body of propositions adhered to that are routinely used to claim truth (Reid et al. 2006, 11). Western science is one such knowledge system with its norms and procedures for 'truth-making'. Western science is said to work through a process of validating, abstracting and generalizing knowledge, while local knowledge is seen as embedded in people and institutions and characterized by being contextual and applied (Agrawal 2002). Traditional ecological knowledge is according to Berkes and Folke (1998, 8) a "cumulative body of knowledge, practice and beliefs, evolving by adaptive processes and handed down through generations by cultural transmission". It may or may not be indigenous, but "has roots firmly in the past" (Reid et al. 2006, 11). Local knowledge is then referring to place-based experiential knowledge, oral and practice-based, as opposed to formal education. These cumulative 'bodies' of knowledge evolve over time and individuals may very well accept some parts and question other.

This way of contrasting science and local knowledge risks seeing them as two internally homogenous knowledge systems. Local traditional knowledge is not limited to local scales of knowledge, but rather involves multiple time frames and geographical scales; it is only the level of the actors that is 'local'. And much science is both contextual and based on local scales of observation, making the process of abstraction and generalization carry a risk of improper applications in other contexts. However, science and other knowledge systems are distinct in that they are still unequal in terms of legitimacy, political influence and economic power.

Scale of observation is thus inherently political because ecological assessments that give precedence to expert knowledge may discriminate against indigenous, local knowledge, minorities or marginalized groups (MA 2005, Reid et al. 2006, Termeer et al. 2010). As a way to deal with the limitations and biases imposed by the scale of observation, studies in ecology, common property and related SES work agree that there is need for multi-scale assessments and cross-scale studies (Levin 1992, O'Neill and King 1998, MA 2005, Allen and Holling 2010). According to the Millennium Ecosystem Assessment report on multi-scale assessments, "an effective assessment of ecosystems or human well-being cannot be

conducted at single temporal or spatial scales" (MA 2005, 23). The motivation behind this statement is that single scales are too limited and risk misinterpreting results.

The use of multi-scale assessments thus potentially have two types of benefits: information benefits and impact benefits. First, multiple scales might improve accuracy, validity or applicability of findings (Reid et al. 2006). For example, scholars propose that local knowledge should complement scientific knowledge (Reid et al. 2006, O'Flaherty et al. 2008, Gagnon and Berteaux 2009). Thus in a Canadian study on Inuit traditional ecological knowledge and scientific knowledge about the arctic fox and greater snow goose in the tundra, Gagnon and Berteaux (2009) see traditional and scientific knowledge as complementary – increasing the temporal extent and adding more spatial scales to combined knowledge, thereby increasing validity of results. The impact benefits of multi-scale assessments are considered to increase the relevance, credibility and legitimacy of results for all stakeholders involved (MA 2005, Reid et al. 2006). Local assessments, for example, may lead to recommendations about societal response that requires action at national levels but find these actors unwilling to respond. Similarly, global scale ecosystem assessments may lack credibility and relevance for local actors in areas where action is needed (MA 2005, Ostrom 2009). However, multi-scale assessment does not remove the issue of scale politics in ecosystem assessments as strategic interests and powerful actors will still try to forward their agenda. Lebel (2006) argues that all actors involved in assessment processes should make their scale choices transparent to achieve legitimacy through a shared understanding of scope and assumptions. This is a good principle for all NRM research and policy processes. Given the way scientific knowledge often takes precedence over local knowledge systems in NRM, scientists should take responsibility for highlighting the implicit assumptions resulting from scale of observation and problem definition.

If problems of scale mismatch are taken seriously, it has implications for our working methods. Both individual researchers and teams should use multiple observational scales and preferably mixed methods. The following case is based on data gathered by one researcher, using a combination of quantitative and qualitative methods, generating two data sets. These sets are then brought together through triangulation for divergence. 'Triangulation' of data is most often used for validation of results, i.e. comparison of data from different sources to look for convergence. There are however, two other less common approaches to triangulation: triangulation for complementarity (e.g. Huntington et al. 2004, Gagnon and Berteaux 2009)

and triangulation for divergence – where data sets do not match. Divergence as an approach analyses not only for complementarity, but also examines the partiality of knowledge and helps to reveal the mismatches between scales of knowledge of the actors – scientists, government officials and citizens – involved.

In sum, we see the choice of observational scale by researchers – due to habit, determined by standard methodological packages or practical circumstances – as part of the process of creating preferential rights of interpretation and legitimacy for certain actors, perspectives and policies. Among local actors there is both a politics of scale in terms of making knowledge claims by referring to 'western science', and differences in scales of knowledge that shape the local responses to NRM and policy. Seeing local, traditional or indigenous knowledge as complementary to science is important but simultaneously strengthens the idea of separate systems and risks overlooking the differences within communities and between local knowledge systems. In the following case study of Nepalese forestry, scale is produced and politicized when more powerful actors frame the problem and the vision of the forest in a way that sometimes conflicts with visions and needs of some less privileged groups in society. It matters both for ecological outcomes and its reshaping – sometimes undermining – of local knowledge systems.

3. Community forestry in Nepal: scale mismatch and the knowledge scales

Forestry programmes in Nepal are some of the most progressive in the world, with several different types of decentralized, participatory programmes giving control over management to village users (Ojha et al. 2008). Community forestry is the largest and most well-established of these programmes and is often held up as a global model of successful, participatory resource management. The case study information presented here was collected over many years (1993-present) (Nightingale 2003, 2005, 2006) and includes the latest developments in forestry policy.

Recently, questions of knowledge and observational scale have moved to centre stage in Nepalese forestry debates. Climate change in the Himalayas is projected to be some of the most severe globally causing significant changes in glacial run off, rainfall and temperature (Duan KQ 2006, Xu et al. 2009). Given these predictions and as a least developed country, Nepal has been targeted for pioneering carbon adaptation and mitigation programmes such as REDD+ (Reducing Emissions from Deforestation and Degradation). REDD+ is a mechanism

to allow developing countries to sell carbon credits generated from forest conservation programmes. In Nepal, a coalition of actors has been working to try to distribute potential revenue from this programme to individual community forestry user-groups. The desire to bring direct benefits to the ordinary people widely believed to be most responsible for the tremendous gains made in forest cover over the past thirty years is laudable, but throws into relief scale issues. To understand the challenges posed by current climate change concerns, we will first illustrate how mismatch between scales of knowledge and scale politics have played out in the past.

The development of community forestry (CF) in Nepal, beginning in the 1980s and gaining momentum after 1990, quickly became a programme wherein scientific 'expert knowledge' was given priority over local knowledge systems. This development took place through a set of organizational, symbolic and material practices embedded in existing power relations clearly seen in the process of constituting a group. In order to take over the management of a community forest, a user group must first map the forest and develop an operational plan (Shrestha et al 1995). The District Forest Office (DFO) staff and, where relevant, foreign-donor project staff, provide substantial assistance to user groups during this phase. Once the forest has been surveyed, mapped and the operational plan approved, the government continues to legally own the land but villagers have the right to manage, use and sell all forest products (GON/MFSC 1995). Development practitioners in community forestry programs promote the diffusion of knowledge to local people with an underlying assumption that ordinary villagers are 'backwards' and need to be 'sensitized' to proper forest management and more recently, climate change. Knowledge is understood as professional/expert knowledge, and something different from local traditional knowledge and in many respects, sits at the core of decentralization goals.

Decentralization in this context is based on the idea that common resources need to be privatized and regulated through collective management. Such property arrangements assume the existence of a recognizable and uncontestable local community that can own and manage the forest (Zimmerer 2000, Nightingale 2005). For people to be legitimate managers of the forest they need to be trained by officials and gain the 'right' type of knowledge. The maps and operational plans required to constitute a community forest user-group thus take on significance beyond simple management documents. They become symbols of 'professional' forestry and scientific knowledge and as such are strategically used by local actors to control

resources (Nightingale 2005). In Mugu district, knowledge claims intersect with power relations within user-groups such that literate, high caste, usually male members use their superior abilities to read, interpret and 'understand' these documents to assert their right to control the group. Meanwhile, the knowledge of illiterate, usually lower caste and female members is marginalized.

Importantly, the management plans and maps are based on different temporal and spatial scales than knowledge held by local users. The map represents a detached position, at a larger spatial scale and without the detail of local conditions on the ground (Rocheleau 1995, St. Martin 2005). Management rules are based on general knowledge gained in other contexts, usually from monoculture forestry for timber production rather than multi-use forestry. Monoculture forestry does not provide the biodiversity required for multi-use forests that are currently needed for sustainable rural livelihoods in Nepal. Despite this, industrial forestry guidelines are given priority over local knowledges. As a result, CF becomes a terrain wherein the scale of forestry management both in terms of knowledge and social organization is produced and rescaled to the interests of the local elite. Within the local community, people with more everyday experience of the forest are dismissed as illiterate and ignorant, while high caste men who do not work in the forest claim to be the ones knowledgeable.

Scientific representations of forest change – e.g. remote sensed data – are becoming increasingly dominant for determining changes in forest cover, land use and environmental degradation (Nightingale 2003, 80). These developments have implications both in terms of the quality of information and the credibility and legitimacy of different knowledge systems for forest policy, a trend which is compounded by concerns over climate change in the Himalayas. Ignoring the mismatch between scientific scales of observation and the scales of knowledge mobilized by local actors may lead to misinterpretation of results, misdirected policy, and conflicts between stakeholders. Community forestry user-groups are well aware of changes occurring in their environment even if they do not cast such knowledge in the language of 'climate change'. As one donor supported user-group member said after listening to a FM radio programme on climate change,

> ..in earlier times, I used to hear the news about drought after hail, hunger problems, firebreaks and sometimes floods. But now, I find less rain, and there is change in the timing of rain too. The days are becoming hotter and hotter. Water flow level is also decreasing in rivers and streams..." 65 year old man,

western hill district (quote curtsey of the Livelihoods and Forestry Programme Kathmandu)

Programmes like those on FM radio and the Livelihoods and Forestry Programme's (LFP) Climate Adaptation Planning initiative are rapidly spreading 'knowledge' about climate change into the far flung villages of rural Nepal, but while this may bring some common vocabulary, it does not fundamentally resolve the mismatch in problem framing. Rather, villagers are concerned about *particular* water sources drying up, changes in under story grazing species in *their* forest, while the government and international donors are concerned about whether the geographic distribution of forest ecotypes (i.e. valuable hard wood *Sal* forests vs. lower value coniferous forests) will change, or if wide spread food insecurity will result from changes in rainfall and vegetation types.

In order to interrogate and tackle scale mismatches, we suggest the use of mixed methods (qualitative and quantitative) to explore the gaps between different knowledge systems (Nightingale 2003). In Mugu District, one author used qualitative ecological oral histories to assess landscape change from the perspective of local people. The oral histories were based on 65 in-depth interviews with local people, using theoretical saturation (asking the same questions to different people until you get no new information) and participant observation (about 12 months total 1993-1994; 1997; 1999) for tests of reliability and validity. Most people when asked about how the forest had changed during their life time, told stories of thick and wild forests, controlled by the village headman, that dominated many parts of the valley during their childhood: roughly 35-60 years ago. In the 1970s, however, the district forest office (DFO) took over management and according to these narratives, ecological conditions rapidly declined. After forest management was returned to village through the community forestry in 1991, people were adamant ecological conditions improved, increasing their access to firewood, timber, and leaf litter.

A quantitative analysis based on an aerial photo time series (1978 - 1996), providing snapshots of land cover change at a resolution of 1:50,000, was combined with a vegetation inventory sampling 5 % of the area (Nightingale 2003). The vegetation inventory was triangulated data from satellite imagery and this combined analysis produced an internally valid data set, but one that told a different story about forest change. A slight increase in forest cover could be seen overall, with most improvement evident close to the villages. When these

findings were triangulated with the interviews—which showed divergent results—it was possible to draw conclusions about the relative importance of different parts of the forest, and to understand how the villagers' understandings of forest change were based on different criteria than simply total forest cover. Areas that are most accessible to local people had improved the most, helping to explain people's positive responses. Yet, this conclusion emerges from the gaps between data sets, when asked about the forest, people emphasized that the whole forest was important to them.

The examples given above illustrate how the forest and its problems are understood differently by actors at different levels, and also *within* local communities. Such differences emerge in part from the forest ideal they envision and the temporal and spatial scales of their knowledge. Forest officials see monoculture stands for timber as the main resource, and base their expert recommendations on generalized scientific knowledge extracted from other geographical places and periods in time, and data from satellite imagery, maps and ecological surveys. Whereas local people's knowledges about the forest spans multiple time frames, based on people's life-long relation to it, the daily and seasonal harvesting of various forest resources, and the oral knowledge and symbolic meaning traded from older generations—as well as their interactions with forestry officials. Spatially, the local forest is discontinuous or network-like: the forest signifies the nearby tree stands, key places in the forest where certain resources are found, "wild" forest where people do not go, the routes for travel, areas that are seen as natural borders to neighboring villages, but also the area under local control, and areas under the jurisdiction of the district authorities. Finally, the forest also signifies the dynamic social and political relations villagers have with each other and to external actors. The forest is differentially accessible temporally and spatially for women and men, rich and poor, high and low-caste (Nightingale 2006). In saying that the forest has improved with community forestry, people refer to changes both in forest cover and social and political relations that are seen as positive. Thus, when people oppose community forestry, they may do so because their interests and knowledge are being disregarded. Scale mismatch in community forestry, then results in a shift in power relations, the production of a new ecosystem and the undermining of local knowledge systems. But these shifts occur not only through misunderstanding produced out of inherently differently scaled knowledges, but also from the ability of particular actors to mobilize different scales of knowledge for their own interests.

When we bring this analysis to climate change and programmes like REDD+, it is clear scale politics pose some challenges for participatory CF. Decentralization of forest management is attributed with giving village users a greater sense of ownership and thus a willingness to ensure the long term viability of their forests. In order to sell this 'carbon' on a global market, however, a mechanism is required that can bring together thousands of user-groups into one package that can be marketed to a global buyer. A coalition of donor and civil society leaders are keen to see such a mechanism reflect the participatory, inclusive practices that have been institutionalized within community forestry, but exactly how to achieve that is far from obvious. Most user-groups presently use annual assemblies of all members to deliberate key decisions, but the demands of a global carbon market will necessitate the formation of a core of 'elites' who can act as an intermediary between the grassroots and national and international contexts. The proposals under consideration bring forest department staff as well as user-groups and civil society representatives into such a forum. If we examine this issue in terms of scale politics, we see tremendous potential for 'local' knowledge to be superseded by 'national' and 'global' understandings of climate change, as well as for local interests to be subsumed in order to sequester 'carbon'. Ambitions to include local knowledge in such negotiations are likely to ignore the multiple scales of knowledge within communities, seeing partial and political claims to knowledge by elites as representative of local needs and interests.

4. Conclusions

By exploring the mismatch between scales of knowledge held by actors in relation to each other and in relation to the forest ecosystem, we are able to explain how various actors perceive forest change, why there are struggles over implementation of community forestry in Nepal, and why the expert position taken by researchers is not an objective or neutral one, but of strategic interest for actors involved in forestry and for resulting policy making. Nepalese forests and forestry have undergone rapid changes since the 1980s, and one way to explain this is by saying that the social and ecological systems have not aligned properly, resulting in scale mismatch and disruption in the functions of the social-ecological system. However, whether the change is positive or negative depends on what functions are of interest; questions that are highly contested. As we demonstrate in the case study, the current promotion of 'expert knowledge' by the DFO is strategically used by local elites to assert control over forest resources, leading to ecosystem change, a redefinition of the forest as a

source of timber rather than a multi-use forest for local livelihoods and places of meaning, gradual disappearance of local knowledge, and changes in people's access to the forest and forest resources.

The use of mixed methods and data sets with different observational scales helped reveal how the forest signifies different things to the actors involved, but it also helped illustrate how these differences came about. We want to emphasize that such an understanding can only emerge by taking the epistemological position of situated, political and partial knowledge, which turns the eye on the researcher and her or his underlying assumptions about the world. Instead of seeking a coherent view of reality, the position allows us to explore the gaps between worldviews. By using mixed methods, the incompatibilities between data sets become evident. When we scrutinize these gaps from a scale perspective, it becomes clear how these data sets – and knowledge held by actors – are based on different temporal and spatial scales, influencing the delineation of the forest as associated value, and as problem; creating multiple stories of forest change. This is particularly important because acknowledging multiple and divergent stories has policy implications. It requires a different organization of the NRM process, one which can allow open dialogue between actors without striving for a single dominant story as output.

The approach by scientists to these questions is crucial as the choice of observational scale is part of creating preferential rights of interpretation and giving legitimacy to certain actors and perspectives. Attention to mismatch between knowledge scales is an important challenge for NRM that aims at bottom-up development and empowerment of marginalized groups. The objectives of such programmes are potentially undermined by scale politics and scale mismatch such that forests are not managed well, the poorest of the poor do not benefit adequately, and livelihood benefits are compromised.

While efforts to integrate local and scientific knowledge are laudable, such integration requires caution and questioning of the improper applications of science to new contexts as well as an interrogation of how different knowledges may be fundamentally embedded in different scales, influencing problem definition and solutions. Local traditional knowledge is contextual and applied, which also means that it is diverse and inherently multi-scalar. Scale politics and mismatch between scales of knowledge exist *within* local communities, meaning that scientific knowledge will necessarily intersect politically as well as epistemologically

with local knowledge. It is not simply the case that one needs to confer with local elites or those considered local experts, rather one needs to attend to how scales of knowledge produce a politics of knowing that can have real implications for on-the-ground management.

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