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Electricity for better lives in rural Tanzania and Mozambique

– understanding and addressing the challenges

HELENE AHLBORG

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

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

Table of contents

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; WB
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

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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.

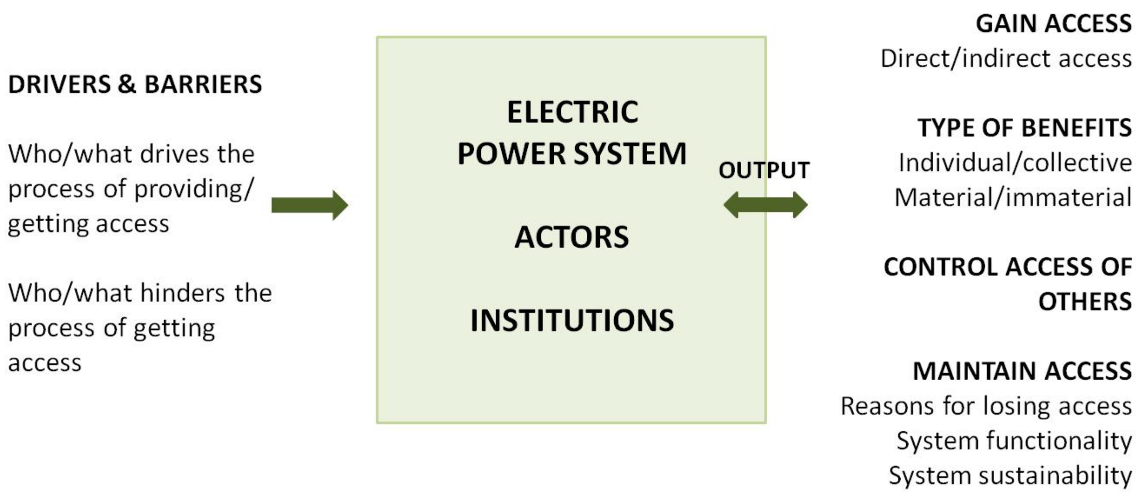

Figure 1 visualizes how I conceptually understand the introduction of electricity in a rural community. Involving more than building of new infrastructure, a technological system develops around the electric power system, with actors (both local and external individuals, groups and organizations) and 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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