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Walking Along the Lines of Power

A Systems Approach to Understanding Co-emergence of Society, Technology and Nature in Processes of Rural Electrification

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Abstract

Many African governments, international and local organizations involved in development policy and practice consider rural electrification (RE) to be a priority. In the absence of electric grid infrastructure, rural populations rely on, for example, diesel generators, batteries and solar panels for their electricity supply and on kerosene, wood and charcoal for lighting and heating purposes. Increasingly, renewable energy technologies in small-scale decentralized systems are promoted as a complement or an alternative to the extension of national grids. Large-scale and small-scale RE processes differ in many respects. However, both are troubled by the gap between expected and actual outcomes. This thesis scrutinizes the assumption that 'electricity brings development'. It shows the importance of asking questions related to the encounter between local societies and externally introduced technology in order to understand how and why RE processes in general, and decentralized RE in particular, unfold in particular ways – with short and long-term consequences for life in rural areas.

In this thesis, I bring together socio-technical approaches, philosophical debates on human power and conceptualizations of scale. This allows me to explore RE processes and the points of intersection between society, technology and nature that are important for shaping the outcomes for different actors, and producing certain *kinds* of development. Together, these perspectives help us see how electrification processes are inherently political with on-the-ground dynamics embedded in and influencing more long-term development processes at higher societal levels.

The thesis presents a synthesis of four empirical studies and combines broad and general analyses – of Tanzania's and Mozambique's energy sectors and RE prospects, and the role of democracy and institutional quality for public electricity provision in African countries – with two case studies of decentralized generation and micro-grid distribution in Tanzania. A fifth paper explores dimensions of scale, which

are central to the theoretical and methodological approach of the thesis. The theoretical contribution is an analytical framework for studying processes of system formation in decentralized RE. It can guide further research and assist interdisciplinary communication around the complex challenges involved in RE processes. Furthermore, the thesis develops a conceptualization of the multiple workings of human power in electrification processes, which helps us understand how social inequality is maintained and contested. The conclusion is that even small-scale systems of local generation and distribution can be powerful enough to redirect processes of social and economic change and bring accompanying shifts in social identities, people's use of and understanding of spaces, and the distribution of material resources.

The thesis contributes to existing knowledge by developing conceptual tools for understanding the 'messy' human aspects of socio-technical change in relation to technical and ecological elements and processes. For the actors involved in RE processes, the thesis helps illustrate why conflicts of interest can be expected to emerge and where points of friction can occur. These are the points that require the continuous attention of actors involved in order to create positive feedbacks and avoid negative spirals. One of the conclusions is that actors involved in RE processes may contribute to the sustainable functioning of energy systems and positive outcomes by creating processes for dialogue, negotiation and learning.

Appended Papers

This thesis is based on the work contained in the following papers:

1. Ahlborg, H. and Hammar, L. (2014), 'Drivers and barriers to rural electrification in Tanzania and Mozambique – Grid-extension, off-grid, and renewable energy technologies', *Renewable Energy,* 61, 117-24.

2. Ahlborg, H., 'Dynamic access: the rise and fall of a micro-grid'. Manuscript.

3. Ahlborg, H. and Sjöstedt, M. (2015) 'Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages', *Energy Research & Social Science,* 5, 20-33.

4. Ahlborg, H., Boräng, F. Jagers, S. C. and Söderholm, P. 'Provision of Electricity to African Households: The Importance of Democracy and Institutional Quality', submitted to a journal.

5. Ahlborg, H., and Nightingale, A. J. (2012) 'Mismatch between scales of knowledge in Nepalese forestry: epistemology, power, and policy implications'. *Ecology and Society*, 17(4), 16.

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1 Introduction

"It feels like I have been living my life in the dark, now I want my grandchildren to live in the light"

- old man and farmer in Leguruki village, Arusha, Tanzania 2011

This thesis begins on the hill above the Mawengi hydroelectric power station in the Kisongo river, Ludewa district, Tanzania. From there, over 100 km of electric transmission lines stretch across the valley below and up the mountain, and cut through the forest to the small villages around. The 300 kW hydroelectric power station is the centre of a network of electric power lines that connects thousands of people in nine different communities. The presence of electricity marks the space and distinguishes the "lit" area from the "unlit". People speak of events occurring before and after the lights were switched on. At night, the valley below is full of scattered electric lights that glow steadily. As the manager of the local utility expressed it, "Our remote villages are developing fast, we are now connected to the rest of the world."

There is much to learn from this particular process of small-scale electrification regarding the challenges associated with providing electricity services in poor rural communities that have so far primarily relied on wood, charcoal, candles, kerosene, batteries and diesel generators to meet local energy needs. Most people were not expecting the introduction of grid-based electricity services and were unprepared for the associated range of issues that they were confronted with. In rural areas of Tanzania, less than 7% of households are electrified, supplied either through the national grid or by solar panels (REA and MEM 2011).

Provision of modern energy services is considered important in order to alleviate poverty in rural and urban areas of Tanzania. The Tanzanian government anticipates a combination of centralized electricity provision, via extension of the national grid, and small-scale decentralized electricity provision using renewable energy sources (MEM 2014). Whereas construction of large-scale transmission and distribution networks is very expensive, decentralized generation and distribution can be a least-cost option for rural communities (Kaundinya et al. 2009), for example where small-scale hydropower can supply electricity in local grids (Eberhard et al.

2011: 105). The potential for electrifying rural areas by use of renewable energy technologies (RETs) in decentralized installations is deemed large, but the track record of these kinds of systems is not very good. Many decentralized systems stop operating ahead of their expected lifetime (Bångens et al. 2013; Kankam and Boon 2009). Further, in many places where electricity has been made available, the expected social and economic development does not occur (Madubansi and Shackleton 2006; Peters et al. 2009). There is a growing body of literature engaging with these societal challenges; still, many knowledge gaps remain. For example, there is need to better understand the prerequisites for various kinds of decentralized rural electrification (RE) processes and how and why these unfold in particular ways – with short and long-term consequences for life in rural areas.

1.1 Research domain

It is widely assumed that provision of modern energy services, including electricity, is of decisive importance for societal development (SE4All 2015; SEI 1999; UNDP 2004; WB 2008). This thesis examines the narrative of 'electricity brings development' and shows the importance of asking questions related to the encounter between local society and externally introduced technology, in order to understand: (1) how RE processes develop at the local level; (2) why some decentralized systems stop functioning or continue to deliver electricity services over time; and (3) what decentralized RE processes 'do' in terms of their effects on local society (Li 2005).

In order to explore outcomes of RE processes in rural Tanzania, I bring together three conceptual starting points. The first starting point is a *socio-technical system perspective,* for reasons I will now explain. Characteristics of the technology shape (but do not determine) its uses and what development can take place (Langdon 1980; Pinch and Bijker 1984). Electricity is a highly useful energy carrier. As a resource, it grants humans new (or different) opportunities and has the potential to transform our capacities, i.e. it enhances specific human powers – to carry out heavy labour, generate light, communicate etc. – if combined with other resources and abilities. However, electric systems of larger generation capacity that supplies many users requires financial capital, particular types of knowledge and skills for construction and operation of the system over time. Continuous and reliable electricity supply demands coordination and interaction between numerous technical and natural components and human actors (Wolsink 2012): the system for electricity generation

needs to be adapted to the characteristics of the energy resource (e.g. a water resource or wind conditions); the grid infrastructure must be robust given the place-specific conditions (e.g. against termites and wind); technical staff and computers interact to control the system performance (e.g. balancing power generation and demand); the actors managing the supply need to organise service delivery, relate to users and handle economic budgets over time; and users need to pay for and make use of electricity services. These interactions can be fruitfully analysed from a socio-technical system perspective. It is an interdisciplinary perspective, which allows for holding together these dynamic relations between humans, technology and nature together, rather than selecting one domain.

Further, by analysing system dynamics I can identify points of intersection between social, technical and ecological processes and factors and attend to how technology and its context co-emerge, i.e. the emerging socio-technical and ecological change where the system develops in relation to its context and both system and context change along the way. Arguably, a systems perspective is appropriate for studying the ways in which rural electrification (RE) processes change how energy supply and use are embedded in everyday life. For example, conditioned by specific technical and social system configurations, access to reliable and affordable electricity of higher capacity can initiate a restructuring of the local political economy. When electric machinery is used to replace manual labour, the capacity to carry out work (e.g. moving water or crushing grain) can be held by one or a few persons with the right technical and managerial skills, no longer requiring the work or collaboration of many physically able people. This is one of the points of intersection where RE may change the social dynamics around work organization and the speed and size of material flows in local resource use and production. As we will see in succeeding sections, even a small-scale system of local generation and distribution can be powerful enough to redirect processes of social and economic change and bring accompanying shifts in social identities, people's use of and understanding of spaces, and the distribution of material resources.

Similar processes are also at work in relation to other types of infrastructure. Previous work on large-scale electricity infrastructure (Hughes 1983; Summerton 2004), road infrastructure (Langdon 1980) and water supply systems (Harris 2006) provide us with the understanding that the shaping of these physical structures and the way humans interact with them is fundamentally political. Here, I use the term

political in a broader sense in line with Nightingale's (forthcoming) definition of politics as the "contestations and collaboration between people and institutions that serve to order and govern everyday affairs". The definition includes, but is not limited to, formal political and governmental processes.

Hence, the second starting point is that large-scale as well as decentralized RE processes *involve the exercise of power* – at the national level and the local level – in struggles for control over and access to various resources and for influence in decision-making. Energy scholars also suggest that the domains of energy supply and use are highly gendered, although this has been overlooked and needs further attention (Clancy et al. 2011; Clancy 2013; Skutsch 1998). There are important linkages between energy, gender[1] and poverty, and relations of power are at the core of this nexus. Therefore, I build on theories of human power in order to theorize the processes whereby RE (re)produces relations of power. The use of brackets signifies the process whereby power relations are produced, maintained, contested and transformed at the same time. That is, the process of (re)production is dynamic also when seemingly nothing changes and social hierarchies remain stable (Butler 1990; Nightingale 2006, 2011).

The focus on relations of power requires reflexivity on the activity of doing research, and my own exercises of power in relation to the people and places I study. As highlighted by scholars in many fields, researchers contribute to the production of (the dominant) discourses on technology (Nahuis and Lente 2008; van den Bergh et al. 2011), modernity (Appadurai 1996) and ideas of African societies as being less developed than Western countries (Ferguson 2006; Mbembe 2002a). Therefore, it is important to account for (see section 1.2) underlying assumptions about development, normative standpoints and the choices made regarding the "scale of observation", i.e. the temporal, spatial or quantitative dimensions used by researchers to measure and study the world (Levin 1992). Here, there is a link between relations of power and the third starting point: *scale.*

Scale matters in multiple ways. Methodologically, our choices of analytical levels and system boundaries influence what we can see and what conclusions can be

[1] I understand gender in line with Bondi and Davidsson who sees gender as an aspect of subjectivity that is bound up with other dimensions of human experience and subjectivity such as class, sexuality, age, 'race' and so on. Concepts and practices of gender are intertwined with power exercise (Bondi and Davidson 2003).

drawn (Cumming et al. 2006; Gibson et al. 2000; O'Flaherty et al. 2008; Rangan and Kull 2009). The insight from the debates on scale, similar to systems theory (Checkland 1999), is that 'scale' and 'systems' are social constructions (Sheppard and McMaster 2003) and simplifications we use to make sense of the world. The choice of observational scale may be deliberately made by scientists to highlight specific features, while at other times it is for practical or logistical reasons (Levin 1992), but the choice of scale may also be taken for granted. 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 (Coenen et al. 2012; Lebel 2006). This calls for transparency on choices made and reflection on the limitations of our analyses. However, scale also matters empirically as the concept reflects spatiotemporal relationships between objects, processes and entities in the physical world that cannot be changed at will.

Importantly, the difference between conventional RE by grid extension and decentralized RE based on locally available renewable energy sources and off-grid solutions, is fundamentally one about scale (Goldthau 2014). Large-scale electric power infrastructure exhibits technical, economic and organizational characteristics that are very different from small-scale installations in rural communities, such as: the scale of technical systems (geographical extent, size of installations), the scale of investments needed (amount of funding, number of installations) and time scales of processes (return on investments and lifetime of technical components). Many of the challenges involved in RE processes in Tanzania have to do with lack of alignment between organizational structures, time scales of decision-making processes at local, district, national and international levels and the processes involved in (a) managing and maintaining well-functioning infrastructure in rural communities, and (b) solving emerging problems. Local RE processes are "cross-scale" processes in the sense that they are embedded in (inter)national politics at the same time as they are influencing more long-term development processes at higher societal levels (Coenen et al. 2012; Goldthau 2014). Attention to scale relations is, I argue, an important dimension of analyses of system dynamics as well as the politics of rural development.

Thus, the theoretical and empirical attention converges on the concepts of socio-technical systems, power and scale. This allows me to explore the moments in RE processes and points of intersection between society, technology and nature that are

important for shaping the outcomes for different actors, and producing certain *kinds* of developments.

1.2 Research aim and approach

The aim of this thesis is, thus, to explore dynamics of rural electrification processes, from the perspective of multiple actors at different organizational levels, in order to explain:

(1) How and why actors are enabled and constrained in their capacities to engage in RE and achieve outcomes that are in line with their expectations, goals and interests.

(2) What development outcomes that emerge (and fail to emerge) in encounters between electric systems and the context in which they are introduced.

By context, I mean the multifaceted circumstances that form the setting for RE processes, including 'spaces' of decision-making and governance, as well as 'places' in terms of specific geographical locations where infrastructure is built and supplies electricity to users. 'Actors' is used as a general term for all organizations and people directly or indirectly concerned, such as representatives of various organizations and citizens without group affiliation. The analysis evaluates outcomes from multiple points of view, in order to render visible how assessments of system weaknesses and strengths are positioned and partial. That is, actors perceive energy systems as functioning better or worse depending on their viewpoints, needs, interests and goals (Pinch and Bijker 1984).

Given the complex area of research, the working strategy has been to combine broad and general analysis of the country's energy sector and RE prospects with in-depth analyses of a couple of cases of decentralized RE. I use mixed methods but with an emphasis on interviews. The data consists to a large degree of actors' stories, statements and positions taken in relation to the topic.

The studies focus in on specific questions, and together, they illuminate different aspects and phases of RE processes. In article 1, the prospect for decentralized RE is seen in relation to the conventional, and so far dominant, way of undertaking RE by large-scale grid extension. This is an area where the state dominates the electricity sector. However, the state has not been capable of extending the power network throughout its territory. The situation for Tanzania as a country (in

general) is contrasted to its southern neighbour Mozambique, and in article 4 also to other African countries, specifically in a cross-country comparative analysis of how household per capita energy consumption has changed over time.

The in-depth cases (articles 2 and 3) explore a particular kind of decentralized rural electrification process: local power generation with micro-grid distribution. Micro-grids have historically played a crucial role in early industrialization of many countries (Zomers 2003) and scholars propose that they will be important parts of future electricity sectors (Tenenbaum et al. 2014; Wolsink 2012). Micro-grids are also interesting in the Tanzanian context because of their relatively large size – in comparison to diesel generators and solar home systems – which allows them to supply local businesses with sufficient power to promote small-scale industrialization, at the same time as the system may supply electricity for household use and public services. The two RE processes are driven by non-governmental organizations (NGOs) and funded by international and national donors. NGOs play an important role in RE processes in Tanzania. The organizations studied here are motivated to provide rural communities with electricity services for the same reasons as the government – to catalyse social and economic development and alleviate poverty. However, as NGOs, they occupy a place in society that is ambiguous, somewhere in between the "local" and "international", and they mobilise resources and carry out projects according to a logic that differs from that of the state (Fowler 1991; Gupta 2014; Kamat 2004). They abide by national laws but access funding from the international development community. As Ferguson argues, they are not really active in a space "below" the government but rather they are integral parts of a "new, transnational apparatus of governmentality" (Ferguson 2006: 103); and they fill the gap where the state is "absent".

A few comments should be made regarding the research approach here. First, the base in systems thinking provides a tool for interdisciplinary analysis and communication – two activities that are indeed rewarding, but challenging. My attempts to use systems thinking as a means of communication and translation between scientific fields have not been without difficulty. I discuss some of the limitations involved in the methodology section.

Second, I repeatedly use the concept 'development' in this thesis. In the dominant development discourse it is assumed that electricity is an integral part of modern society. The concepts of development and modernity are often used in

conversations around electricity in Tanzania. I cannot pretend to know the multitude of aspirations people hold and their understanding of the concept of 'development'. The critique of 'modernity' and 'development', delivered by critical scholars in numerous fields (Appadurai 1996; Diouf 2000; Gupta 1998) is indeed very important and relevant to this work. However, in line with Ferguson, I see a risk that insistence on a 'culturalized' and relativized[2] understanding of development and modernity can undermine possibilities to discuss the aspiration for modernity in the context of very real political and economic inequalities faced by the majority of citizens. In interviews with people in rural villages, I have often asked: "what kind of life do you want for your children in the future?" followed by: "What is a good life?" The answers have been very similar: a good life is having enough food, a proper house, clothes, education, good health, good social relations and employment opportunities. For many people in these villages, the aspirations to material and social welfare are not met today.

Ferguson writes: "Yet in Africa, modernity has always been a matter not simply of past and present, but also of up and down. The aspiration to modernity has been an aspiration to rise in the world in economic and political terms; to improve one's way of life, one's standing, one's place-in-the-world. Modernity has thus been a way of talking about global inequality and about material needs and how they might be met." (Ferguson 2006: 32). The work presented here aims to contribute to improved understanding of how these aspirations and needs might be met.

Still, the priority given to economic growth in dominant development discourses must be critically approached. We are currently witnessing unsustainable economic structures and practices, and ongoing exploitation of humans and ecosystems all around the world. Despite the dominance of destructive economic practices, I argue that economic development is needed in many rural communities in the sense that continued reliance on subsistence-based agriculture and export of a few cash crops creates vulnerability in a time when local resources are increasingly attractive for external actors, and intermediaries reap the profits of the food production of smallholder farmers.

[2] Rather than understanding societies and cultures as located along a linear development track of pre-modern and modern, some scholars have insisted that there are multiple ways of being modern, that is, there are alternative modernities (Appadurai 1996; Diouf 2000).

Third, the methodological choices on the scale of observation have political consequences. The implications of this insight are discussed in depth in the fifth article appended – *Mismatch between scales of knowledge in Nepalese forestry – epistemology, power and policy implications*. In this thesis, the article on scale is a methodological contribution primarily, as its empirical discussion is based on my co-author's work on forestry (Nightingale 2001, 2003, 2005, 2006, 2010). But there are three aspects, discussed in the article, of relevance for the chosen research approach:

(1) When we study systems that we conceive of as complex, then it follows that studying them on single scales is too limited and risks misinterpreting results. Multiple scales of observation are, thus, necessary to increase the credibility and relevance of findings (MA 2005). This, in my view, motivates conducting studies that investigate RE processes in Tanzania on different geographical and time scales, and societal levels of decision-making.

(2) There is a politics of scale acting on the framing, conducting and use of research with implications for how problems are outlined and who is identified as a stakeholder (Lebel et al. 2005; Lebel 2006). The selection of scale of observation 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 joint research processes should make their scale choices transparent to achieve legitimacy through a shared understanding of scope and assumptions. The scales of observation for each study and the choices made throughout the research process are accounted for in the Methodology section.

(3) In article 5 we develop a discussion around what we call 'scales of knowledge'. Scales of knowledge refers to the spatial and temporal extent and character of knowledge held by individuals or collectives (public or scientific). Through the example of forestry, we show how different scales of knowledge interact with contestations of power, and shape actors' perceptions. As a result, actors interpret both the forest *itself* and the *rationale* of forest management through specific, and often conflicting, frames. Therefore, the idea of 'local knowledge' is problematic and hides from view struggles of power within communities. This has implications for how we collect and interpret data. We should expect heterogeneity and conflicting perspectives in 'local' knowledge.

1.3 Intended audience

The intended audience is people working in the field of energy and development – as researchers, policy-makers, donors and all kinds of practitioners. My research can be placed within the field of socio-technical system studies and innovation system (IS) studies, but bridges over to discussions in other fields that have in common that they explore the interfaces between either: society–technology, society–nature or technology–nature. Hopefully, it can contribute something of interest also to people with many years of experience in this working field.

1.4 Thesis outline

This introductory text provides a theoretical and empirical synthesis of the work carried out over the past five years. The background section (section 2) explains the motivations for electrifying rural areas and provides the necessary background to the current situation in Tanzania's energy sector, and how Tanzania is situated in the international context. Section 3 reviews previous research on RE in African countries. It summarizes the findings of scholars on factors that drive or hinder conventional as well as decentralized and renewable energy based RE in similar contexts. Section 4 introduces the theoretical perspectives that have informed this work, based on which I develop a socio-technical framework for analysis of decentralized RE processes, and a conceptualization of power specific to RE processes. The theoretical discussion ends with specific research questions for investigation. The reader who wishes to read the research questions before plunging into the background section, will find these in section 4.4. Section 5 provides the methodological starting points, and a description of how the different studies have been conducted. The research questions are answered in Section 6, followed by discussion and identification of areas for further research. Finally, section 7 concludes by summarizing the thesis' contribution; and provides some recommendations for policy and practice.

2 Background

2.1 Motivations for rural electrification

RE is undertaken to render possible rural development. The United Nations General Assembly has declared 2014–2024 to be the "Decade of Sustainable Energy for All", and the UNDP states that development of modern energy services is a prerequisite for achievement of the Millennium Development Goals on combating poverty worldwide (UNDP 2005: 1). In sub-Saharan countries, the situation has been designated as a power crisis. The average price of power is double that of other developing regions, and the power generation capacity is lower than any other region in the world (Eberhard et al. 2011). The starting point for the energy transition in this region is, therefore, largely a different one than in the rest of the world.

Tanzania is ranked 159 out of 187 countries on the Human Development Index and about 66% of the population are living in poverty (UNDP 2014). The majority of Tanzanians live in rural areas (around 70%) and make a living primarily on subsistence-based agriculture (NBS 2013). Poor households spend a considerable portion of their income on meeting their energy needs. For example, Tanzanian rural families pay more for kerosene for oil lamps than it costs households to be connected to the national grid (Tracy and Jacobson 2012). However, the upfront costs associated with installing electricity in a house deter low-income families from connecting to the grid.

Evidence from African countries shows that provision of electricity can result in substantial social benefits[3] – 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). Also, there is evidence that decentralized electricity supply can contribute to higher incomes and small business activities (Bairiganjan et al. 2010; Chaurey and Kandpal 2010).

These benefits are much sought after. The Tanzanian government estimates that almost 99% of households in the country rely on bioenergy for cooking purposes and

[3] Electricity is primarily used for lighting, entertainment purposes and small-scale business, not for cooking or heating (Madubansi and Shackleton 2006), although the pattern varies between places, depending on local availability of energy resources, climate, price levels and household incomes (Kituyi et al. 2001; Louw et al. 2008).

almost 89% on kerosene for lighting (NBS 2013; REA and MEM 2011). It is primarily women who provide the work and time involved in household energy provision (Bryceson and Howe 1993; Clancy et al. 2003). For this reason, women suffer disproportionately from the negative aspects of current energy use in Tanzania and many other poor countries. The fumes from kerosene and smoke from wood/charcoal for cooking have significant negative health impacts and lead to higher mortality especially for women and children (Clancy 2013; WB 2008). Electricity access can, therefore, have positive consequences for the health and wellbeing of women and children. However, a positive outcome of electrification for women as a group cannot be taken for granted. More ambiguous or negative outcomes for women have also been documented, such as women's already long work days becoming longer (Clancy et al. 2003; Winther 2008).

2.2 Development of the Tanzanian electricity sector

The United Republic of Tanzania was formed in 1964 out of the union between mainland Tanganyika and the coastal archipelago of Zanzibar. On the mainland, independence from the United Kingdom was gained in 1961. The first President, Julius Nyerere, strove for freedom and development for Tanzania by means of his vision of African socialism.[4] He believed that development of Tanzania had to come from increased production in the agricultural sector and export of agricultural products to international markets, as agriculture was the most important economic sector.[5] Loans, financial aid and investments from abroad were important but not sufficient, and they undermined self-reliance and political and economic autonomy (Nyerere 1968). The economic policies included full and partial nationalisation of important sectors. In 1964 the government acquired shares in the two major electricity supply companies, which were merged in 1975 to form the current Tanzania Electric

[4] Nyerere's vision had a strong moral and ethical foundation: development must build on socialist principles of social equality (including the emancipation of women), cooperation between people and hard work by all capable citizens. The rule of Nyerere was controversial, and he is remembered as a non-corrupt leader and 'the Teacher' who worked to install national unity and who made Kiswahili the national language. However, his government became increasingly repressive over time, and in some parts of the country, state officials used coercion and forced resettlements in order to realise Nyerere's vision of rural development (Hillbom and Green 2010; Scott 1998)

[5] He foresaw a transformation of the countryside, with the population resettling into "modern villages" instead of the "traditional homesteads". Economic development would come about through agricultural development using "modern" practices and joint investments in tools, machinery and agricultural inputs by farmers' cooperatives whose members would share the profit.

Supply Company Ltd (TANESCO), owned by the government (MEM 2014). At time of independence the electric grids were limited mainly to the larger cities and industries. In the coming decades, grid connection rates remained at around 1.5% of the population, barely keeping pace with population growth (REA and MEM 2011). The Tanzanian economy failed to grow, and agricultural production actually fell during the years of the resettlement campaign (Prashad 2007; Scott 1998: 239). When Nyerere relinquished power to his successor, Ali Hassan Mwinyi, in 1985, Tanzania was one of the poorest countries on the African continent.

In the 1980–90s, donors such as the World Bank pushed for 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). An energy sector reform was initiated in Tanzania in the 1990s, which opened the sector to private investors. TANESCO continues to dominate the sector but there are some independent power producers providing additional generation capacity. However, private sector actors have shown little interest in the areas of transmission and distribution (Marandu and Luteganya 2005; MEM 2009). Long distances, high investment costs and low individual loads among rural customers make grid-extension a financial burden on the public treasury. Partially as a result of this burden, Tanzania has continued to rely on donor funding for building the infrastructure.

The challenge of providing access to modern energy services for all Tanzanians is on a scale today that is very different from the situation in 1964. According to UNPD (2012) estimates, the population in 2015 has grown to 52 million inhabitants, compared to around 10 million in 1960. Unless birth rates decrease, the country's population may have grown to 90 million in 2038 (UNFPA 2015). During the past decade, economic growth rates have been around 6% p.a. (African Economic Outlook 2012) but this is concentrated in the cities. The rural economy is severely hampered by lack of energy, transport and communication infrastructure. In the absence of electricity from the grid, rural industries, well-off farms, workshops, mills etc., rely on expensive diesel generators. Industry needs reliable power of high capacity, and diesel generators are often used as backup even after connection to the main grid (VPC 2008; WB 2008). Low power quality, typified by blackouts and power rationing on national grids, is a common phenomenon in Tanzania (and in the sub-Saharan region at large), incurring costs associated with production stops and damage to equipment (WB 2009).

2.3 Infrastructure, actors and institutions in the electricity sector

Tanzania's electricity generation relies primarily on hydropower and natural gas, complemented by imported oil and cogeneration from agro-industry (MEM 2009, 2014; Otieno and Awange 2006). In 2014, total installed generation capacity came from hydropower (35%), natural gas power plants (34%) and liquid fuel power plants (31%) (MEM 2014). Between 2008 and 2014, the total installed power capacity increased from 1100 MW to 1583 MW.

However, average generation in 2008 was at a level below 60% of installed capacity, due to climatic conditions with little rainfall, breakdown of installed infrastructure and mandatory shutdowns for maintenance. Droughts continued to create problems for hydropower production in 2010, leading to power supply shortages and emergency supply from other sources at high cost (MEM 2014).

The transmission and distribution infrastructure is in need of rehabilitation, upgrading and development. Technical losses are considered a major problem, in 2008 they amounted to 19% of generated power (MEM 2009, 2014). The transmission grid reaches only part of the country. In 2011, the grid connection rate was below 1% in nine out of 30 regions (REA and MEM 2011). The average percentage of rural population that is connected to national grid electricity was previously estimated to 2–3%, while the urban rate was 14% (MEM 2009; Otieno and Awange 2006). Current estimates by the government suggest an increase to 7% rural electricity access (4.6% grid and 2% solar power) and 24% for the mainland population as a whole (MEM 2014; REA and MEM 2011). The government goals in RE are ambitious and the Power System Master Plan from 2008 set the target at 100 000 new grid connections per year. In 2009, 60 000 new connections were established, which reflects the challenges involved in reaching the targets (Bångens et al. 2013).

In order for the reader to gain an overview of the sector structure, the most important actors are listed below and their role in the electricity sector described.

The Ministry and TANESCO: The power sector is dominated by the national electric company TANESCO, operating under the Ministry of Energy and Minerals (MEM). The Ministry is responsible for strategic planning and formulating energy policy.

REB: The Rural Energy Board governs the Rural Energy Fund and REA.

REA: A new government agency called the Rural Energy Agency (REA) became operational in 2007. REA is the executive body and secretariat of the REB and responsible for "promotion and facilitating access to modern energy services in rural areas of mainland Tanzania" (MEM 2009: 8), including the promotion of off-grid systems. The government and development partners provide funding for RE activities to the Rural Energy Fund (REF), which is managed by REA. The establishment of REA and the REF means that TANESCO is working on a more business-like manner, no longer responsible for funding (but still implementing) rural grid-extension projects (Bångens et al. 2013).

EWURA: Regulation of the electricity market (tariffs, licensing, standards) is provided by EWURA (Energy and Water Utilities Regulatory Authority), which was established in 2006.

NEMC: The National Environmental Management Council ensures that developers observe environmental regulation and conduct environmental impact assessments.

COSTECH: Tanzania Commission for Science and Technology is responsible for coordinating and promoting research and technology development activities.

Development partners: The World Bank, the European Union, the African Development Bank, UNDP, UNHCR and UNIDO, GVEP and GEF are among the international organizations funding various electrification programmes and actively influencing policy-making. Foreign governments and development partners also provide investment and financial assistance, for example China, Japan, Denmark, Norway and Sweden (Bångens et al. 2013; REA and MEM 2011).

A number of legal acts and regulatory policies provide the formal institutional frameworks for the sector. "Institutions" are commonly defined as "the rules of the game", and include a variety of external factors shaping and constraining human behaviour and learning (North 1990). These include both formal institutions (e.g. political system, laws, policies and regulations) and so-called "informal" institutions (e.g. values and norms, traditions and 'common sense') (March and Olsen 1989; Peters 1999). Practices of corruption or forms of decision-making that are part of an "organisational culture" that does not adhere to formal regulation are considered as informal institutions (North 1990).

The important formal frameworks regulating the electricity sector are the National Energy Policy from 1992 (revised in 2003), the Electricity Act 2008, the Rural Energy Act 2005 and the Power System Master Plan 2008. There is no Rural Energy Policy or Rural Energy Master Plan in place to clarify priorities and identify the most important rural energy projects (Bångens et al. 2013). The process of energy sector reform is still ongoing, and the electricity sub-sector is in a process of restructuring. Privatization of the national utility TANESCO was halted in 2005 "for economic and technical reasons" (MEM 2014). Current proposals for reform include: (1) a gradual unbundling of TANESCO into independent generation, transmission and distribution companies, and (2) regulatory and structural changes of the electricity market in order to encourage private sector involvement in generation and distribution, including the introduction of standardized small power purchase agreements (MEM 2014).

It is too early to know what consequences the current reform process will have on public access to electricity services in rural areas. However, similar reforms in other African countries have not met expectations and have been widely criticized (Haanyika 2006; Karekezi and Kimani 2002; Wamukonya 2003; Weisser 2004; Zomers 2003). In essence, the criticism is related to the low interest of the private sector in getting involved with RE, due to weak rural markets, and the general failure of reforms to provide RE benefits for the poorest.

2.3.1 Decentralized systems as an alternative to grid extension

Renewable energy sources other than hydro, such as wind, solar and geothermal, accounted for less than 1% of Tanzania's national energy balance in 2008 (MEM 2009: 31). It has recently been proposed that investments in electricity generation should lead to diversification of sources for improved energy security. Primarily, investments are planned to result in an additional capacity from coal (2900 MW), but also in wind (200 MW), solar (100 MW) and geothermal (200 MW) by 2025 (MEM 2014). International organizations are also investing in new small-scale hydropower plants.

There is thus a declared intention to better utilize the renewable energy potential, particularly in the context of RE (MEM 2009). It reflects the general understanding that universal access to electricity cannot be achieved with central grid infrastructure alone (Bazilian et al. 2012; Wolsink 2012; Zomers 2003). Actors who

engage in the diffusion of RETs in Tanzania are motivated by the desire to speed up the pace of RE, in combination with financial, social and environmental considerations. A growing network of actors promotes and invests in decentralized electricity provision, including international and domestic non-profit organizations, private enterprises and developers, church organizations, individuals living in rural communities and educational organizations involved in pilot projects and technical experiments. The decentralized trend has implications for the roles of actors in the sector. Rural inhabitants who install their own systems for electricity generation are becoming producers of electricity for household consumption, and there is a development towards locally managed micro-grids based on one or more renewable energy sources (Blyden and Lee 2006).

The current development of Tanzania's energy sector is moving towards a larger diversity of actors, technologies and modes of production and distribution in comparison to previous decades. In the absence of national grid infrastructure, other actors find their niches, such as the two NGOs that I study in this thesis.

3 Previous research

The literature on energy and development in African countries is dominated by disciplinary research. Engineers and natural scientists produce the major share of research writings whereas contributions from the social sciences are less common (Hancock 2015; Sovacool 2014). In the most widely cited social science energy journals, the fields of economics and policy-making dominate the contributions. Energy studies focused on African countries are few (Sovacool 2014). When reviewing the scientific and 'grey' literatures that deal specifically with RE in African countries, I have found that, so far, most studies of electrification projects in African countries focus on large-scale, grid extension projects based on hydropower or fossil fuels. The literature on decentralized RE is relatively small, but growing. The following review summarizes what previous research has identified as drivers and barriers to RE in African countries in general and decentralized energy systems in particular. In this thesis, the concept of a barrier is defined in line with Wilkin's (2002) work, as any technical, economic, institutional, organizational, political, social, geographical or environmental factor impeding the deployment of a new technology. Barriers tend to be interrelated and it is therefore 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.

3.1 Drivers for rural electrification identified in previous studies

The rural population's access to electricity services differs substantially between countries, with higher RE rates in, for example, South Africa and Morocco, whereas the sub-Saharan region as a whole is underpowered, with generation capacity largely stagnant during the past three decades (Hancock 2015; WB 2009). This situation is about to change in some countries. A number of large hydropower dams are in the pipeline, financed by the World Bank and China (WB 2009, 2015). According to the World Bank, official development assistance to public investment in the power sector has been the main funding source averaging USD 700 million per year over the last decade (stated in 2009), 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 (WB 2009).

While most investments and political effort go into large-scale infrastructure development, there are also factors driving the interest in small-scale RETs. The

energy issues are making a comeback on the global development agenda in relation to policies of climate change mitigation and adaptation. The potential[6] of RET-based electrification is considered to be high in Africa (Bugaje 2006; WB 2009), for multiple reasons: (1) Renewable energy sources are quite evenly distributed throughout the continent, and with local generation the costs of transportation of fuels and long-range transmission are minimized (Karekezi 2002). (2) The current reliance on poorly functioning diesel generators (VPC 2008; WB 2008) and imported fuel creates an interest in small-scale RETs, especially as the prices become increasingly competitive (Akella et al. 2009). (3) Investment capital needed for RETs is generally smaller than for conventional fuels, as small/medium-scale technologies and systems can be established and enlarged in modules (Kaundinya et al. 2009; Palit et al. 2013). (4) The number of actors within the energy field has grown, and the supply of technical competence is catching up with demand. National and regional networks of actors are increasingly building capacity and spreading knowledge and technology (Hancock 2015; Karekezi 2002).

To these more general drivers, we may add specific factors driving the uptake of particular RETs. In the East African region, 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). Various solar PV technologies can provide relatively cheap energy supplies in rural areas with scattered settlement patterns, where supply via grid infrastructure is comparatively expensive (Ellegård et al. 2004; Ulsrud et al. 2015). Certain areas have a climate, topography and settlement pattern that offers possibilities to install small-scale hydropower systems for local use (Maher et al. 2003; Pigaht and Plas 2009).

3.2 Barriers to rural electrification identified in literature

Factors that are commonly mentioned in the literature as hindering or slowing down the pace of grid-extension to rural areas are: scattered populations and long-distance transmission (Karekezi 2002; Kirubi et al. 2009); high investment costs and lack of financial capital (Bugaje 2006; Marandu 2002; Peters et al. 2009); lack of generation capacity and technical losses (Ilskog and Kjellström 2008; Marandu and Luteganya 2005); low institutional quality, including inappropriate institutional frameworks,

[6] The potential for an RET can, according to Painuly (2001), refer to its technological potential, techno-economic potential or economic potential.

corruption and political interference in national utilities (Barnes 2011; Haanyika 2006; Mulder and Tembe 2008; Nawaal Gratwick and Eberhard 2008; WB 2009); inadequate organizational structures and capacities (Jones and Thompson 1996; Murphy 2001; Pigaht and Plas 2009; WB 2009); the need for cost recovery in projects – and related to that a view that subsidized tariffs are counterproductive (Ilskog and Kjellström 2008; Kankam and Boon 2009; Marandu and Luteganya 2005). The views on whether or not to subsidize tariffs diverge, and so do the opinions on what role the private sector should play (Karekezi and Kimani 2002; Marandu 2002) and whether there is sufficient political interest in RE (Zomers 2003).

The use of RETs in decentralized installations in this region is still in an early phase. Barriers identified as hampering diffusion of RETs in Africa are found at national level where lack of political support, inappropriate institutional frameworks and difficulties in accessing funding impede investments (Ellegård et al. 2004; Kankam and Boon 2009; Karekezi 2002; Lucon et al. 2006; Pigaht and Plas 2009). After installation, there are challenges in keeping the systems operating well. These are interrelated, but often classified as: (1) *Economic challenges* due to high running costs and low customer demand (Alzola et al. 2009; Gullberg et al. 2005; Ilskog et al. 2005; Kirubi et al. 2009; Tenenbaum et al. 2014); (2) *technical challenges* due to intermittent energy generation, low quality of equipment and difficulties accessing spare parts (Gustavsson 2007; Maher et al. 2003; Murphy 2001; Sheya and Mushi 2000); and (3) *social challenges* that are related to, for example, educational aspects (lack of required knowledge and skills), cultural aspects (unwillingness for behavioural change, traditional gender roles) and organizational aspects (how to create local participation, ownership and engagement) (Åkesson and Nhate 2006; Alzola et al. 2009; Murphy 2001; Peters et al. 2009; Winther 2008).

Poverty is considered to be a critical barrier to sustainability of small-scale systems and to electrification resulting in the desired social and economic development. Poverty is multidimensional and associated with much more than income level. It also encompasses the lack of access to education, basic healthcare, clean drinking water, ability to influence political processes and several other factors

that matter to people.[7] However, economic dimensions of poverty receive most attention in the literature.

Low incomes create barriers for the majority of rural inhabitants to mobilise the resources necessary for electricity access and use. Therefore, RE primarily benefits the better-off minority who can afford to use the services (Ilskog and Kjellström 2008; Marandu 2002; WB 2009). Among electricity users, many remain at very low levels or increase their electricity use very slowly (Louw et al. 2008). Evaluations show that the impact of RE on economic development is often weak (Barnes and Binswanger 1986; Foley 1992; WB 2008). From the perspectives of large and small electricity supply organizations, the low income levels among rural users create difficulties in recovering investments, balancing budgets, earning profit and accumulating capital for expansion and reinvestments (Gullberg et al. 2005; Jacobson 2007).

Many scholars propose solutions to the barriers identified and recommendations range from general 'principles' for success (Bazilian et al. 2012; Sovacool 2013) to detailed suggestions on models for financing etc. (Tenenbaum et al. 2014; Tenenbaum 2015). The recommendations for sustainable small-scale and decentralized electricity provision in rural areas often include an emphasis on local ownership, local engagement and capacity building (Alzola et al. 2009; Palit et al. 2013; Pigaht and Plas 2009; Ulsrud et al. 2015), that is, the suggestion that local actors should operate and maintain energy systems also when these have been initiated, financed and possibly constructed by external actors. In contrast to centrally controlled large-scale grid infrastructure, small-scale systems therefore require a different setup, and place higher demands on the competences of local actors. However, local ownership and control also brings opportunities for employment, influence and participation that are not available to the same degree in relation to national electric grids (Bairiganjan et al. 2010; Kirubi et al. 2009; Sovacool 2013).

Based on hindsight assessments of (large-scale and decentralized) RE processes where the introduction of electricity resulted in economic development, scholars conclude that productive uses of electricity – i.e. electricity used directly for income-generating activities such as agricultural production, refining of tradable goods and

[7] Chambers identifies a cluster of disadvantages that trap poor people in deprivation: poverty itself (having few material assets), physical weakness, isolation, vulnerability and powerlessness (Chambers 1983, 103).

commerce, or electricity uses that influence productivity indirectly such as education – are crucial if RE is to boost economic development in rural areas (Holland et al. 2001; Peters et al. 2009; Ranganathan 1993; Sovacool 2013).

To summarize, previous literature shows that the challenges for large-scale and small-scale RE are only partly the same. Actors operating decentralized systems face significant difficulties in reliable and continuous operation over time. The risk of system failure is larger. However, decentralized systems provide an opportunity to access electricity long before the national grid reaches the area, and RETs can be more affordable and bring other welcome opportunities than the national grid. I will now discuss some gaps of knowledge identified by other scholars as well as through this review.

First, other poverty-related barriers are given less attention, but there is evidence that energy supply and use is deeply gendered (Clancy et al. 2003; Clancy et al. 2011), i.e. gender inequality produces, and is produced by, the ways in which energy supply and use are organized in society, related to gender divisions of work, assigned roles, rights and responsibilities. It is argued, and there is empirical evidence to support the claim (UNDP 2004), that energy development programmes that include strategies for enhancing women's control over and access to energy services have a better chance of succeeding. Whereas gender inequality has been given relatively little attention in energy studies, it has been highlighted as a serious problem for economic development in East-Africa. Discriminatory institutions and practices hamper women's participation in business and market activities (WB 2012). Its negative influence on small-scale energy systems is less well studied.

Second, the attention given to human-related aspects is so far very limited (Sovacool 2014; Wolsink 2012). The focus tends to be more on techniques, structures and regulations rather than the people involved and their perceptions of the situation. For example, what does it mean that a 'cultural mindset' works as a barrier to technology diffusion; what is a 'poor maintenance culture' or 'lack of local capacity'? Energy scholars and practitioners sometimes use these concepts to capture aspects of human behaviour that are considered as barriers to development. But each of the concepts hides a rich and heterogeneous repertoire of human reasoning, ideas, behaviour and perceptions. Arguably, a stronger focus on actors, their perceptions, abilities and interactions will be necessary for explaining the behavioural and

organizational aspects of energy supply and use. Social scientists are needed for their interest in the messy aspects of human–technology interactions.

Third, it has been argued that the energy and development field suffers from a lack of systematic case study comparison. As highlighted by Ilskog (Ilskog and Kjellström 2008; Ilskog 2008), the large number of case studies and evaluations of various energy interventions on the continent lack a common frame of analysis, and cross-case comparison is therefore very difficult. In response to this observed weakness in the field, Ilskog proposes a method for evaluating energy projects by means of indicators. As mentioned, other scholars have made similar cross-case comparisons in order to identify factors of principles for success. These contribute very important knowledge. However, the enumerations of indicators, factors and principles are based on empirical cases rather than on a common theoretical framework. So far, they lack theoretical justification: how do the factors identified as critical relate to one another, what is the interplay? Are factors bound to place-specific contexts? (Coenen et al. 2012) Are factors ordered hierarchically, which ones are dominant? Do factors contradict one another, or create synergies? At what level do factors play out? Are there cross-level interactions between factors, in the sense that national and local processes are intertwined?

For example, it has been proposed that energy programmes should be integrated with other development efforts, requiring cross-sector coordination (Åkesson and Nhate 2006; Kirubi et al. 2009). But what are the points of intersection where cross-sector coordination and parallel investments are needed? Established systems for energy supply and use are embedded geographically and organizationally in other societal sectors and energy system lifecycles intersect in innumerable ways with resource exploitation, production, distribution, consumption, (recycling) and waste (Markard 2011). Given that energy issues cut across societal sectors and scales, arguably, informed decisions require a wide knowledge base and analyses that take these into account.

To summarize the research gaps, there is need for further attention to the interplay between factors in RE processes, how systems for decentralized electricity provision interplay with existing energy use and supply, and how they become embedded in rural contexts and in other societal sectors. I argue that socio-technical approaches can assist scholars to analyse the relationships between relevant factors, and identify general and system-unique patterns. Hopefully, this will contribute to

developing a solid conceptual base for case comparisons and improve the preconditions for informed policy-making. This thesis contributes to some extent to better understanding of the interdependencies between national level and local level, and the co-emergence of energy systems and local contexts, although much work remains to be done. Also, the review points to lack of knowledge on human-related aspects, including dimensions related to class and gender. The thesis seeks to make a contribution to filling this gap by exploring the differentiated views and experiences of actors at multiple organisational levels, and by investigating how relations of power and RE processes influence each other.

4 Theoretical perspective

This section consists of three parts. First (section 4.1), I review socio-technical approaches of relevance to the empirical object of study: RE processes. The review results in an outline of the systems-theoretical starting points, and the positioning of the analysis in IS (innovation system) studies. Two fields for theoretical development are highlighted. Second (section 4.2), by alternating between theory and empirical work, I develop a theoretical framework specifically for analysing the introduction of small-scale electric systems in rural communities and the process of formation of a new socio-technical system that co-emerge with the context. Third (section 4.3), the review of the IS literature leads to the conclusion that existing conceptual frameworks do not allow me to fully capture the political dimensions of RE. Therefore, the IS perspective needs to be complemented by theories on human power. The resulting contribution is a conceptualization of how power relations are being (re)produced, negotiated and contested in human–technology–nature interactions in RE processes. Together, the three parts inform the framing of research questions, and thereby the type of analysis conducted.

4.1 A systems approach to rural electrification

Systems thinking is focused on messy relationships and challenging problems in the real world, and uses simplified models to produce holistic understanding about complexity (Checkland 1999; Meadows 2008). A general definition of a system is "a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its 'function' or 'purpose'." (Meadows 2008: 188) Systems analysis involves delineating a system boundary and selecting what to include and exclude – based on the question or problem in focus, the desired level of detail, and the abilities and aims of the observer. Therefore, systems analysis represents a partial perspective (Haraway 1991; Meadows 2008; Rose 1997).

Socio-technical systems approaches[8] see society and technology as interrelated and co-evolving. In this view, innovation and technological change are characterized

[8] There are not one but multiple analytical perspectives that can be commonly identified as socio-technical. The disciplinary backgrounds of scholars are diverse, including history of technology; sociology; industrial and evolutionary economics and management studies; political science; and cultural studies.

by uncertainty and complexity, with a multiplicity of actors and factors influencing its direction (Hughes 1983; Nahuis and Lente 2008; van den Bergh et al. 2011). When a technology is successful, it goes through a general process from invention (discovery), to innovation (the first commercial application) and diffusion (widespread replication and growth) (Grübler 1998).[9]

One of the early and very influential works that inspired the development of socio-technical change as a field of study was the historical study of large technical systems (LTS) by Hughes (1983). He studied the development of large networks of power lines reaching across industrialized countries during the years 1880–1930, and conceptualized the development of power systems as a history of technology and society: "Electric power systems embody the physical, intellectual, and symbolical resources of the society that constructs them … In a sense, electric power systems, like so much other technology, are both causes and effects of social change. Power systems reflect and influence the context, but they also develop an internal dynamic." (Hughes 1983: 2)

The scientific fields of IS studies and science and technology studies (S&TS) have produced significant contributions to the study of energy transitions. The IS literature – with its roots in evolutionary economics – explicitly takes a systems perspective on innovation (Bergek et al. 2008b; Carlsson and Stankiewicz 1991). Technological and institutional characteristics of the socio-technical systems are analysed jointly "because they co-determine each other" (van den Bergh et al. 2011: 9). The analytical approach is to identify system elements, structure and behaviour, or, in other words, to study system configurations and their performance. There are various complementary models that differ in their analytical focus and delineation of the system boundary (van den Bergh et al. 2011): national innovation systems (NIS) and regional innovation systems (RIS) delimit the system for study spatially, whereas sectorial systems of innovation (SSI) and production focus on the sector of a particular (group of) product(s). Technological innovation systems (TIS) focus on technology and knowledge as the base for system delineation, often in combination with a spatial delineation. There are also other differences: whereas the TIS

[9] Different models of technological diffusion have the S-shaped development curve in common, with time along the x-axis and a performance indicator, e.g. percentage of adoption, along the y-axis (see e.g. Grübler 1998: 51; Rogers 2003: 11).

framework has focused mainly on emergent technologies and innovation systems in the initial formative phase – where the system structure is still unstable and forming – SSI studies have focused on novelty in established sectors that are quite stable (Coenen and Díaz López 2010; Karltorp 2014; Markard and Hekkert 2013).

The IS literature conceptualises development of system structure as a process of reconfiguring and coevolution between system components. Structural features are perceived as important but not enough to explain the potential discrepancy between system behaviour and wished for performance (Jacobsson and Bergek 2011). To this end, TIS scholars have identified a set of generic sub-processes that contribute to achieving the goal of developing, diffusing and utilizing new technologies. The processes are: (1) knowledge development and diffusion; (2) entrepreneurial experimentation; (3) influence on the direction of search; (4) resource mobilization; (5) market formation; (6) legitimation; and (7) development of positive externalities (Jacobsson and Bergek 2011).[10] The strength of TIS analysis is that the combined analysis of system structure and behaviour allows scholars to identify factors blocking development of the TIS. Indeed, the aim of TIS analysis is to assist policy-makers and other actors who want to develop the 'TIS' to identify points of intervention in the system (Jacobsson and Bergek 2011).

In the S&TS field, the multi-level perspective (MLP) has emerged, partly as a critique of IS approaches, as an analytical frame for understanding the societal context of socio-technical change and the interplay between processes at different scales and organizational levels (Geels 2004; van den Bergh et al. 2011). It analyses socio-technical change at three interrelated levels: the development of radical energy innovations in *niches* (incubator spaces), embedded in *regimes* and *landscapes*.[11] The MLP literature provides explanatory analyses of the relative stability of socio-technical regimes and how pressures for change in the regime can originate both at the niche and landscape levels (Alkemade et al. 2011; Geels and Raven 2006; Rosenbloom and Meadowcroft 2014). MLP scholars have provided rich empirical work on processes occurring within the level of niche – the practices of learning,

[10] There are alternative versions, e.g. (Hekkert et al. 2007) of this list of key processes in TIS literature, but there is no significant conflict between them in terms of conceptual content.

[11] In short, *niches* consist of emerging technologies, innovative practices and actor networks; *regimes* consist of incumbent institutions, practices and technologies; and the *landscape* is a wider societal context wherein macro level political influences and unexpected events take place (Rosenbloom and Meadowcroft 2014).

collaboration and experimentation (Alkemade et al. 2011; Geels and Raven 2006; Ornetzeder and Rohracher 2006). Learning processes enhance technical and organizational innovation and reflection on the innovation process itself (Farrelly and Brown 2011; Geels and Raven 2006). Scholars also provide strategic advice on 'Strategic Niche Management', i.e. how to achieve reflexive management of experiments in real settings (Geels and Kemp 2007).

IS and MLP approaches partly overlap, they have different merits and complement one another. [12] They each provide a specific point of view and situate the researcher differently in relation to the problem studied. In these interdisciplinary research communities, scholars integrate concepts and ideas from nearby fields. Among those, two ideas are of particular relevance for the conceptual understanding of RE processes: the idea that complex systems can self-organize and the idea of non-human entities as 'actants'. First, the literature on complex systems proposes that such systems can develop the property of self-organization, that is, they are able to structure themselves, create new structure, to learn, diversify and become increasingly complex (Gunderson and Holling 2002; Meadows 2008; van den Bergh et al. 2011). As Meadows (2008) frames it, complex systems develop their own dynamics beyond the intentions, desires and control of human actors. The more complex the systems are, the harder it is for actors to direct them.

Second, in the wider field of S&TS, one of the critical ideas that has emerged is that artefacts become enrolled in exercises of power and play an active role in regulating human behaviour (in ways similar to institutions), working as 'actants'. [13] The concept originates in actor-network-theory (ANT), which erases the *a priori* distinction between human, animal and machine. Infrastructures are said to work as actants because their physical structures provide durable regulatory arrangements. For example, the Paris underground was designed using non-standard rails in order to prevent private railway companies to traffic the rails. Thereby, the political leadership at the time effectively ensured long-term public ownership (Latour 1988). Artefacts have features working as "scripts", which regulates human behaviour by encouraging, allowing and forbidding certain types of uses, with social, material and discursive

[12] See for example (Alkemade et al. 2011; Geels et al. 2008) for discussions on how to bridge between MLP and TIS perspectives and other relevant literatures.

[13] The concept of 'actants' has also been used for animals and should have relevance also for natural forces, such as wind, and geographical conditions that condition human behaviour.

consequences emerging (Akrich 1992). In the ANT literature, actants are conceptualized as parts of complex networks. Networks are hybrid compositions of humans and non-humans, which emerge from the accumulation of choices, decisions and actions, at multiple societal levels. Macro structures, such as electricity networks, are conceived of as complex networks that remain local at their nodes (Latour 1991).

These two ideas challenge the idea of human agency as the only 'action' or 'power' we need to consider and they emphasize the importance of human–non-human interactions in nested systems. To summarize my stance towards the socio-technical system literature, I use its rich systems understanding as my theoretical starting point. In particular, I build on the analytical focus on: (1) processes (rather than states), (2) interactions between system elements, (3) the multi-layered and nested structure of subsystems embedded in systems (4) the understanding of system behaviour as emerging in relation to the context, and (5) both system and context changing in the process. Further, I draw on (6) the understanding (especially in S&TS) of technology as an active and dynamic force in society (rather than a passive tool), which informs my attempts at understanding the importance of the material properties of electricity infrastructure.

In this wider literature on socio-technical approaches, I position myself in the field of IS studies. This is because its conceptual understanding of system dynamics provides a fruitful starting point and conceptual tools for analysing RE processes in Tanzania. However, I chose a general and explorative approach rather than a single framework to guide my analysis. First of all, this is because the existing frameworks focus on specific sectors or technologies, whereas I focus on RE processes at multiple organizational levels and geographical scales, by use of different technologies. Second, there is, arguably, a more fundamental problem embedded in conducting theory-driven analysis that applies existing analytical frameworks (NIS, TIS, SSI and LTS) to contexts very different from the (mainly) industrialized contexts in which these frameworks were developed. The risk is that applying, for example, the TIS framework to the diffusion of small-scale hydropower in Tanzania results in a conclusion that the TIS is poorly developed with important components lacking. Such analysis contributes to reproducing African societies as "bad copies" of Western society (Ferguson 2006).

If we use a more general and open conceptual approach we can, arguably, theoretically characterize the Tanzanian energy and electricity sectors and capture

what is there, rather than *what is missing*. It allows for reflection upon what insights the different frameworks can lend us in specific contexts, and what theoretical development can come from iterating between empirical findings and theoretical perspectives. A brief description of the features of the electricity subsector of Tanzania can help make this point clear.

At the spatial scale of Tanzania, the energy system is fragmented and very different from energy systems in, for example, European countries. The technologies for large-scale production, transmission and distribution are mature and well-known technologies invented and developed in other contexts, transferred to Tanzania. Expansion of the national grid is done according to internationally accepted technical and security standards. However, in terms of an LTS, the national grid is not well developed. Its diffusion is on a limited scale and it has not saturated the market for electricity, not even in the urban areas where the infrastructure is more developed. In comparison, the widespread use of diesel generators and batteries can be considered mature technologies that have diffused widely, that have a large share of the urban market and dominance in rural markets for electricity, together with kerosene, wood and charcoal in the areas of lighting and heating.

Looking at RETs for decentralized electricity generation and distribution, the solar PV market is growing, but is still at an early stage. It is linked to the international market with the technology (hardware and software) mostly imported from abroad, and a range of products diffusing in urban and rural markets. There are also examples of niche development (protected from mainstream market pressures), for example pilot projects funded by donors where technical, organizational and financial experimentation and innovation are taking place, with more or less success (Bångens et al. 2013). Small-scale hydropower installations have a long history in Tanzania and are being installed, using mature, mostly imported, technology and a combination of foreign and domestic expertise. There are also elements of niche experimentation with local manufacturing of turbines, and linkages to the international TIS around in-stream turbines. A domestic innovation system is most pronounced within the bioenergy field. There is experimentation and local manufacturing and innovation around, for example, biofuels (also for use in generators) and improved cook stoves.

There are previous studies that have applied one specific analytical framework to African energy sectors. For example, Szogs and Wilson (2008) conceptualize

biomass digestion technology as a NIS, and Kroesen and Kamp (2010) study the solar PV sector in Kenya as a TIS. They have concluded, unsurprisingly, that the systems are at a very early stage of development with important components lacking. The authors have raised doubts regarding the usefulness of innovation system frameworks in their current shape in studies of various African countries, due the limited (or non-) existence of such systems (Muchie et al. 2003; Szogs and Wilson 2008). In contrast, Tigabu et al. (2015) conclude from their analysis of emerging bio-digestion TIS in Kenya and Rwanda that the TIS functional approach can be fruitfully applied in the East-African context. The critique by post-colonial scholars (Appadurai 1996; Ferguson 2006; Mbembe 2002b) of how researchers continue to portray 'Africa' as a continent of absence and failure is critical to reflect upon, As IS scholars move ahead with studies in African countries.

To conclude this review of socio-technical approaches, I outline two areas of development, where the use of socio-technical approaches in the East African context can generate interesting research at the same time as it contributes to theoretical development of the IS field.

The first area for development has to do with the way energy systems are embedded in society. The political economies in rural Tanzania are linked to energy systems in ways quite different from the European context. While it is clear that economic aspects (for example widespread poverty and low level of industrialisation) influence the process of socio-technical change and have repercussions on diffusion of energy systems, it is not clear how new energy technologies change the way energy supply and use are embedded in local economies. In order to understand the potential for widespread diffusion of small-scale and renewable energy systems in African countries, and the consequences thereof, it is necessary to consider the structure of the economy and the direct link between local livelihoods and available natural resources. The theoretical consequence is that scholars should examine how energy systems are embedded in and overlap with local economies and include the natural resource base for electricity generation in their analysis (Wolsink 2012). This is not always the case in IS studies (Karltorp 2014), but in this type of poor, agrarian setting, it is, arguably, necessary. Or else, we run the risk of missing out on factors of critical importance for the continued functioning of the energy supply and distribution system and its consequences for local livelihoods.

The second area for development I want to highlight is the political dimension of socio-technical change. The IS literature has a strong focus on the importance of actors and institutions. However, according to some scholars, the political dimensions are not always adequately addressed in writings in the field (Meadowcroft 2011; Smith et al. 2010). This can be problematic, because, as Meadowcroft argues, energy transitions are inherently political. Interventions that aim to assist a transition to sustainable energy systems disrupt established political interests, and, therefore, bring conflict (Meadowcroft 2011). Some scholars provide rich descriptions of the crucial role of politics and policy in historical analyses of energy transitions (Jacobsson and Lauber 2006; Rosenbloom and Meadowcroft 2014). For example, the development of wind power and solar PV in Germany between 1974 and 2003 involves a 'battle over institutions' between the emerging advocacy coalition for these technologies and incumbent energy sector actors with ties to the coal and nuclear industries (Jacobsson and Lauber 2006).

Still, Meadowcroft suggests that a stronger focus on the relations between 'interests', 'institutions' and 'ideas' is necessary in order to capture the political dimension of socio-technical change (Meadowcroft 2011: 73). I share his opinion. However, I argue that the theoretical *conceptualizations* of (and not just the empirical attention to) political dimensions of energy transitions are still at an early stage. Engagements with the rich philosophical debate on human power can assist us in improving the clarity and precision of analysis and use of concepts. I take a few tentative steps in that direction by integrating and developing theories on human power in relation to electrification. But first, I present the framework for analysis of decentralized RE.

4.2 Framework for analysis of decentralized rural electrification

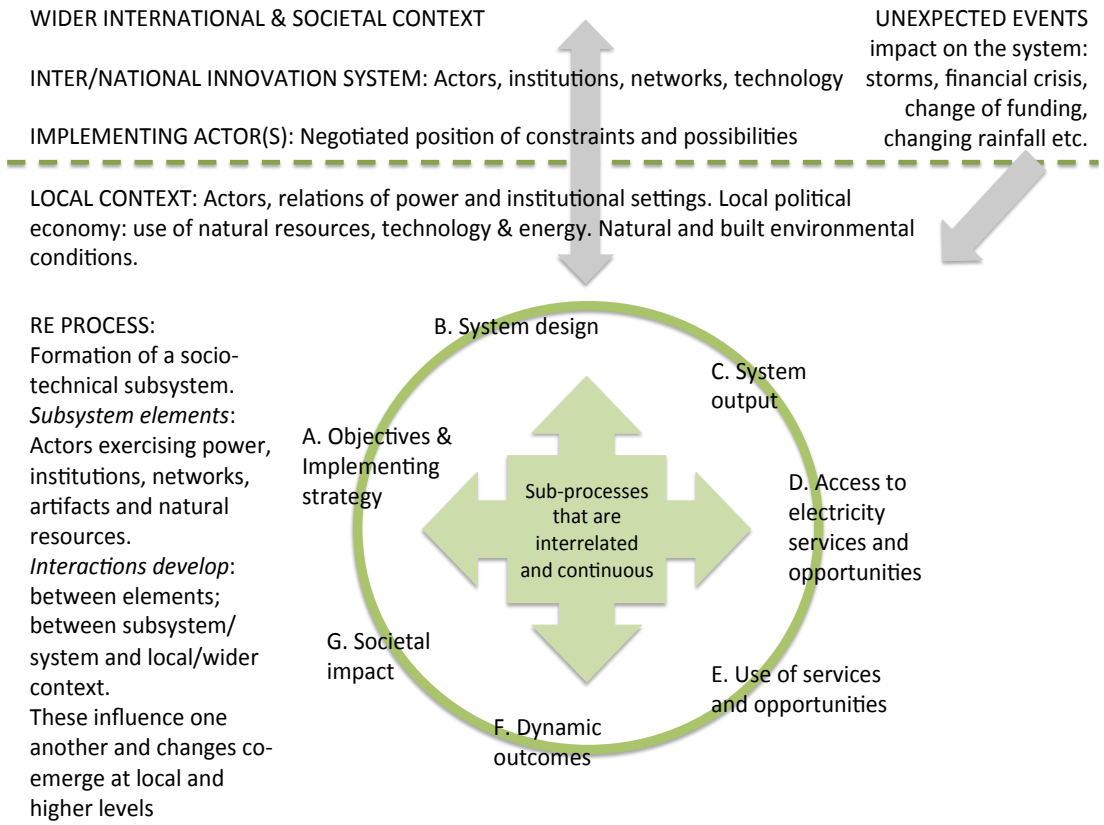
I conceptualize small-scale systems for local electricity generation and distribution by use of renewable energy sources as subsystems in an innovation system that is emerging at the inter/national level around small-scale and renewable energy based systems (Goldthau 2014).[14] At this early stage of RE in Tanzania, the success or failure of individual projects contributes to the societal learning process (Geels and

[14] In Tanzania such systems can be used both in areas with and without large-scale grid infrastructure. In rural areas, decentralized generation *and* distribution dominate. In contrast, small-scale RETs for decentralized generation in, e.g., Europe are more often connected to large-scale grid infrastructure, and thus distribution is not necessarily decentralized.

Raven 2006). Successful projects can help mobilise resources for further investments and contribute to forming markets for technical components and services in the region (e.g. turbines, transformers, grid components, software, technical services and skilled technicians). Failures may undermine the legitimacy of RETs as a solution for rural areas and as an alternative to the current use of diesel generators.

What then is taking place at the local level where an electric system with local production and grid-distribution is introduced? Moving from the general IS perspective to a conceptualization specific to decentralized RE, Figure 1 (below) visualizes the interrelated sub-processes of system formation at the local level. Even though this framework represents a simplification of real-world processes, it helps identify the intersections and potential points of friction in NGO-led electrification, which disturb the causality between introduction of electricity services and desired social and economic development (see section 6.3.3). What it does for us, therefore, is to identify processes that require our attention and questions that we can ask in order to understand what is going on in a particular "case".

Figure 1. A socio-technical framework for analysis of small-scale rural electrification processes



4.2.1 System formation

Electrification is understood as a process of formation of a new socio-technical system (see Figure 1). Throughout the process, what is understood as the system structure and behaviour develops interrelated with, and mutually influencing, the local context. What we label as the 'system' depends on the analytical focus (and hereafter I will simply use the term 'system' when the discussion is focused on decentralized electric systems). The system forming at the local level is embedded, and consequently a subsystem, in the inter/national innovation system. Also the larger innovation system is embedded in an energy sector and wider societal context. Hence, there are cross-scale interactions and multi-layered structures to consider. Over time, as a decentralized system becomes embedded in and an integrated part of the local context, both change, and so do their interactions with higher levels. In the following, the discussion is mainly focused at on-the-ground processes in rural communities.

System formation is an ongoing process that starts with the plans of introducing the technology in a new setting and also continues after the components are in place and the service delivery has started. So my use of system formation is different from the concept of 'formative phase' in the IS literature, which refers to the early innovation phase that ends with the take-off and market saturation phases (Bergek et al. 2008a). For actors in local social-technical systems, operating the system in a dynamic environment requires continuous attention to emerging problems, and taking action, in order to maintain a well-functioning system.

In line with IS scholars, I identify actors interrelating in networks, institutions and artefacts as system elements, but also include natural resources required for electricity generation in the system (Hughes 1983; Karltorp 2014). There are three relevant categories of interactions to consider: (1) relationships and networks between actors, (2) interactions between human and non-human elements, and (3) interactions between non-human elements (e.g. between technical components, or technology and ecosystem). Where humans are involved, we can identify moments where exercises of power are manifested, and the interactions hold potential for dominance and empowerment. Systemic properties emerge from all three types of interactions, often as a result of feedback loops in the system, and can lead to desired as well as unexpected and negative outcomes.

In the following, the interrelated sub-processes (A–G) of the formation process (depicted as a circle in Figure 1) are described. It is a summary of the theory section

in Article 2, here providing only an overview. The framework is explicitly applied in the analysis of the two cases of decentralized RE in section 6.3.

A. Objectives and implementation strategy

The way the implementing and executive actor(s) work(s) and exercise(s) power in relation to other (local) actors is of great importance for the direction of the RE process. What are the objectives and strategies? What kinds of relationships are established? How are decisions made and by whom? Different kinds of actors work according to different logics and constraints. The kind of actor driving the process is therefore important: is the RE process undertaken by a local or external actor, as a 'development project', a 'business investment' or a 'social service to the community'?

B. System design

System design is about what kind of system is planned. I conceptualize system design and configuration as dynamic and iterative processes where actors negotiate and exercise decision-making power on what system to put in place. Depending on what actors are driving the process the system design can be expected to differ in the degree to which it is tailored to local conditions and needs. Place-specific characteristics (geographic, ecological, social etc.) condition the translation from plans to practice.

C. System configuration

The many choices made on various aspects of system design result in a particular system configuration (Ulsrud et al. 2015; Ulsrud forthcoming). The system configuration is about what kind of a system is actually put in place on the ground. The configuration results in conditioned electricity services, made available to potential users at certain conditions (e.g. at a certain cost, for specific hours and places, by contractual agreement). Hence, we also need to ask: what are the conditions for use of services? The system configuration changes over time.

D. Electricity access

I define access to electricity as the capacity to utilize services or capitalize on opportunities related to the provision of electricity. Access involves specific exercises

of power. It is a process that involves a number of actions to gain access and maintain it, and the risk of losing access. There are also actors who control the access of others. We need to ask: who gains access and how? What factors enable and constrain individuals and groups from gaining access? What social relations, institutions and assets are mobilized in the process? Who controls the access of others?

First, at the local level of a community, a range of factors (individual, contextual and unexpected) impact positively and negatively on individuals' and collectives' capacities (i.e. power). Second, I identify strategies used by individuals and collectives to gain, maintain and control access: mobilizing assets, drawing on relations, discourses[15] and institutions (see also Ribot and Peluso 2003). These strategies of exercising power are often used in combination, and may involve attempts at dominance as well as empowerment. People who have connected to the grid may control or restrict the access of family members, or facilitate others' access by sharing with family, friends and kin. People who control access can thus use it to maintain or remove barriers to access for other people.

E. Use of services and opportunities

Being capable of utilizing energy services and related opportunities leads to the question: what do individuals and collectives use energy for? What uses are prioritised? How do uses change over time? The literature on energy and development tends to distinguish between productive use, household use and use for public services. But the boundaries between these are not clear, as many non-commercial uses and purposes have economic dimensions to them (Cabraal et al. 2005). The household should not be used as the smallest unit of analysis as there are intra-household differences and relations to consider (Agarwal 1997; Carney 1996; Winther 2008).

F. Dynamic outcomes

What are the consequences of electrification for individuals and groups? Who perceives what as a benefit? How do outcomes change over time? If people lose

[15] There are multiple meanings of the concept discourse. In this context discourse refers to sets of interlinked expressions, statements and concepts, such as the 'development discourse'. There are multiple and competing discourses. Discourses influence how we understand and interpret the world (Eriksson et al. 2015).

access, why is that? As indicated by these questions, outcomes are dynamic and can be positive, negative or ambiguous. Analytically, I distinguish between outcomes at the levels of individual, group and system. System outcome is conceptualized as perceived system 'functionality', that is, how actors judge the system behaviour in relation to their desires, expectations, needs and interests (Mehlwana 1997; Ornetzeder and Rohracher 2006; Pinch and Bijker 1984). Asking whether the system works 'well' opens up an analysis of competing discourses, differing perspectives and conflicting interests between actors and the degree to which competing claims are acknowledged and considered legitimate (Pinch and Bijker 1984).

G. Societal impact

Analytically, RE leads to societal impact when outcomes for individuals and groups translate into impact on the community at large, that is, when a broader societal change can be convincingly said to occur and is linked to the socio-technical system formation: Is daily life reconfigured in time and space around electricity use? Are there changes to local livelihoods and quality of life?

From this brief outline it should be clear that there are political dimensions, exercises of power and potential conflicts of interest embedded throughout the RE process. It is also a process where the productive and creative abilities of humans can be enhanced, and people can work together for mutual benefit. Further, there are numerous potential feedbacks and feed-forwards in the formation process (see Figure 1). For example, individual and group outcomes influence the system configuration over time (F→C). Users losing access can have a negative effect on the ability to operate and maintain a well-functioning technical system. Positive economic outcomes for many individuals can result in a growing local economy and cash flow (F.individual→G→D→F.system), enable new businesses to grow and demand electricity services, generating higher incomes for the utility. If demand exceeds capacity and expansion is not possible (G→B), limited capacity of the energy system can become a bottleneck to further development of the local economy.

Finally, an energy system intervention that includes processes for learning and evaluation will assess outcomes and impact and draw lessons for how to improve the current, as well as other systems (A→F→G→A→B→C). In the ideal case, monitoring and evaluation leads to improvements and problem-solving along the

entire chain and a positive spiral of co-emerging subsystem and context (Farrelly and Brown 2011; Geels and Raven 2006; Ulsrud forthcoming).

4.2.2 Positioning the analysis in relation to the analytical framework

The framework is intended to guide research on decentralized RE. It is possible to use the framework to zoom in on particular parts of it and open up to a whole set of detailed questions, exploring for example: what is required to remove barriers to access; what technical, financial and organizational innovations will allow the system to adapt to changing circumstances; how can societal impact and qualitative changes be evaluated; and how is learning organized within and between projects? These are all interesting and relevant questions. My interest lies specifically in the *encounter* between the new system (its elements, interactions and structure) and the local society. I wish to know how and why social relations and the new system influence one another, what the points of intersection are; and what that means for individuals, groups and the system. Therefore, it is necessary to engage more closely with the concept of power.

4.3 Human power relations and electrification

Electrification processes often serve to (re)produce existing social hierarchies and the privileged position of some groups in society (Clancy et al. 2011; Winther 2008). This pattern is also seen in other resource use contexts (Harris 2006; Schroeder and Suryanata 1996; Schroeder 1997). However, as the following discussion will show, the introduction of electricity services from a well-functioning source and of higher capacity can also destabilize existing social relations and expand the space for individual and collective agency in tension with existing societal structures (Grammig 2003; Harris 2006; Schön et al. 1999). This makes electrification processes highly interesting and important objects of study, as they can provide insights into the social and material base of political economies, and relationships between agency and structure in processes of socio-technical change. In the following, I will provide some theoretical starting points in existing conceptualizations of power that are relevant to the discussion.

Power is a theoretically contested concept with multiple meanings. Empirically, studying power is challenging, and there are many pitfalls for any researcher trying to capture the workings of power in her or his data. It has been proposed that the most effective power at work is the one that masks itself and becomes invisible to us

(Lukes 2005). Discussing and defining power is in itself a political act because our conception of power "may serve to reproduce and reinforce power structures and relations, or alternatively it may challenge and subvert them" (Lukes 2005: 63). Further, there are scholars, for example Latour, who question the usefulness of the concept of power and consider it a pliable and empty term (Latour 1986). Despite these debates and the challenges involved both in theorizing and empirically studying 'power', I find it relevant and helpful to apply the theoretical discussions on power to my particular empirical area of research, in order to better grasp the transformative potential of rural electrification. Before we engage with the workings of power specifically in relation to electricity, we must first learn more about two different conceptualisations of power: (1) power as human capacity, and (2) power as constituting social relations, but also, interactions between human and non-human entities of importance to outcomes in RE processes. Thereafter, I identify two areas (in addition to the ways in which electricity can transform the social organization of work, as mentioned in the introduction) where destabilization is likely to occur: in the distribution of and control over resources; and in the relationships between places, identity and social hierarchies.

4.3.1 Power as capacity and constitutive power

In the first conceptualisation, power is understood as 'ability' or 'capacity' to act (both words are used, sometimes interchangeably in the literature on power).[16] In its most general sense, "having power is being able to make or receive any change, or to resist it (Lukes 2005: 69). This understanding of power is what Allen (2014) refers to as an action-theoretical conception of power. In this view, we can consider power*s* in the plural, as multiple, dynamic and situated capacities of individuals or collectives. These are, more or less temporarily, actively or passively, employed or mobilised in specific situations, in specific places and in relation to other humans, living beings generally, artefacts and the natural world. Thus, the capacity to exercise power(s) is contingent and emergent (Allen 2008, 2014; Valentine 2007).

Powers are exercised in ways that are productive and repressive, and have effects that can be seen as negative, positive or both. *Productive* power creates action, whereas *repressive* power says no to action and exerts influence to hinder action

[16] I will use the word 'capacity' as it has a wider meaning than 'ability' (Sevä and Jagers 2013). Ability also refers to the possession of skills, which are more stable than the contingent exercise of power.

(Lukes 2005). Power as capacity presupposes a certain degree of freedom and choice and a possibility to act differently or refrain from action (Lukes 2005). Power as dominance is usually referred to as power *over*, but there is also power as a positive force that is creative and nurturing: power-*from-within* and collectively shared: power-*with* (see Figure 2).[17] Human relations are messy and can display all these in parallel. Social relations of dominance and subordination are important for explaining differing outcomes in RE processes. However, electricity as such also opens up to collaborative exercises of powers and actions for mutual benefit and social equality. Domination and empowerment are interconnected (Allen 2008), and for this reason my conceptualisation must include this empowering dimension as well. Figure 2 visualises four types of power that can be inferred from the action-theoretical conceptualization.

Figure 2. Four types of action-theoretical power. Based on Lukes (2005) and Allen (2014).

	Power to	
	Dominance *Power over*	Empowerment *Power-from-within* *Power-with*
Repressive power	A	C
Productive power	B	D

Much has been written on the two types of dominance, represented by boxes A and B in Figure 2. Among feminist scholars, exercises of power of type D have been given attention in addition to types A and B. An example of type C exercise of power is, I propose, the collective act of women in the Pink Saris movement[18] to protect the

[17] Some scholars want to reserve the concept of power for analysing dominance (e.g. Lukes 2005). A number of feminist scholars have, on the other hand, argued that the productive, creative and mutually empowering aspects of power together have been overlooked due to male bias in science (Allen 2008; 2014).

[18] http://www.gulabigang.in Accessed on 4 April 2015.

rights of women by beating up abusive husbands and letting them know they will suffer more violence if they ever mistreat their wives again.

Power as dominance takes many shapes and can involve a more direct or indirect exercise of power, control over the discourse and agenda, and the naturalization of dominance, i.e. securing the consent of subordinated groups (Lukes 2005). Dominance can also be secured by uneasy compromise between actors, as shown by Li (1999). There are stabilizing mechanisms at work that (re)produce social hierarchies: dominance is produced by means of discourses and embedded in institutional arrangements (e.g. legal institutions and administrative procedures) and maintained/reinforced through material and symbolic practices (Butler 1990; Foucault 1995; Lukes 2005).[19] For example, 'development' planning is an important activity and mode through which 'the state' can continuously restate its raison d'être and assert its authority and legitimacy in relation to the citizens (Li 1999). At the same time, discourses and institutions are unstable and 'development' programs can become arenas for struggles over power, where relations of rule are compromised and put at risk (Li 1999). As seen in many different resource-use contexts, actors draw on dominant discourses and institutions strategically to forward claims and protect their interests (Ribot 2009; Schroeder 1997; Sikor and Lund 2009).

Discourses commonly build on categories of social difference (for example class, gender, colour of skin, religion, age, sexuality and physical ability) to legitimise dominance (Harris 2006; Young 1990). As scholars have convincingly argued, the use of simplistic social categories imposes a stable and homogenizing order on a much more diverse and complex social reality, thereby (re)producing social hierarchies (Butler 1990; McCall 2005). This insight is captured by the concept of 'intersectionality', which highlights that social positions at the individual level are fluid, multiple, intersecting and situated (Shields 2008; Valentine 2007). The concept emerged from a combination of critiques[20] in the 1980s of the way that common analytical categories of sex, race, class, sexuality etc. were used by scientists at the

[19] It should be noted that there is a significant overlap between the concepts of 'discourse' and 'institution'. Partly, it is a matter of disciplinary preference. Power produces both, and discourses can be seen as taking the shape of institutions, regulating human behaviour and being more or less codified (Li 2005).

[20] McCall mentions the following: feminists of color against white feminists' use of gender and women as unitary and homogeneous categories; by feminist scholars criticizing the male bias in philosophical underpinnings of science and modernity; and the critique by postmodernist and poststructuralist scholars of Western philosophy, history and language.

time (McCall 2005). This critique has been important for the discussion on how to handle social categories, given the fluidity of social positions, in research on social inequality; whether or not we can meaningfully talk about "women" without reinforcing a homogenizing and discriminatory social order (McCall 2005). [21]

However, the refusal of social categories can lead to a theoretical inability to account for structural relations of inequality at the group level. In line with McCall (2005) I intend to use social categories strategically and explore how, in particular, gender and class are produced and become salient or foregrounded as social markers of difference in relation to particular resources (Harris 2006; Nightingale 2006). The focus is on the process whereby identities are un/made in relation to the discourses, specific resources, places and situations in everyday life where individuals may have multiple and sometimes conflicting experiences of subordination and empowerment (Butler 1990; Gururani 2002; Valentine 2007).

It is in relation to the rich work on discourses and institutions that the second relevant conception of power has developed – inspired to a great deal by Foucault's work on disciplinary power and subjection (e.g. Foucault 1980; Foucault 1995). It does not build on the idea of human capacity at all. Instead, power is spread throughout the entirety of the social body (Allen 2008). This 'constitutive conception' of power "focuses on the fundamentally trans-individual and relational ways in which individuals and the social worlds they inhabit are themselves constituted by power relations" (Allen 2014).[22] The idea of constitutive power has opened up to new conceptualizations of human–technology interactions (such as in the ANT literature) and human–nature relations as mutually constitutive (Castree and Braun 2001; Gururani 2002; Nightingale 2006). For example, Nightingale (2006) shows how norms related to gender and caste become important in processes of environmental change in Nepal. Work practices related to social norms have real ecological effects and environmental change influences, changes and (re)produces aspects of social

[21] Some scholars reject the use of categories at all and work to deconstruct them; others complicate existing categories by identifying neglected points of intersection between for example class, gender and colour of skin; and a third approach is to use categories strategically as 'anchor points' for the purpose of investigating how social relations are (re)produced and changing (McCall 2005).

[22] A core concept here is the idea of 'subjection', the processes whereby oppressed individuals often more or less fully accept and identify with subordinating norms, such as ideas around gender roles. Scholars have shown how subjection is ambivalent and how attempts to resist culturally prescribed behaviour are contradictory, because they paradoxically also confirm subordinating norms (Allen 1998; Butler 1990; Mahoney and Yngvesson 1992).

relations. In this framing, ecological environments are treated not as background or context, but as particular and specific places and spaces influencing social relations.

In the more system-theoretical oriented IS literature, there is, in my view, a fruitful parallel between the idea of constitutive power as a multiplicity of 'force fields' (alternatively a 'network' or 'web' (Allen 2014)) and the framing of systems as having emerging properties, sometimes self-organizing behaviour, and producing outcomes beyond the control of actors. Bringing these perspectives together opens up to analyses of the interplay and points of friction between human actors, non-human 'actants' (both artefacts and ecological entities) and emergent 'systemic' behaviours.

The idea of constitutive power has also been hotly debated, especially for the potential denial of agency, i.e. that the idea that power constitutes human subjects leaves no room for autonomy and the possibility of individuals being relatively free from the dominance of others (Allen 2014). What the discussion highlights, in my view, is the constant tension in everyday life between: human agency and space for action, forces and pressures that emanates from non-human entities and processes, and the disciplinary workings of power that subject individuals, institutionalize and naturalize dominance and social inequality. In RE processes, we find these tensions very clearly among the factors that enable and constrain individuals and groups.

To summarize the theoretical possibilities available to us, we should thus expect RE processes to involve multiple and simultaneous workings of repressive and productive powers, exercises of dominance and empowerment, and workings of power that originate in human agency and in trans-individual and systemic interactions. Finally, I will explain why destabilization can occur in RE processes as a result of: multiple and partly undirected changes in resource distribution and valuation and; shifts in the ways people use and understand places in relation to new identifications and shifting social positions.

4.3.2 Electrification, resources, place and identity

In externally driven RE, an actor enters from outside, bringing with it a powerful resource/technology, according to a logic that reflects the (inter)national discourse on development and progress. An organizational and technical design, significant material, human and financial resources, work practices, and possibly regulatory procedures accompany the new resource. The external actor establishes relations and networks and negotiates with local actors. As highlighted in relation to the framework

for analysing decentralized RE (section 4.2), the specific ways in which this happen interplay with the context and the existing social relations and shape the kinds of development outcomes that can occur.

When electricity is introduced in a context of unequal resource distribution, it can be expected to largely reinforce inequality. This is because subordinate groups find it more difficult to mobilise the resources required for investments in connection, appliances, machinery and new skills (Madubansi and Shackleton 2006; SEI 1999). People with capital are in a better situation to seize new opportunities. That is, existing dynamics of power will impact the process so that subordinated groups are more likely to find themselves as losers in a development process that distributes costs and benefits unequally. As a result, the income gap increases between families in the same village. This process manifests visually as the presence of electricity – as electric lights in the valley below, inside and outside houses, in the marketplace – shifts what used to be a dividing line between village and town to within the village. This marker of 'social difference' distinguishes the families who can afford electricity and live within reach from the grid, from the others who become excluded (in their own and others' view) or who selects to not be part, sometimes as an act of resistance.

This is the general pattern, but at the same time the redistribution of resources that occur and the new opportunities coming with it tend to shift the discourse on values in multiple ways, by changing the relations between time, labour, material resources and services.[23] In this process, coincidence, luck, ability, endowments, strategy and cooperation (just to name a few factors) mesh and produce winners and losers. Some services are of greater importance for rural households in terms of freeing time, reducing costs, improving health and increasing the productivity of land, e.g. electric milling and water pumps for drinking water and irrigation. The positive consequences of such services for the individuals – often women – who are responsible for providing their families with food, water and fuel can be significant and can enhance their agency, improve their work situation, cash flow and economic position and thus be empowering (Clancy et al. 2011). Besides facilitating existing activities, through its productive powers electricity also brings new opportunities for

[23] For example, the value of land and housing within the area identified as eligible for grid connection often increases to the benefit of the people who own this land.

making a living, the development of new professions and reinterpretation of other professional identities.

To summarize, the inflow of resources and the mobilization of and changing value of existing ones result in a redistribution of resources. The productive powers of electricity bring potential shifts in work practices, places and identities in relation to electricity. In the encounter between system and context we can expect that RE largely (re)produces relations of power at the micro level, but it may also shift and disturb these. The dynamics around resources, work, place and identity are potential points of friction that we need to pay attention to, where specific development outcomes emerge. Conflicts of interest are inherent to the RE process. Even when external actors collaborate with locally dominant groups and align with their interests there is a certain destabilization of the existing social order (Walker et al. 2010; Winther 2008). It means that RE increases the room for individual agency and brings opportunities that some individuals are able to utilize to renegotiate their places in social hierarchies.

4.3.3 Summarizing the theoretical discussion

The theoretical section has resulted, first, in a conceptualisation of small-scale electric systems as socio-technical systems, embedded as subsystems in national and international innovation systems. I have outlined the formation process of new socio-technical systems and the co-emergence between system structure and the context, and highlighted the differentiated outcomes. This discussion mirrors the second part of the aim, to explain what emerges out of encounters between electric systems and the context in which they are introduced, i.e. the outcomes of RE processes (for individuals, groups and system functioning) and potential societal impact.

Second, the discussion has explored what shapes actors' capacities (situation-specific powers) to drive RE processes, to access the services and opportunities related to electricity, and even to resist what they perceive as undesired change. It has highlighted that RE processes involve agency and negotiation, exercise of dominance, experienced subordination as well as potential for empowerment. Returning to the aim of this thesis, this theoretical discussion mirrors the first part of the aim: to explain, from the perspective of different actors, how and why they are enabled and constrained in their capacities to engage in RE and achieve desired outcomes.

4.4 Research questions

The theoretical discussion has repeatedly highlighted the interplay between certain dimensions as critical to my analysis: the importance of actors in their roles and capacities, interactions between actors and non-human entities, the formation of system structure and internal dynamics in relation to the context, resulting in a process where system behaviour and outcomes of RE processes emerge. These dimensions form the basis of the research questions. The following questions represent overall research questions for the thesis as a whole, and thus they differ from the questions formulated for each article. The articles contribute partial perspectives to the larger aim. The following questions are formulated at two levels of analysis. First, articles 1 and 4 conduct analysis at the level of the national electricity sector and its structure and performance in relation to policy goals. These articles are not only concerned with Tanzania but, for sake of coherence, the results and discussion will be focused on (and limited to) Tanzania:

1) *How do actors' capacities and the structure of the energy system at national level interplay with the country context and international context to drive and hinder the provision of electricity services in rural areas?*

Second, articles 2 and 3 are in-depth case studies of specific decentralized RE processes. The interrelated dimensions are therefore investigated for each case. Each case is rich in detail, and for the sake of clarity in the results section, I separate the dimensions analytically into three different questions:

2) *What enhances and constrains the capacities of actors involved in the electrification process?*
3) *How do the system and context influence each other?*
4) *What explains outcomes for individuals, groups and system functioning and how do these correspond to the goals, needs and interests of actors?*

5 Methodology

My approach to science is based on the philosophical debates, following the work of Kuhn (1962/1970), in sociology of science and feminist critiques of science that have created an awareness of the plurality of knowledge systems, the way knowledge is linked to the contexts in which it is created, and the normative underpinnings in how we do science (Barnes and Bloor 1982; Haraway 1991). Science is, as Mendelsohn (1977) says, a social activity. In the interdisciplinary fields of IS studies and energy and development scientists with different theoretical and methodological backgrounds meet. My own approach to research includes an assumption that crossing disciplinary boundaries, and engaging with actors from public and private sector and civil society (Hirsch Hadorn et al. 2008), is necessary for studying complex phenomena at the interface of society/technology/nature and for solving important societal problems. Further, the work is problem-oriented and has normative underpinnings: I try to contribute to ecological sustainability, social justice and well-being for people.

5.1 Conducting the studies

Based on the understanding that the scale of observation influences what can be seen and what conclusions can be drawn, the work is conducted at multiple scales. The articles approach RE processes from different entry points and use different data collection techniques. The following discussion will highlight specific challenges encountered and the strategies used in order to maintain the high quality of the work. The weaknesses and strengths of respective studies and methods are discussed.

Tanzania and Mozambique were chosen as case study countries for the first study, based on their similarities and differences, the similarities being: (1) they have low RE rates; (2) the pace of rural grid electrification is very slow; (3) they face similar challenges with low population densities, weak customer bases, large distances and inadequate infrastructure; (4) the governments dominate the energy sectors; (5) electrification of rural areas is considered a political priority; and (6) they have large potential for several renewable energy sources (hydro, biomass, wind, solar and geothermal). At the same time, the two neighbouring countries display important differences in their history, culture and social and institutional structure. The comparison between cases did not aim at testing of any hypothesis, but at exploring what were country-specific and shared challenges.

At this stage of the research process, the objective was to gain an overview and a contextual understanding of challenges for conventional as well as off-grid RE. Thus, article 1 was delineated spatially to national boundaries and, temporally, it centred on the current situation (of access to electricity services in rural areas), with respect to the historical development and discussion on future prospects. It was clear from the findings that small-scale RE and large-scale grid extension differ in important respects. Findings indicated areas of interest for further analysis and influenced the choices made in subsequent studies. For example, local participation in the RE process was identified as an important precondition for successful decentralized RE. Lack of local engagement and capacity to sustain off-grid systems implemented by external actors appeared to be an important barrier. These factors were often mentioned, but very few scholars provided any in-depth discussion on these topics. Why was local participation important, how and in what ways would it lead to better outcomes? How would it influence interactions between actors and the interactions between the energy system and local society? In order to address these questions, I therefore undertook in-depth case studies in rural communities.

I used two selection criteria for the in-depth studies: (1) a high degree of local participation and (2) systems with grid-distribution of electricity (rather than for example a programme aimed at the diffusion of solar home systems). The second criterion was motivated by my interest in organizational and institutional dynamics in processes involving a larger number of actors. The case studies were conducted in one country only, which made it easier to gain the country-specific knowledge that facilitates interpretation of data. Language-wise, it was better to conduct interviews in Tanzania, with translation between English and Kiswahili, than in Mozambique (where good skills in Portuguese are required). The focus for my remaining data collection therefore shifted to Tanzania and indeed, by the end I came to see the thesis as being 'about Tanzania' even though it includes empirical materials from elsewhere.

The ESP project in Leguruki (article 2) was identified in discussions with energy sector actors in 2010, who considered the NGO-led project to be innovative and promising. The project was donor funded and carried out based on 'participatory approaches' and with a focus on social benefits and poverty alleviation. The project had involved implementation of three different systems located in different communities at considerable distance from one another. Upon arrival in Tanzania, I held meetings and interviews with NGO staff in order to learn more and plan for data

collection in one of the communities. The system in Leguruki seemed the most relevant case in relation to my selection criteria. However, upon arrival at the regional NGO office, one of the staff informed me that the system was no longer functioning. This came as a surprise, considering that this was not explained in the previous interviews, despite my questions on problems encountered and technical functioning. Thus, I had to quickly reconsider the study design, reformulate interview guides and revisit the scheme for analysis and coding. Instead of studying a system in operation, I studied a system that was no longer working, and explored the process leading up to the cessation of service delivery. The experience mirrors what is highlighted in method discussions on practical limitations to ideal case selection and people's desire to convey positive responses in interviews (Willis 2006).

The second, and more successful, implementation (article 3) of a small-scale energy system was identified in 2011, and selected for in-depth study after a brief visit in 2012. In contrast to the previous study, I could study the ongoing process where the electric grid was introduced for the first time in multiple communities. It is also donor funded and implemented by an NGO. I prioritised the possibility of spending a longer time working in the area instead of studying multiple cases for short periods of data collection. Still, it was not possible to work in all nine communities involved in the process. I worked in two of the three villages that have been connected to the grid the longest. I also worked (but for fewer days) in villages where construction of infrastructure was still in process and service delivery was about to start.

Thus, the two RE processes, by taking place in very similar rural contexts, allowed me to gain insights into how the time scales, size of investments and geographical extent of infrastructure, as well as the strategies applied for engaging local actors in the process effected system outcomes. Many of the problems encountered in the first case are avoided or solved in the second case. In the end, the NGOs have drawn very different conclusions regarding the benefits of community ownership. Together, the two unique cases provide a rich insight into system dynamics.

The findings from article 1 indicated that there is an issue of translating policy into practice that has to do with low institutional quality in implementing agencies. Whereas the donor community appears to focus primarily on formal frameworks and policy-making, there are important challenges *within* responsible organizations of

informal institutional character. The comparison between Tanzania and Mozambique provided some insights. Possibly, we could learn more about the role of democracy and institutional quality for governments' provision of electricity services to the public by analysing these linkages across a larger number of countries. The fourth study (article 4) thus deals with state-led electrification by using a statistical cross-country analysis at the continental scale and over a period of 14 years. By analysing whether there is a general pattern across a larger set of countries it was possible to assess the scope of this partly neglected dimension of state-led electrification.

5.1.1 Data collection: scale of observation

As indicated above, each stage of the research process represents partial explorations of the analytical framework. As such, each paper drew upon somewhat different data, although each of them informed the other. The following data sets form the basis for analyses. The studies conducted as part of the PhD represents partial explorations of the analytical framework. The following data sets form the basis for analyses.

Article 1

Data was collected in Tanzania and Mozambique over eight weeks in 2010. The data set includes 16 interviews with government officials[24], international donors, technical consultants and NGO staff. The actors have many years of experience working in the sector. In parallel to interviews, our team visited operating off-grid systems using solar, wind, diesel generators and small-scale hydro to observe such systems directly. At each site discussions were held with involved actors (entrepreneurs, management staff and local users).

Article 2

Data was collected in Tanzania during four weeks in 2011. The data set consists of project documentation, observation and 53 semi-structured interviews with NGO staff and actors in the community where the project took place. Interviews covered the entire process, from the initial contact between village leaders and the NGO to the situation in 2011.

[24] These persons had the following kind of positions: Ministry commissioner; utility manager; utility director; agency director; agency manager; and manager at the regulatory authority.

Article 3

Data was collected in Tanzania in 2012 and 2013, during a period of around three months. The data includes three sets of interviews: (1) 90 interviews about the project and how it has developed over time; (2) a small set of interviews on land rights, savings behaviour and the use of electricity carried out in 14 households; (3) a set of 38 interviews, plus visits and group discussions with rural entrepreneurs in the project area and in the nearby town, Njombe, on the related topic of constraints and opportunities in the local economy. Taken together, the interviews provide very rich material on how the area has developed over the past decades, and how people's lives are changing over time.

I also analysed project documentation and studies undertaken by the NGO, including: (1) the data from a quantitative baseline study on local livelihoods of >300 households (this provides contextual data at one point in time), (2) a GIS-mapping of soil erosion risk in the catchment area (based on satellite images and site inventory of vegetation), and (3) a daily work calendar undertaken in focus groups with women and men separately (where participants outlined as a group what their average work day includes).

Article 4

The statistical analysis uses a time-series cross-section dataset for 44 African countries over the time period 1996–2009. Data come from national statistics on household electricity consumption, and international indexes of the degree of democracy and institutional quality. The respective indexes are composed of a combination of measures (further described in the article).

Article 5

The article on scales of knowledge is a theoretical and methodological contribution, which uses empirical data to illustrate theoretical arguments and the value of the methodological approach of triangulation for divergence. My co-author collected the empirical data during two periods of fieldwork in 1993–1994 and in 1999, using mixed methods.

5.1.2 Methods used in data collection

Here follows a brief account of the work process and techniques used in the qualitative studies. The methods used in the quantitative study are discussed in detail in article 4, and so are left out from the following account.

Preparation for data collection: Consistent with my commitments to the joint production of knowledge, I paid particular care to generating working documents before the periods of data collection and sharing these with colleagues to achieve so-called 'construct validity' or 'internal validity' (Sarantakos 2005; Yin 2009). The documents include: (1) A field guide[25], (2) a plan for data collection[26], (3) interview guides[27], (4) a coding and analysis scheme[28] and (5) an information package.[29]

Semi-structured interviews: The interviews had two main purposes: (1) to gain systematic data on how people interacted with the RE systems (e.g. the access to and uses of electricity) and (2) to gain insights into *how* they experienced the RE intervention. The interviews thus both revolved around observable 'facts' and subjective experiences, which do not necessarily match. To handle this possible contradiction, the way the interview guide was used in both individual and group interviews was revisited during the research process. The guide was adapted to the type of respondent and designed to outline a few themes of inquiry, but also contained a set of questions that were asked in each interview. Follow-up questions were particularly crucial for purpose number two, namely to allow for open-ended discussion about how the RE system was experienced (Mikkelsen 2005; Willis 2006). The interviews were recorded digitally, unless the respondent was uncomfortable with being recorded. I also took notes during the interview and typed them out in the evening or on the following days. One important learning experience is the value of engaging people in telling their personal stories and experiences in relation to the

[25] It included theoretical and methodological starting points, aim, research questions, motivation for study design and ethical considerations.
[26] It specified when and where to work, type of respondents, visits, how to share results and documentation of the rationale of selecting respondents.
[27] When interpretation was needed we translated the guides with all their questions to Kiswahili before data collection.
[28] It linked the research aim and questions to themes and sub-themes that I explored in interviews.
[29] It contained relevant research, reports, country information etc. that provided relevant background knowledge.

topic, asking for concrete examples and situations and personal reflections on these, instead of asking generally framed questions that push people into explanations of how it *should* be, rather than what they actually experience.

Translation has been an important aspect influencing the quality of interviews (Bujra 2006). My female interpreter has worked with me since 2011. By working together on multiple occasions, we have improved our communication and interplay (and my Kiswahili skills). Still, there are language barriers creating occasional misunderstandings. In order to know how well the translation works, I have had a third person to translate some of the recordings from Kiswahili to English, which confirmed the interpretation worked well almost all the time.

When interviewing I continued to ask questions related to specific topics until my interpreter and I agreed that we got the same answers and nothing new came out in the interviews, i.e. until we reached 'theoretical saturation' (Krueger 1998). This is not always possible. For example, during data collection in Mawengi, entirely new issues emerged (e.g. related to conflicting interests in upstream communities) during the last two weeks, and there was not enough time to fully explore these interesting and important events. Thus, the base of evidence was less solid, and results less certain. The preliminary results were compiled and in the follow-up visit six months later, I conducted individual interviews to complement the previous data and specifically brought up the situation in upstream communities for discussion in a workshop with local actors. Starting from a description of personal observation and some anonymous quotes from villagers, I asked the participants if they found the interpretation to be valid (had I misunderstood the situation in the upstream area somehow?). This turned into an animated discussion on an important but previously marginalized issue. Following suit, the participants worked in small groups with defining the situation from their own perspective (was this even a problem?) and discussed the consequences for their work and the energy system. Through this group process, new perspectives emerged on the topic, contrasting discourses were voiced and participants confirmed the preliminary analysis as relevant and credible.

Observation was used to gain greater insights into overall life and how electricity was experienced on a daily basis, to learn about events and practices of relevance to the RE process that would not necessarily come be captured by the interview guide, and for purpose of triangulation between multiple data sources. I lived in the

communities during periods of data collection. Documentation of the research process, personal reflections, stories told by villagers and observations of life in the village are gathered in a daily research diary. In addition, interview notes, photographs of people interviewed, videos and voice recordings are used for documentation.

Stakeholder workshops: During the course of the PhD work, I organized six workshops in Tanzania for two slightly different purposes: (1) Four workshops were for sharing preliminary results. This was done in order to validate findings and gather additional data before results were published; also to give something back and engage in a dialogue for mutual learning. (2) I also organized a couple of workshops with national-level stakeholders in order to share final study results, to contribute to mutual learning and to initiate a discussion of the general relevance (or so-called external validity (Sarantakos 2005)) of results for the energy sector at large. These occasions were valuable from a research point of view as they help bring out diverging interpretations and contrasting perspectives. They provide participants with an opportunity for mutual learning, networking, sharing experiences, and initiating new collaborations. The workshops have been much appreciated by participants and documented in reports (Ahlborg 2012; Ahlborg and Molander 2014), and made available to the public on the internet.

5.1.3 Coding and analysis

Collected data was analysed in an iterative process that moved between organising the data, looking for patterns in the data, sharing preliminary findings with stakeholders and colleagues, and refining the analysis based on the input. While this is fairly standard practice in qualitative studies (Desai and Potter 2006; Mikkelsen 2005), I paid particular attention to allowing participants and stakeholders a voice in the interpretation of results. I have used coding software to organize the interviews and research diary. The very systematic coding and analysis scheme, developed before data collection, was used in the process of coding, and new codes were created to capture themes and patterns in the data that had not been foreseen.[30] However, coding was a time-consuming process and I had to prioritize what data to code. Interviews

[30] In many ways, the research approach used here is a so called 'abductive' approach (Dubois and Gadde 2002).

that were not coded using software were still included in the analysis, but instead of coding them digitally, they were printed and coded by hand and read through on repeated occasions.

In parallel to and after coding, data was analysed according to specific topics and types of respondents. I looked for patterns, similarities, contradictions and gaps in the data. While analysing and compiling the findings, I triangulated between respondents and data sets (interviews, observation, project documentation). Triangulation of data is most often used for validation of results by convergence (Mikkelsen 2005; Sarantakos 2005). There is also triangulation for complementarity (Huntington et al. 2004; Gagnon and Berteaux 2009). In order to attend to different perceptions, Nightingale (2009) proposes the use of a specific technique called triangulation for divergence. Divergence as an approach examines where data sets do not match and it helps to reveal the mismatches between scales of knowledge (as discussed in section 1.2) of the actors involved – scientists, government officials and citizens. I used all three types of triangulation during analysis. Triangulation for divergence was used specifically when comparing across types of respondent and across data sets, e.g. when contrasting interview data with survey data or observation. The sharing of preliminary findings and draft articles were critical to validate findings and improve my understanding of the RE processes.

5.1.4 Ethics in fieldwork

The understanding that the research process is embedded in relations of power also had important methodological implications for how the work was conducted. In my role as researcher, I was largely in control of the research process before, during and after the data collection. The work is problem-oriented and of relevance to stakeholders, but still the research process and its results are primarily benefitting my own career (Wolf 1996). The unbalanced relationship was also due to the common situation that I met people with different class backgrounds (in terms of formal education and income-level) and cultural backgrounds (colour of skin in an environment where white skin brings social privileges). Awareness of these power dynamics has led me to take responsibility for the privileged position and adopt a ‘no harm’ principle (Wolf 1996). Still, the exploitative dimension of research represents a dilemma.

I am committed to critical reflection on how my 'position' generated bias throughout the research process (Haraway 1991), how my behaviour affected the people I worked with and met, and the consequences for other people of how I share and publish results, etc. However, general characteristics of my position (young, white, female) provide limited help for descriptions of the interactions with respondents. I rarely learned how the respondent perceived me during the interview and how that influenced the her/his answers (Joseph 1996). Also, relationships changed with multiple interactions.

While at times I experienced a privileged position (Wolf 1996), I sometimes experienced subjection to social hierarchies, dominance and exploitation in specific situations. It is much more complicated than a binary relation of power between researchers and researched (Hsiung 1996). For example, I have been pressured into donating money to 'the community' by a person in public office who referred to village regulations for working in their community, and then realizing directly afterwards from the person's behaviour that s/he intended to take the money for personal gain.

In order to navigate social hierarchies in a way that reflected my conceptual and methodological commitments, I needed a strategy for gaining access to communities. We visited local authorities and leaders to explain what we were doing and why. In these situations, my Tanzanian interpreter used her social skills and experienced colleagues and local partners provided advice. I employed a person from the community to function as our local guide. So far, this has worked very well. The guides have been young men (around the age of 30) who are well networked in the community, but not in any formal positions of leadership. The local guide assisted in finding the people I want to talk to, according to instructions, and arranged for interviews at convenient times. He also made introductions at the beginning of the interview.

The guide had a crucial role, for that reasons we discussed the rationale of research and how to work before starting. These discussions were foundational to how I 'entered' the field. For example, we decided how he should introduce me and communicate with respondent on expectations around the interview. This person thus became a gatekeeper to the local society and influenced who I talked to (but he was supposed to leave when the interview started). In some interviews with older people who spoke the local language, the local guide functioned as interpreter to Kiswahili.

The person also provided important knowledge and helped to bridge the social gap between the interpreter, the respondent and me. In particular, our guide asked potential respondents for interviews in advance, which gave them the chance to say no and learn that there was no payment for interviews.[31]

This discussion has highlighted some of the many ethical considerations associated with conducting research in real settings. Personally, I see it as my responsibility to interact in a kind and non-authoritarian way, to listen carefully, be non-judgemental, communicate straightforwardly, and open up for dialogue. These ethical aspects provide yet another motivation for sharing preliminary results with actors interviewed, sending draft articles to the organizations studied (for them to see and comment on how they are portrayed), and organising workshops for sharing results and enhancing dialogue among stakeholders.

5.2 Limitations of the methodological approach

The research approach has at least two important limitations that need discussion. The first limitation has to do with studying ongoing RE processes over short periods of time. In order to capture system dynamics over time and evaluate the impact of RE on societal development, research should ideally be conducted at multiple points in time, before electricity is introduced, during implementation and after some years of operation. There is also a need for a combination of qualitative and quantitative studies in order to create a really strong base of empirical evidence for exploring linkages between RE processes and societal change. The work presented here does not meet these criteria of multiple sets of studies of the same process over time. There are signs of significant change in relation to the energy system in Mawengi, but the time horizon is too short to assess whether cumulative outcomes will lead to societal impact and what the consequences will be for different individuals and groups.

The other important limitation of the work presented here has to do with the challenges I have experienced in working with an interdisciplinary research design. I have used systems thinking in order to communicate across disciplinary boundaries and find a language that can be understood by engineers and social scientists alike. This exercise of translation has been very difficult and full of tensions. Coming from

[31] Under particular circumstances and based on advice from my interpreter and the local guide, I have made small donations in return for the time taken from work activities. If the respondent is willing to have her/his photo taken, I have printed those and brought a copy back to the person as a gift.

a critical development discourse, feminist theory and poststructuralist thinking, I found it something of a cultural shock entering the scientific field of energy and development, which is dominated by engineering and economic science. I have tried to do justice to the experiences and insights in the empirical field, but in the process of engaging with a whole range of new literatures I temporarily lost contact with current debates and critique taking place in other communities of social scientists. It is a balancing act to stay up-to-date on developments in more than one field, but also, to handle the points of conflict between disciplines.

The choice of a systems approach has helped me make sense of competing discourses, but it also opens up to critique and scepticism. I have noticed the dislike and dismissal in respective field of the theoretical and methodological approaches used by the 'others'. The conclusion I draw is that systems thinking provides a promising means of communication, not only with research colleagues but also in relation to stakeholders in society. The danger is to lose sight of the limitations inherent in our work, but this is a challenge also shared by disciplinary science.

The conceptualization of systems as nested structures, embedded in society and in a continuous process of becoming is enriched by the theoretical understanding of scalar relationships – while simultaneously troubled by the epistemological considerations regarding scale of observation (see article 5). That is, clear and precise use of the concept of scale assists analysis of how inter/national and local processes and structures interact. However, the epistemological focus on contrasting perspectives and data sets, and keeping in mind that 'systems' are not real-world entities (Checkland 1999), reveals, but does not solve, the tensions coming from the use of mixed methods and multiple scales of observation. The engagement with different methods – quantitative and qualitative – and with different scientific discourses – positivist and poststructuralist – was motivated by the interest in diverging perspectives and conflicting views. It has been inspiring and valuable, however, neither the attention to scale nor the use of systems thinking removed the epistemological tensions. Rather, I have tried to work with these tensions in the analysis and to present the final papers in a manner that allows some of those tensions to remain.

In article 4, the quantitative analysis informed my interpretation of findings in article 1 in a manner that otherwise would not have been possible. At the same time, article 1 highlighted the limitations of the quantitative study, which also sits a bit

awkwardly next to articles 2 and 3 and their mainly qualitative data. However, I firmly believe that such disjunctures are revealing in themselves. They are a constant reminder of the partiality of all perspectives and the impossibility of 'seeing' an entire system at once, despite our desires to do so.

6 Empirical findings

Based on the conceptual starting points and the methodological approach, the four empirical articles (1-4) engage with the research problem – of how to understand the systems dynamics in RE processes and why these unfold in particular ways – from different points of view and positions in the systems 'architecture'. Hence, the section is divided into two parts: the first is centred on dynamics at the national level and the findings in articles 1 and 4; the second part shifts its centre to the local scale and the two in-depth cases (articles 2 and 3) of decentralized RE.

6.1 Findings in articles 1 and 4

The first research question to be answered is: *How do actors' capacities and the structure of the energy system at national level interplay with the country context and international context to drive and hinder the provision of electricity services in rural areas?*

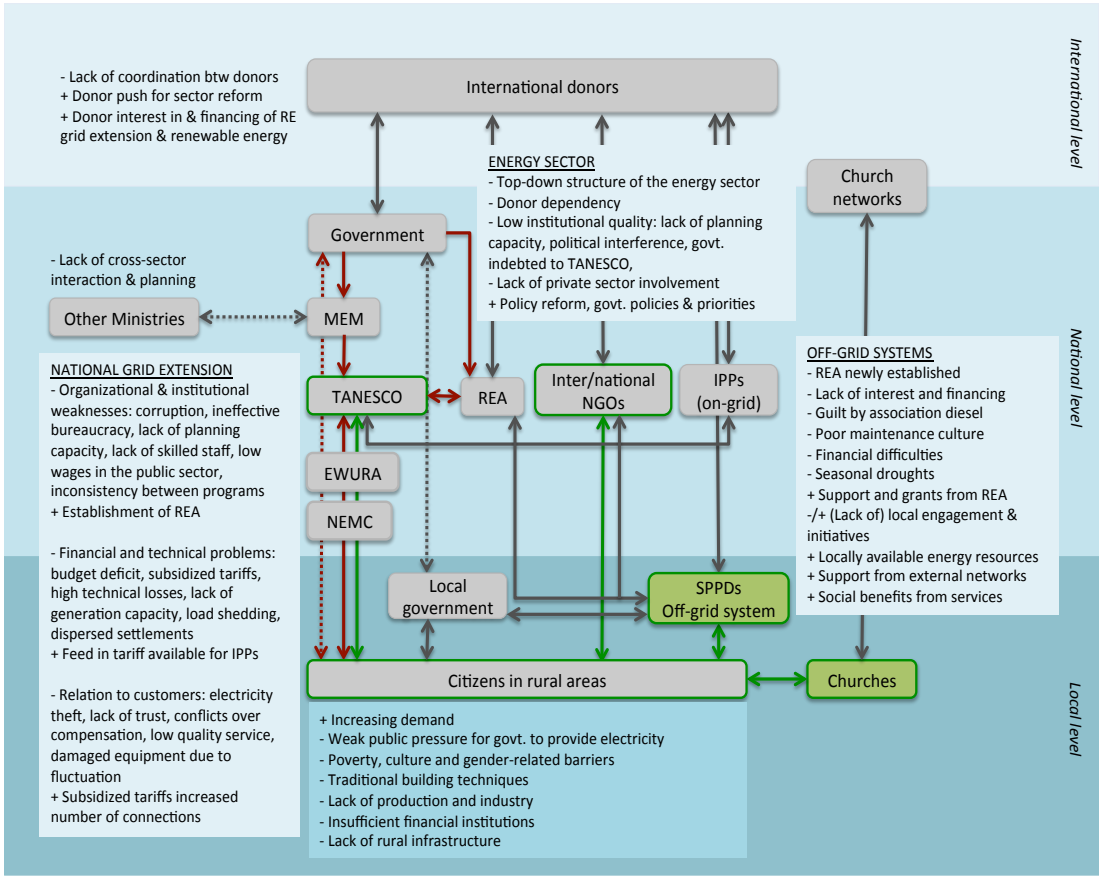
Article 1 has the title *"Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off-grid and renewable energy technologies".* The study is an empirical contribution to the literature on rural electrification in sub-Saharan Africa. The aim is to identify, from the 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 findings include drivers and barriers that are (a) general for the region (b) specific for each country (c) specific for actors involved and (d) technology specific. In the following, I will focus in on the findings for Tanzania and, in the second part, contrast these to local-level analyses.

Large-scale RE processes require concerted and coordinated efforts among multiple actors. Therefore, the actions taken and not taken by key actors are behind many of the 'drivers' and 'barriers' to RE. But there are also non-human factors to take into account. Based on the interviews, the most important drivers are perceived to be: political priorities and development policies; support from donors; and the ongoing power sector reform. Increasing consumer demand for electricity is considered a driver for RE. When it comes to decentralized RE, drivers include the existence of local actors (churches, industry, entrepreneurs) who install and operate their own electric systems, and, from the point of view of TANESCO and REA staff, the high cost of grid-extension creates an incentive to install decentralized systems. Some actors suggest that decentralized systems enhance the local demand for

electricity, thereby paving the way for a subsequent grid-extension. International donors are identified as the actors most actively supporting installation of renewable energy systems in urban and rural areas.

In interviews, actors identified a large number of barriers to RE. Figure 3 gives a summary of drivers and barriers identified in interviews.

Figure 3. Key actors and factors driving and hindering rural electrification by grid-extension and decentralized systems in Tanzania.



Boxes represent actors. Arrows indicate interactions. Red arrows depict the connections investigated in article 4. Green arrows and lines indicate actors installing off-grid systems of various sizes. Dotted lines indicate weak connections. IPPs = independent power producers, here used to refer to private commercial generation of electricity that is sold to TANESCO. SPPDs = small power producers and distributors, used here to refer to local generation and distribution that is off-grid, either commercial or non-profit.

The figure is not a complete overview of the energy sector. Rather, it visualizes the findings in articles 1 and 4 (due to which not all relevant actors show in the figure).

As can be seen in Figure 3, the actors and factors working as drivers and barriers to RE in Tanzania are both interrelated horizontally and vertically. That is,

actors interact across organizational and sector boundaries (REA provides funding to TANESCO, TANESCO buys power from private power producers), and across organizational levels (e.g. international donor agencies provide funding and capacity building support to REA, who in turn offers grants to small power producers). Churches are displayed separately as they have their own networks for funding and support.

Within the sector, problems combine to curtail the capacities of actors to drive RE processes. The key organizations experience both internal weaknesses and problems arising in interactions with one another. The barriers identified as most important are: lack of funds; donor dependency; top-down management in the energy sector; low institutional quality (including corruption and political interference in bureaucratic processes); weak organizational capacity; inadequate planning (in various government bodies); and lack of complementary investments. Further, there is said to be a general lack of interest among national-level actors in supporting local initiatives and decentralized energy solutions. The top-down structure is symbolized in Figure 3 by one-way arrows from government to MEM, REA and TANESCO, as well as by a weak link between the government at local and national levels. Here, the in-between levels of region and district are *missing*. In fact, there is no bureaucratic office for energy matters at regional, district or local level, as opposed to other areas of policy-making (such as agriculture, forestry, education and trade).[32] The centralized structure of the energy sector results in RE programmes being implemented without cross-sector coordination at lower organizational levels.

Figure 3 does not display the dimension of time, and so in order to explore the dynamics we must analyse the chains or webs of interactions between elements that generate weaknesses in the system. Importantly, the consequences of those play out at different geographical and time scales. For example, the lack of generation capacity is in itself a manifest outcome of a combination of factors and interactions: e.g. seasonal lack of water in hydropower systems, lack of financial resources, poor management and maintenance of existing power plants (MEM 2009). There are further interrelated factors (environmental, managerial, educational etc.) and explanations behind each of these factors, and actors aiming to improve generation capacity may need to consider and address some of these. In the other direction, the lack of generation capacity has

[32] The government agency REA has recommended that energy experts should be employed at both regional and district level (REA 2011).

multiple negative consequences: load shedding in the national grid impacts negatively on consumers throughout the country (households, business and industry), which hampers economic activities and, in the end, impairs TANESCO's finances.

The financial situation of TANESCO is also due to important contextual barriers to RE that are seen as generic for rural areas: large geographical distances; low population density; traditional building techniques (these three are relevant in particular when constructing grid infrastructure); rural poverty and low purchasing power among rural inhabitants; lack of entrepreneurship, rural production and industry; limited rural infrastructure; and what actors refer to as 'cultural barriers' to technology adoption. Many of these factors are important barriers to the development and successful operation of the national grid and decentralized energy solutions alike.

As highlighted by previous research, the provision of electricity often does not result in wished-for socioeconomic development due to a combination of social, cultural, technical and economic factors. Many aspects are directly or indirectly linked to high poverty levels – low incomes, people not affording grid connection, low purchasing power, low educational levels, lack of local technical skills and low levels of productive use (Madubansi and Shackleton 2006; SEI 1999). The findings presented here confirm previous literature that sees the relationship between poverty and energy as complex and multidimensional (Clancy et al. 2003; Clancy 2013).

Here, I want to look at the situation specifically from a systems perspective. What comes into view then, is that local energy systems (with or without electricity services) are intertwined with multiple dimensions of local livelihoods, but far from all of them. People who find themselves in positions of poverty experience much more than lack of access to modern energy services. Local entrepreneurs who are able to afford connections are constrained in their business by a range of issues that are not solved with provision of electricity (e.g. poor infrastructure, lack of access to markets, unfavourable trading terms, lack of investment capital, gender discrimination) (Ellis et al. 2007). The complex relations that produce and maintain economic inequalities are not addressed in RE programmes and they do not come with organisational structures for handling the interactions and overlaps between the local energy system and other social, ecological and economic systems of immediate concern to rural inhabitants.

To summarise the overall answer to the research question, there are important structural weaknesses in the energy sector that have to do with lack of funding,

organizational weaknesses and low institutional quality. Neither separate actors nor the sector as a whole perform very well. The situation in Tanzania since independence has been one of poverty, and it combines with geographical and demographic conditions to generate a negative feedback between rural poverty and the slow pace of grid extension. Energy supply and use is embedded in many ways in rural economies, but it is not reflected in the top-down structure of the energy sector. When electricity services fail to reduce poverty levels and boost the local economy, demand remains at a low level with financial implications for the service provider. Although it is problematic for the national utility TANESCO, small-scale off-grid systems are usually more vulnerable to financial difficulties.

Article 1 thus points to the need to probe how actors' capacities and interactions, organizational structure and institutions come together to shape the conditions for RE. Barriers are interrelated and co-emerge through chains of interactions between factors at different societal levels. Arguably, these relations are important for actors to understand who are seeking to improve access to electricity in rural areas. The findings indicate that multiple contextual barriers combine at the local level to hinder provision of electricity in rural communities as well as RE resulting in desired development. It suggests that these dynamics should be further investigated.

Article 4 has the title *"Provision of electricity to African households: the importance of democracy and institutional quality"*. The point of departure is what seems to be a contradiction: how come public electricity access and use are so limited when they are seen as crucial for development of African economies, welfare services and poverty alleviation; particularly when an abundance of energy sources and technical solutions exist? In order to investigate the relationship between political priorities and realization of those in RE, we built on theories that highlight the importance of democracy and institutional quality for provision of public services, such as large-scale provision of electricity services. We used a regression analysis in order to analyse the degree to which the level of per capita household electricity consumption can be attributed to African countries' democratic status and their institutional quality. As can be seen in Figure 3, the connections explored by means of regression analysis (red arrows) underpins how we have conceptualized these system relationships as part of the larger system dynamic.

The results show that democracy and institutional quality both have significant positive effects on per capita household electricity consumption, together with GDP per capita. This positive correlation between measures indicates that not only political and legal procedures of government matter, but also, the quality of the implementing bureaucracy contributes to explaining variation in per capita levels between African countries. This general pattern on a continental scale strengthens our previous qualitative findings for Tanzania and Mozambique, and the importance that respondents attribute to institutional and organizational weaknesses.

Article 4 thus shows the importance of relating the performance of the electricity sector to the wider societal context and the economic, institutional and political context (van den Bergh et al. 2011; Verbong and Geels 2010). Taken together, the two articles suggest the need to probe how these linkages appear from the different perspectives and when we use different types of analysis. In the following I discuss what we can learn about the linkages between RE, democracy and institutions from letting these two studies speak to one another.

6.2 Discussion of the linkages between democracy, institutions and electrification

Interviews with energy sector actors show that they see the recent energy sector reform and the new institutional frameworks as positive development that can enhance RE. Together with the findings from the statistical analysis one might come to the conclusion that the solution to successful RE in African countries lies in democratic and institutional reform and that progress in electrifying the public will follow. However, the interviews also indicate that informal procedures, norms and work practices are equally important for how interactions between actors in the sector happen in practice. Li (2007) suggests that the gap between the formal rules and the actual bureaucratic practices is inevitable, but also necessary to cover up the shortcomings of government and maintain rule. Therefore, low institutional quality (in practice) can co-exist with formal institutional frameworks that live up to principles of good governance (on paper). This lends some insights but also triggers new questions regarding the relationship between formal and informal institutions, politicians in government and citizens in rural areas.

When we contrast the findings in the two articles with one another, and put them in relation to previous literature and the recent history of Tanzania, then it seems

problematic to assume that the relationship between democracy and service provision is linear. There are empirical and theoretical[33] reasons to consider democratization, institutional development and electrification as interconnected and mutually constitutive processes. The historical accounts of the development of the energy sector (see section 2.2) indicate that RE was part of Nyerere's vision, but that the government at the time of independence lacked the financial and human resources to realize the political ideals. As the country was impoverished over the following two decades, necessary (re)investments did not take place and the state of existing energy infrastructure deteriorated. Of particular interest here is what has been called "the withdrawal of the state" (van de Walle 2001). Ferguson (2006) argues that many newly independent African states lacked the resources and capacities for undertaking large-scale development projects that could contribute to consolidating and building the legitimacy of the new states (Li 1999). Public service provision and national electrification programmes had been important components in state politics and consolidation in Western countries. It has also been a key feature of the Western *discourse* on the (ideal) state, in relation to which African states are portrayed as 'failures' (Hansson 2013; Williams 2000).

Donor dependency undermines the autonomy of the Tanzanian state, but I would argue in line with Ferguson (2006) that it also somehow relieves the government from moral obligations towards the public, especially towards people who live on the countryside in 'remote' areas. Domestic actors perceive the involvement of international donors in the Tanzanian energy sector as having ambiguous consequences: the donors bring welcome resources, but the dependency on external funding constrains the capacity of politicians to initiate RE. Donors are not subject to the judgement of Tanzanian voters and cannot be held accountable by citizens through elections. The link between democratic elections and public service provision is thus significantly weakened, and poor performance and low expectations feed back into one another.[34]

[33] Citizens use electricity for a range of services, including communication and information services such as television, mobile phones and internet. It is generally assumed that a more informed public and a free press is capable of exerting pressure on politicians and asserting constitutional rights. Thereby, there is a potential reinforcing feedback loop between a process of democratization and public electrification (Acemoglu and Robinson 2006; Lake and Baum 2001).

[34] The failure to deliver on political promises, what is called a weak "history of play" in political theory (Acemoglu and Robinson 2006), leads to low expectations among the public on current and future performance of the state and public servants.

Thus, the pressure on politicians in government from citizens in rural areas is weak[35] (see Figure 3), which was also highlighted by participants in a stakeholder workshop in 2012. This seems to contradict the view of interviewed actors who mentioned public pressure as a driver in interviews in 2010. However, at that time, national elections were coming up (see also Bångens et al. 2013: 4 on this topic). One villager explained his lack of trust in political promises and how it influenced his initial stance towards the Mawengi project in an interview:

"The first time the [NGO] introduced this project I thought that it is not possible, because we are in a very remote area. So I thought that it was just politics. But later when the [NGO] started the construction I saw materials coming, like the poles and wires. … Politicians were the first to mention the issue of bringing electricity to our area, during their campaign. So when this issue was raised again [by the NGO] people thought it would be the same thing, since politicians mentioned it every time, without any implementation."

The picture that emerges from statements by various actors is that politicians use electricity as a symbol of development, in order to invoke ideas of political leadership. However, based on experience, citizens take such promises with a pinch of salt (Li 1999).

6.3 Findings in articles 2 and 3

Shifting scale of observation, articles 2 and 3 open up the category of the 'local level' and reveal heterogeneous perspectives on RE processes and webs of interactions. In the following, the two articles are introduced, followed by the findings and answer to the three research questions. Thereafter, a discussion returns to the conceptual starting points, followed by an outline of areas for further research.

Article 2 is entitled *"Dynamic access: the rise and fall of a micro-grid"*. The article presents an analysis of an NGO-led pilot project that introduced an energy service platform (ESP) and micro-grid in a rural community, Leguruki, in Tanzania. The implementing NGO, TaTEDO, promoted the ESP (consisting of a diesel generator, milling machine, oil press and alternator for supplying the micro-grid with

[35] This topic has not been systematically addressed in my work. I have limited interview data regarding the role of the state. However, I have had many informal discussions with e.g. NGO staff, inhabitants in villages and people living in small towns on the role of the state in RE. So far, all people I have asked have low expectations on the government providing electricity services. The state is largely seen as unable and lacking the resources necessary for electrifying the entire country.

electricity) as an innovative and promising technology. It considered the pilot project in Leguruki a worthwhile learning experience, despite the fact that the system was no longer operating at the time of my visit. By relating the empirical case to a theoretical discussion on socio-technical system dynamics, the aim of article 2 is to develop the conceptual understanding of how and why supply of electricity by small-scale systems translates (or not) into positive outcomes for rural populations and societal impact. The case study answers the question: what factors explain the outcomes for individuals and groups in the ESP-project in Leguruki, and why did the system stop delivering services?

Article 3 has the title *"Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages"*. As a complement to looking at a failed electrification project in article 2, this article explores a more successful example; the process of economic change following the NGO-led implementation of the Mawengi mini-hydropower system of 300 kW in Tanzania. The aim is to explain the reasons why the donor-funded electrification project developed into an organizationally and economically viable local utility and initiated growth in the local economy. For various reasons, scholars have criticized the roles of NGOs and the 'aid industry' in public service delivery in African countries (Gould and Ojanen 2003; van de Walle 2001). This critique is briefly reviewed in the paper and provides a point of comparison for the actions and approach of the particular NGO, ACRA-CCS, leading the implementation in Mawengi. The research questions focus on the role of the NGO, the implementation logic and relationships between local actors, the NGO and external stakeholders. The economic and organizational aspects of the electrification process and its dynamic outcomes are investigated.

6.3.1 Understanding relations of power in small-scale electrification

First, to understand the exercise of power in small-scale electrification I ask: *what enhances and constrains the capacities of actors involved in the electrification process?* In the following, I will (1) describe the relationships between actors directly involved in the process, (2) map the multiple workings of power relations in my cases and (3) discuss the factors underlying power exercises. This is important because an understanding of power relations is, I have argued, at the heart of emerging socio-technical change and the mutually constitutive relationship between local society and the energy system.

Donor-funded development projects, such as the two projects studied in this thesis, take as their starting point an assumed lack of capacity among the 'beneficiaries' of aid (Li 2005). The recipient communities had a local energy source (jatropha seeds or a river) that could provide the inhabitants with valuable public services, but neither local actors nor the state are capable of exploiting it without external assistance. Thus, the external actor – the NGO – is positioned from the start as the more powerful actor in relation to local actors, and its legitimacy is based on its capacity to mobilize resources and knowledge, which are out of reach for local actors.

In both cases, local leaders were active in contacting the respective NGO and inviting it to their village, thereby giving the NGO the mandate to act within their area of jurisdiction/influence. The NGOs' capacities to undertake implementation are based on their successful communication with donors who provide the funding. In relation to local actors, the NGOs are largely in control of the material resources and the process of implementation. However, the process is shaped such that local actors need to contribute voluntary work and/or to support the implementation in various ways.[36] This creates a mutual dependency. It is intentional – by involving local actors in the process and relying on their moral (and material) supports, the two NGOs (and the donors funding the projects) intend to create a sense of responsibility and ownership for the sustainability of the system.

The cases also differ in the kind of relationships that are established between the NGO and local actors. In Leguruki, the NGO came for short visits, and the construction phase lasted only for a few weeks. Local actors depended almost entirely on TaTEDO for access to resources from outside: financing, technical skills and knowledge. Government actors at higher level than the local authorities did not provide support or act for its continuation. In contrast, ACRA-CCS was present in the Mawengi area for a period of eight years, during which it undertook a large number of activities. The local church in the Mawengi project is part of the influential Catholic Church and acted more like an equal partner to the NGO in the implementation process. The church provided the entrance point to local communities, and was involved in planning and monitoring throughout the construction phase. When the

[36] In Leguruki, local people were paid to assist in construction work, whereas in Mawengi, voluntary work was considered to be an in-kind contribution by the communities to the investment cost.

local utility was established as a legal entity with ownership of the system, the church gained an advisory position on the board of the local utility. Also, the District government (with jurisdiction over the geographical area of the project) gained an advisory position on the board. So the local utility has advisors representing the two most powerful organizations in local society. The NGO, the Church and the District all have their own support networks and links to national and international stakeholders.

The way the two NGOs shaped the procedures had important consequences for the terms of participation, control over the agenda and distribution of benefits (Nahuis and Lente 2008). The strategies, goals and priorities of the NGOs aligned with particular political interests. In Leguruki, TaTEDO actively sought the support and assistance of local government leaders and accommodated their requests. In contrast, ACRA-CCS established a new public utility with a regulation that prohibits local political and institutional leaders from holding influential positions in the utility. Thereby, the NGO opened up a new space for 'ordinary' villagers, partly contesting local hierarchies, while aligning with legal institutions and political goals of actors at higher levels of government (Ribot 1995; Ribot et al. 2008).

Thus, the relations between the main actors involved in these two RE processes are characterised by a particular logic where donors control the financial and time frames of working processes, providing limited room for manoeuvre for the NGOs. The NGOs move in between the (inter)national and local level and hold dominant positions, in their role as experts on development and the actor in control of activities and funding, vis-à-vis local actors. The choices made by NGOs along the way steer RE processes in certain directions. Local actors who engage in the process do so (more or less) strategically, with diverse intentions and interests.

Moving on to the second aspect, a combination of interviews, participatory observation and analysis of meeting protocols has allowed me to map exercises of power in the two RE processes. In Table 1, I provide examples of such exercises by actors involved in the electrification processes in Leguruki and Mawengi. I have used the action-theoretical conception of power (see section 4.3.1) to classify the examples in the four types of power exercise: as A = repressive and dominant, B = productive and dominant, C = repressive and empowering and D = productive and empowering.

However, the classification into four ideal types should not lead us to think that the exercise of power leads to either/or dominance/empowerment. The classifications

represent ideal types rather than a precise reflection of a complex reality, as the exercise of power is not a zero sum game, intentions are not always clear and social relations are messy. As we can see from the examples in Table 1 (below), actions can have ambiguous consequences, and resistance to social hierarchies is ambivalent (Butler 1990; Nightingale 2006).

Three short examples from the table can illustrate the ambiguity of power exercise: (1) When local leaders contact and invite an external actor to their community, they position themselves as a formal representative of the village, and active and engaged in local development. However, they simultaneously reinforce the premise of development aid – their need for assistance and their lack of capacity. (2) Targeting women's interests or needs in development projects is important, because 'gender-neutral' projects tend to privilege men as a group (Clancy et al. 2011; Schroeder 1997). However, identifying women as a marginalized group in need of help also reinforces the idea of the poor 'third-world woman' as subordinated and powerless (Mohanty et al. 1991; Mohanty 1993). (3) When positions of leadership are not accompanied by strong mandate and resources, the inclusion of women in decision-making may result in reinforced stereotypical views on women as poor leaders. This was the case in Leguruki.

Also, ambiguity emanates from the position of the observer: how an action is evaluated clearly depends on whose perspective we take and what we choose to value. Is it an act of dominance or empowerment when one of the customers questions the competence of utility staff in Mawengi? This person has the capacity to voice his concerns and he feels entitled to a dialogue between equals. Therefore, he is uncomfortable with depending on the utility for electricity services. Electricity services enhance his productive powers of carrying out work, but do not let him control the technology.

Table 1. Manifested exercises of power in the studied RE processes

Actor	Exercise of powers
Leguruki:	
Donor	• Provides conditional funding to the NGO: exerts dominance over the NGO (B) and enables it (D)
NGO	• Mobilizes and controls resources and material: becomes positioned as powerful (B) in relation to local actors, and enables the community to access new resources (D) • Enters into dialogue and negotiation with local actors: shares some decision-making power (D) with local leaders confirming their authority (B) in the community and positioning them as partners in the project (D) • Trains local actors on how to operate and manage the system (D)
Local government leaders	• Invite the NGO to carry out a project in the community: thereby positioning themselves as active (D) but in need of help, giving the NGO mandate (D) to work in their community • Say no to private ownership (A), request for 'community' management (D) and that the NGO pay for land (B) • Assist in mobilizing citizens to do voluntary work, and hold public meetings, thereby exerting their control over villagers (B) and supporting the NGO (D)
Village energy team	• Decides on payment system together with customers (D) but fails to enforce payments
Grid customers	• Mobilize resources to connect: position themselves as local elite (B) and competent villagers (D) • Decide on payment and tariffs together with VET (D) • Delay payments/refuse to pay: as an act of resistance against VET (A) or the NGO (C)
Technician	• Operates the machine: thereby providing a service to the community (D) and asserts himself as knowledgeable (B)
Other villagers	• Mobilize resources to use available collective services: positioning themselves as capable (D), in comparison to other villagers (B)

Mawengi:	
Donors	• Provide funding to the NGO, thereby enabling the NGO (D) to carry out the project, and enhancing their own legitimacy as financers of a successful development project (B)
NGO	• Mobilizes additional resources for adapting and developing the system design and configuration: thereby reaching more customers (D) and gaining increasing trust (D) among the public, legitimacy (D) in the eyes of donors, and authority (B) in relation to local actors • Owns and manages the system initially (B) and then transfers the ownership to the local utility (D) • Trains local utility staff on how to operate and manage (D) and provides resources, networks and discursive support that helps the utility negotiate (D) with and exercise authority (B) in relation to local and external actors
Diocese	• Invites the NGO to electrify the area, strengthening the positions of both parties (B/D)
District government	• Holds an advisory position on the board, exerting influence (B) and providing legitimacy to the NGO and the utility (D) • Intervenes on behalf of the utility (D) in conflicts with local actors, constraining the behaviour of local leaders (A)
Local government leaders	• Assist in mobilizing citizens to do voluntary work and hold public meetings (B) • Refuse to pay electricity bills, exerting dominance vis-à-vis utility staff (A)
Utility staff	• Operate and manage the system and service delivery (D) • Enter into contract agreements with customers: providing services (D) and regulating customer behaviour (B) • Disconnect and fine customers who do not pay: constraining dominance by local elite (C) and exercising dominance over customers with low incomes (A)
GA and board members	• Take strategic decisions regarding the system (D) • Supervise the staff and bookkeeping (B)
Grid customers	• Draw on assets, relations and institutions to gain access (D) • Use electricity for a range of individual and collective purposes: exercising power together (D) as well as dominance (B) • Engage in leadership positions in the utility, gaining influence (B) and new knowledge (D) • Provide discursive support (D) or question the competence of staff (B) or legitimacy of disconnecting poor people (D)
Other villagers	• Mobilize resources to use available collective services (D) • Participate in meetings and take leadership roles (D) • Provide discursive support (D) • Question the legitimacy of utility actions/decisions (B/D)

Before we move on to the third aspect of factors underlying relations of power, I want to highlight how specific places are entangled in power exercise and the strategic 'making' of identities (Valentine 2007). The example is based on observation and interviews. An electric grid creates a network of transmission and distribution lines, zones of danger and prohibition in relation to the physical infrastructure, lit and unlit places. When it is a local generation plant and grid, there are specific places for control over the system – the powerhouse, the transformers and the office. The utility office space in Mawengi is a place where new identities emerge and these partly destabilize existing hierarchies. 'Staff' and 'customers' exercise power practically and discursively in innumerable ways, thereby repositioning themselves in relation both to each other and to the electric system. For example, the dynamic around paying bills, asking for advice, service or a grace period for paying bills is shaped by and serves to (re)shape intersectional social relations. People who have not previously shared a collective identity (perhaps a male local political leader and a young woman) find themselves waiting in line together, being treated the same or differently by staff. The utility staff control the technical system, handle money, make decisions, provide help, argue, assert authority, obey orders and so on. The office is a place for negotiation of one's place-in-the-world, as an individual and as collective (see Ferguson 2006).

The mapping of exercises of power provides good insights into the dynamic relations between actors, and indicates that there are underlying conditions that influence the discretion of local actors. In the following, I will locate the factors enabling and constraining local actors' capacities to utilize services and capitalize on opportunities to the interface between the technology and the specific societal and environmental context.

The initial system design embodies the goals and intentions of the engineers and the NGOs (Langdon 1980; Nahuis and Lente 2008). These are not necessarily clear but can be composed of multiple interests, objectives and practices (Li 2005). In the process of system formation, these intentions are translated, with modifications (due to settlement patterns, topography, climate, weather conditions and access to roads, transport and markets) into infrastructure. The placement of the grid is a strategic decision, which reflects the priorities of dominant actors. In both cases, the spatial outline of the micro-grid provides points of connection, and distance from these determines who is eligible for connection. Further, the technical design prescribes

possible uses. In Leguruki, the ESP system generated higher power capacity than the small generators already existing in the area. Among grid customers, electric lights and appliances facilitated activities in the evenings, but the system operated for such a short period that new economic and social practices hardly had time to emerge. The difference between the new system and previous energy systems is much larger in Mawengi. The hydropower system is of enough capacity to accommodate larger electric loads, and the quality of supply is high. This allows the use of various types of machinery and appliances enhancing the productive powers of local actors. Thus, the new technology brings new opportunities for women and men, children and adults, but also new choices to make, sources of conflict and changing priorities and expectations. The technological characteristics and spatial design combine with the societal setting to condition who can access the new resource.

In Leguruki as well as in Mawengi, there is a pattern at the group level where relations of class and gender constrain the space for action for people identified as poor and as women. This is reflected and manifested in the process of gaining access to and using electricity services and related opportunities, and in outcomes at group level. A large part of the population has difficulties mobilising the resources needed for connecting to the grid or investing in electric appliances. It is also manifested in the use of public space. Dominant gender roles constrain women's participation in public meetings and their access to public services. Electrified and non-electrified places become socially positioned through the behaviour of dominant groups who define the norms of the place: who is in place, who is out of place, who belongs and who does not (Valentine 2007). 'Good women' do not watch TV in public in Leguruki, it is a space dominated by men. Similarly, a group discussion on gender roles revealed that many women feel more confortable attending meetings in the morning, before men start drinking alcohol. My data also contains an example of how class and gender intersected in a family decision on where to place the electric lights in the house. All rooms were equipped with lights except the indoor kitchen. The working environment of the young female housekeeper who does the cooking was not prioritized.

The case studies also provide examples of the strategies that people apply to gain access. The Leguruki case shows how low-income households and widows were able to mobilise assets in order to pay the cost of internal wiring. Among the customers in Mawengi, there are women and men who have previously struggled to

make a living, now seizing the opportunity to start up new businesses and earning enough income to afford a higher material standard. What this shows is that existing social hierarchies and dominant discourses influence, but do not determine, the capacity of individuals to utilize services or capitalize on opportunities.

Together, the analysis of relations between actors, exercises of power and the factors underlying the workings of power in RE show how the processes of design, implementation, system configuration, access and energy use are interrelated and continuous in time and space. In each of the sub-processes (see the framework in section 4.2), technology and social relations are linked and shape what is perceived as possible and desirable. Due to these dynamics, the chain from design to outcomes cannot be forged easily.

6.3.2 Explaining the interplay between system and context

In order to probe further the process whereby the local context and system configuration shape each other over time and space, the next research question is: *How do the system and context influence each other?*

One of the striking differences between the two cases is the degree of flexibility and adaptation of the system configuration to the local setting. In Leguruki, the technical components did not function as expected, but they were not replaced. Termites and winds made the electric poles fall down and the climate was too hot for the air-cooled generator to work properly. The limited budget did not allow for any significant adjustments on site or replacement of badly functioning equipment. The NGO had no process in place for handling emerging problems, and local actors were left to take care of the system as best they could. The organization of payment for grid services did not work well, but was not adjusted into a working arrangement.

In contrast, the process in Mawengi was flexible and the system configuration adapted to changing circumstance. The capacity to undertake an ambitious and long-term programme came from access to funding from different donors. Thereby, the NGO enlarged its space for action and strengthened its position in relation to local as well as external actors. During the eight years of the project, the NGO developed the system in terms of: infrastructure, formal and informal institutions (regulatory protection, enforcement and enhanced trust), support networks and enhanced capacity of the local utility to own, manage and operate the system independently. These developments are described in detail in article 3.

Here, I want to highlight the motivations for one major change to the system design and configuration, which was undertaken in response to the dynamics between the energy system, local ecosystems and local livelihood strategies. The NGO and the local utility decided to make a significant economic investment and extend the grid to communities upstream of the hydropower plant. It required a reorganization of the local utility to include the new users as members and it changed the system dynamic in a fundamental way.[37]

ACRA-CCS knew that soil erosion was a potential threat to the technical functioning and life-time of the hydropower system (due to sand building up in the dam, reduced water flow and silty water damaging the turbines). In the area, a number of factors contribute to soil erosion, including farming practices, forest fires, run-off from roads and animals trampling riverbanks. The NGO staff wanted people upstream to change land use practices and they advocated protection of the river in line with the Tanzanian national legislation, which forbids human activities within 60 metres of a water source. But legal frameworks are not enforced, either at district level or by local authorities. Staff realized that without access to the electricity services upstream, communities have no direct incentive to protect the river and the hydropower system. This insight motivated ACRA-CCS and the local utility to expand the grid upstream, despite the cost.

However, connecting communities upstream did not result in the wished-for change of farming activities. The land next to water sources is used primarily for vegetable farming, which provides important sources of food and income. Fertile farming soils are increasingly scarce in the area, there is lack of irrigation systems and poverty levels are high. Many families in these communities cannot afford to connect to the new grid or live too far from it. Hence, their economic benefit from electricity will be limited to improved public services, whereas connected households also benefit economically from reduced energy expenditure. Thus, the social setting disrupts the desired link from introduction of electricity, to access, use, positive outcomes and protection of the infrastructure. The issue took on even greater importance in 2014, when heavy rains and sand in the system caused a temporary stoppage. A conflict of interest has surfaced, which has consequences for the use of

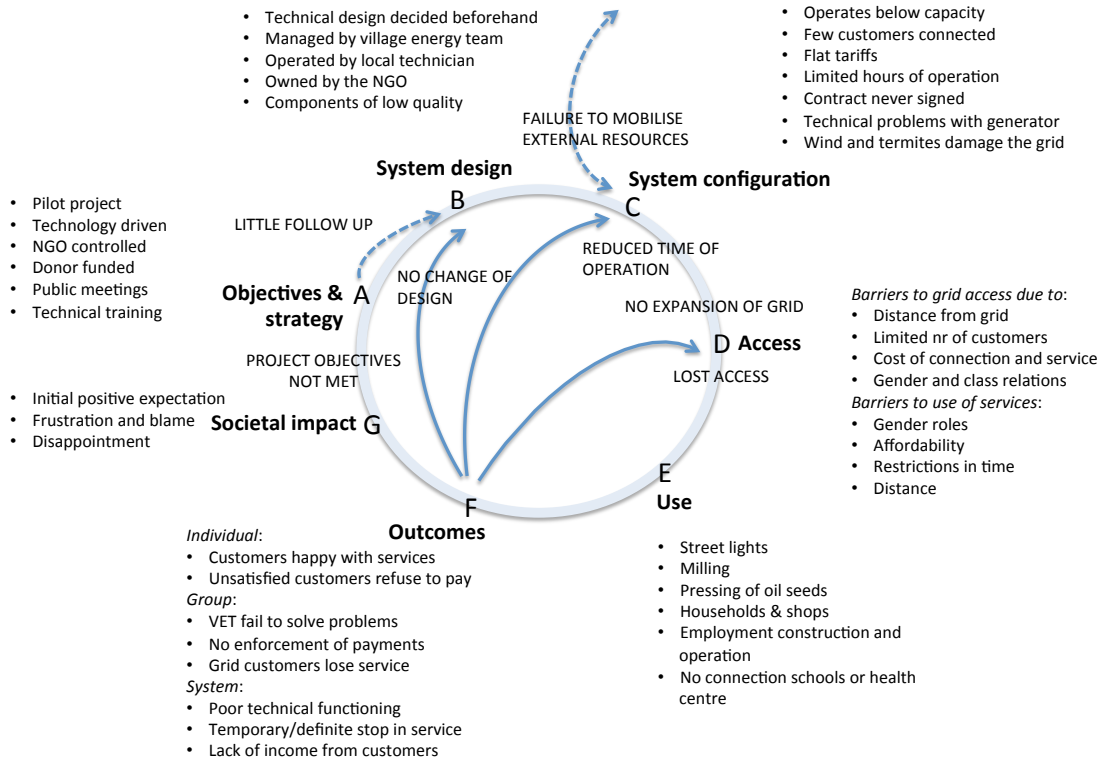
[37] The following description is based on original data and analysis undertaken in relation to the work on article 4.

natural resources and people's livelihoods upstream, leading to various responses from actors involved.

6.3.3 Explaining outcomes in relation to goals, needs and interests

The development of the framework of analysis (see sect 4.2) and the conceptualization of power in RE processes has opened up to a range of possible interactions between system elements, the system and the local context, and to patterns emerging from these. The framework is particularly helpful for visualizing simultaneous and interrelated sub-processes, and exploring what RE processes do and what effects they have, i.e. what outcomes emerge that lead to specific kinds of development. It helps to answer the last research question: *What explains outcomes for individuals, groups and system functioning and how do these correspond to the goals, needs and interests of actors?* The Figures 4, 5 and 6 below visualize the most important factors and feedbacks throughout the process of system formation in the two separate cases.

Figure 4. System dynamics in the ESP-project in Leguruki



A combination of factors explains the outcomes in Leguruki (including the problems already mentioned). The NGO introduced a system according to a predefined design that had been successfully used in West Africa, but not previously tested in a similar setting in Tanzania. Also, the NGO initiated the project without enough funds to realize the planned design, expecting to mobilize additional resources required for connecting the planned number of customers. When the NGO was unsuccessful in applying for additional funds, its capacity to act and drive the project in the desired direction was severely limited. The second phase never took place as planned, and the ownership of the infrastructure remained with TaTEDO. The grid services did not meet the expectations of all customers, and some refused to pay, i.e. they acted in response to a perceived poor system performance. As a consequence there was not enough money to buy fuel, which led to difficulties in keeping the system running. The local Village Energy Team (VET) consisted of elected villagers who were officially in charge, but they were incapable of solving this problem and a negative feedback developed. As time passed and the NGO failed to mobilise additional resources, the discrepancy between local needs, expectations, capacities and the system's service delivery became too large. Local actors took the decision to stop delivery of electricity in the evenings. A few months later, continued technical problems resulted in the stopping of operation of the milling services.

The (lack of) action(s) of individual actors interacted with non-human system elements in ways that created a system behaviour that no one intended or desired. This indicates that it is in the interplay between agency of actors and system 'behaviour' that we find positive and negative feedback loops. As a result, the capacities of actors involved were called into question. As highlighted by Li (Li 1999, 2005), development projects involve high risks for actors involved, also for the dominant ones.

The RE process in Mawengi has taken an entirely different direction. Figure 5 visualizes the emerging outcomes at the end of the first project phase in 2010 and Figure 6 shows how the dynamics developed in 2014.

Figure 5. System dynamics at the end of Phase I in hydropower project Mawengi

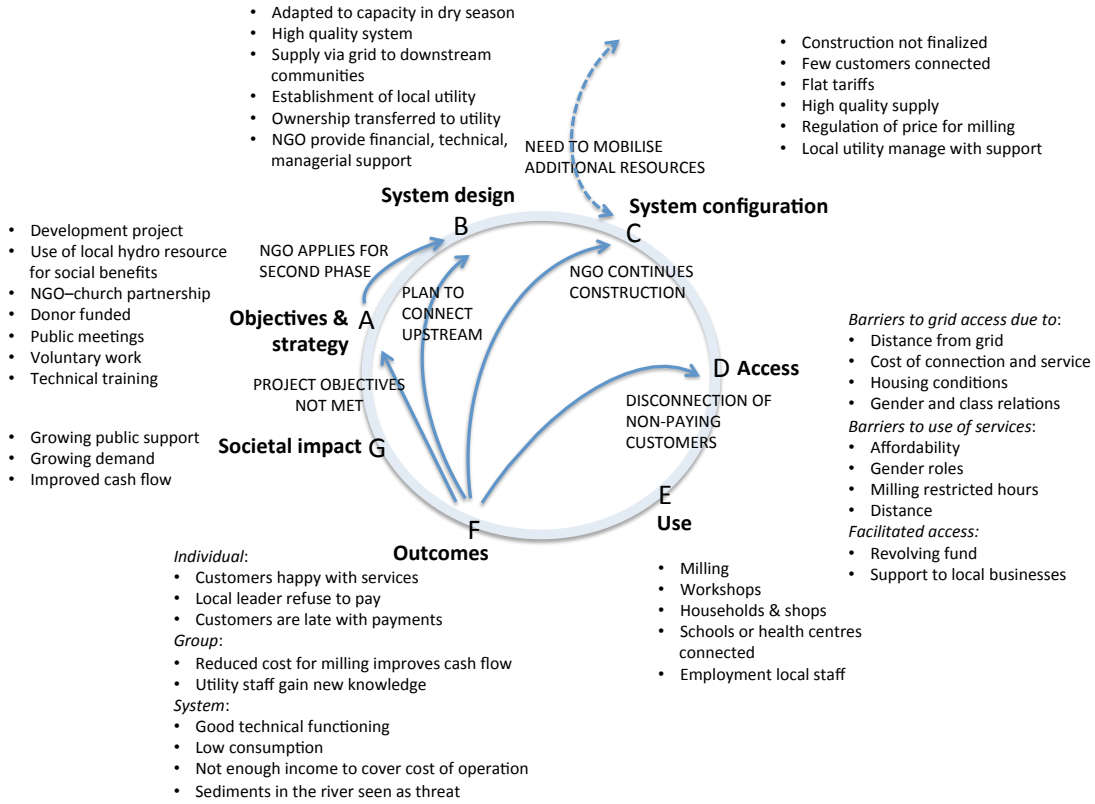
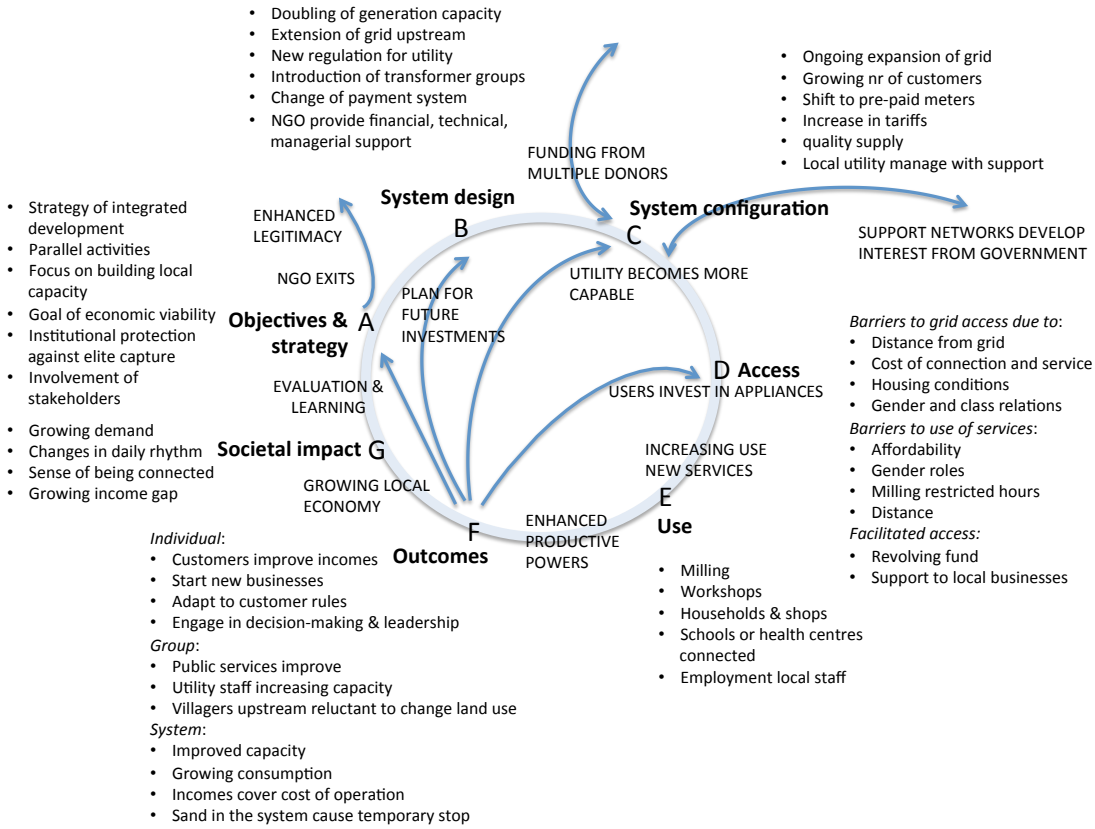


Figure 6. System dynamics at the end of Phase II in hydropower project Mawengi



In Mawengi, a positive loop has emerged between the development of infrastructure, growing numbers of customers, satisfied users who increase their use over time, and the economic capacity of the local utility. The energy system fulfils its purpose of supplying services at high quality and relatively low cost to local communities. The positive outcomes at the system level have developed out of the interactions between actors, technology, society and nature. Certain decisions proved important for emerging positive feedbacks. For example, the decision to regulate the local price of milling services, in order to improve the cash flow of all households in the area, is widely appreciated by villagers and has positive influence on economic activities. The introduction of electric machinery, appliances and electric light is changing the social organization of work in households, shops and workshops. Already after a few years, there is evidence of the local economy being in a process of restructuring.

Importantly, the NGO has been present over a long period and has engaged in an ongoing dialogue with local actors. Therefore, the staff have learned about problems, conflicts and opportunities and been able to act upon those as they occur. What this highlights is that coping with the inherent uncertainties and change of circumstance requires continuous attention to emerging conflicts and opportunities. Presence, dialogue, follow-up and flexibility facilitated this learning process where the system configuration was continuously adapted to its context. Processes for learning are not relying solely on the presence of the NGO. Importantly, the local utility has become an arena for negotiation and problem-solving.

Understanding what lies behind outcomes for individuals and groups relates back to the previous discussion on exercises of power, mobilisation of resources, shifts in activities, identities and people's use of spaces. All these changes emerging out of the formation process accumulate to produce a destabilization of social practices and an enlargement of the space for individual and collective action. It allows for individuals, such as utility staff, to change their positions in social hierarchies. The perspectives can differ regarding whether this is a desirable outcome or not. External actors, such as researchers, donors and the NGO, may consider enhanced social mobility a positive outcome of electrification processes and an indication that poverty-related barriers can be overcome. From my own point of view, empowerment of subordinated groups is a desired goal. However, there has been friction between utility staff and villagers. These interactions have involved conflicts and dissatisfaction to a much larger degree than the NGO's interaction with villagers.

Whereas the NGO is cherished as a competent and trustworthy actor coming to help the local communities develop, some villagers criticise the local utility staff. Their sudden repositioning as 'experts' and actors in control over the technical system and dominant position towards electricity users disturbs existing hierarchies and becomes a point of friction.

The general pattern is, however, that the electrification process has (re)produced social hierarchies (Nightingale 2005; Winther 2008). A minority of the population has connected to the grid and, in general, these households enjoy larger economic and social gains from electricity. Thereby, the contrast between poor and better-off people becomes sharper. Poverty remains a barrier to access of low-income households. This can be understood as an unwanted systemic behaviour: as long as the system configuration requires individual users to mobilise a relatively large amount of resources for investments in connection and appliances, the poorest people will remain excluded from the system.

In general, the development of the project has exceeded the expectations of all actors. International donors and government actors at national and district level see the project as a 'success case'. These stakeholders are impressed by the rapid development of new economic activities in the connected villages, the performance of staff and members of the local utility, and the NGO's efforts to create social benefits and public support. This does not necessarily mean that the outcomes correspond to the desires, needs and interests of all actors.

The most significant conflict has emerged in the upstream communities where the use of land in riparian zones is politically sensitive and complex, with conflicting interests and potential class-based exclusion. In 2013, one woman explained: "At first we thought the project was good, but then we learnt that they want to take our land." It is a challenging situation that the local utility is trying to handle, and it needs to balance between different interests in order to create positive rather than negative interactions and feedback. The long-term needs of the utility – to protect the infrastructure and have a stable consumer base upstream – conflict with place-specific dynamics – economic poverty, natural characteristics of the area, reliance on subsistence agriculture, a growing population and land use practices. The NGO has invested in the success of the project and gives it priority whereas local actors (including government authorities) have more complex and entangled interests and loyalties, where electricity is just one among many priorities. The competing

discourses – the need to protect the hydropower system and river ecosystem versus the need for poor families to have enough food and income; and the importance of legal enforcement versus the unfair prohibition of farming practices that are allowed elsewhere – reveal the tension over what counts as 'good' development.

6.4 Discussion of system dynamics, power and scale

The RE processes in Leguruki and Mawengi differ in important ways. I have applied the same theoretical lens to them and placed them side-by-side in order to see clearly what characterises the processes as they unfold. The process in Leguruki can be understood as a structural system failure. It displays the four types of structural problems identified by IS scholars (Jacobsson and Bergek 2011): infrastructure failure; institutional failure; interaction failure (lack of trust, weak networks); and capabilities failure (actors were not capable of achieving their goals). In addition to this, the way the process was organised did not include a learning process leading to a new project cycle. Learning was instead directed towards future projects in other communities. Similar problems have been encountered in many other development aid interventions and rural energy programmes. The causes for failure are not new, or very surprising. Rather, what is interesting is the question of what these kind of electrification schemes 'do' and what effects that are produced out of the encounter between the rationalities underlying the scheme and the complexity of the place-specific context (Li 1999, 2005).

In contrast, the project in Mawengi contributes to building experience and interest in decentralized RE at the national and international levels and hence feeds into more long-term processes of institutional change. Over the past few years, a stream of domestic and international visitors has come to this office in order to visit the hydropower station and the villages and to talk to the actors involved. The government of Tanzania considers the project and what is happening in the villages as a model for rural development that can inform national policy and practice. However, when the findings were discussed with energy sector actors at national level, the approach was considered too ambitious, expensive and time-consuming to replicate in its entirety. It was suggested that certain elements and strategies could be used in future implementations.

For many years now, it has been highlighted that development according to a 'blueprint' has severe limitations because every situation is unique (Korten 1980;

Mosse et al. 1998). The development community still struggles with how to scale up from successful individual projects to large numbers (Bazilian et al. 2012). What has been highlighted in this thesis is the value of exploring system dynamics and paying attention to power relations and scale, in order to understand why RE processes unfold as they do. The question of scale has raised multiple issues: First, it alerts us to the difference between centralised and decentralised energy infrastructure where energy supply and use are differently embedded in local society and economy; where ownership and control over infrastructure can be either separated or overlapping in space (Goldthau 2014; Wolsink 2012). Second, it leads to attention to the lack of alignment, so called 'scale mismatch', between processes in time and space – the artificial project periods and imposed deadlines in relation to the slow processes of societal change; the seasonality of economies and management of monthly budgets; the cost-effectiveness of short project implementations and the time it takes humans to gain experience, learn and become increasingly capable of managing complex processes. Third, it shows how decentralized RE processes are cross-scale processes embedded in more long-term processes of which some are controlled and other unfold outside the control of societal actors.

For example, rapid population growth, soil erosion caused by human activities and widespread poverty combine into a perceived problem for the long-term sustainability of small-scale hydropower systems. In response to this, actions are taken to facilitate diversification of the economy and initiate protection of local ecosystems. Influences go two ways: local processes are influenced by institutional reforms, and local level institutional change can activate dormant processes of legal enforcement at higher organisational levels. This leads to the fourth insight: when decentralized systems and local contexts co-develop and reshape, the local society becomes 'repositioned' in relation to wider society.

This brings opportunities and risks: Investments in improved healthcare, education and new economic opportunities for women and men can result in lower birth rates and enhance the capacity of citizens to act for improved conditions of life (Sen 1999; WB 2008). Communities where electricity services are introduced become increasingly linked to systems for communication, markets and transport. This brings increased exposure to what MLP scholars call 'landscape level' processes (Geels and Kemp 2007). For example, there is an ongoing HIV/AIDS epidemic in Tanzania, which is connected to transport networks and mobility patterns (Garbus 2004) while

education and information are key to preventing its spread. Further, the structures of global and national political economies are enabling and constraining the powers of actors at the micro-level who are now in a process of early industrialization, bringing the risk of 'inclusion' of local economies in the macro economy on exploitative terms.

These cross-scale linkages highlight how RE processes are fundamentally political. If politics is inherent in socio-technical processes, then the implication is that actors involved in RE cannot 'avoid' local politics. Technocratic implementations seek to be neutral but, in fact, involve the (re)production or contestation of social hierarchies, by means of discourses on 'the importance of electricity', the 'necessity of economic growth', 'climate change mitigation' or other development outcomes seen as inherently good. Discursive dominance can be exercised via the privilege of formulating what is seen as a problem and the preferential right of interpreting legitimate solutions and priorities. In mainstream development discourse, RE processes are depoliticized as a 'national interest' or a 'welfare' project (Chatterjee 1993). Surely, electricity has unique characteristics and it is highly useful for a range of welfare services. But RE processes are politically charged arenas in which relations of power are reworked and negotiated (Li 1999).

Based on the theoretical and empirical analysis, I argue that seeing successful RE as a matter of introducing the right technical and economic model is a blinkered approach. Conflicts of interest are inherent in these processes where different perspectives, goals, interests and multiple rationalities interplay. What 'development' is produced, by whom and with what consequences for social equality, local livelihoods and ecosystems? The conceptual starting points of socio-technical systems, power and scale have allowed me to identify critical moments and points of intersection where development outcomes emerge. The above analyses illustrate the non-linearity of societal change: dynamics of access come in the way of moving from design and system configuration to desired outcomes and societal impacts. The emergence of positive and negative feedbacks is found in the tension between human agency, interactions with non-human 'actants' and a dynamic context. The consequence is that changes in the context (such as the desired economic and social development outcomes) initiate the need for continuous system reconfiguration to handle new opportunities, pressures and emerging conflicts.

The process of iterating between theory and empirical work has been very interesting. The analytical framework developed here for decentralized RE processes

(section 4.2) is a result of this movement back and forth. So how does it relate to the three literatures (IS studies, S&TS and conceptualizations of power relations) from which it builds primarily? Clearly, it is based on existing conceptualisations of socio-technical change in IS studies and applies the concepts related to system elements, interactions, structure and behaviour. It portrays individual energy systems as subsystems in the national and international energy sectors. Processes of formation at the local level take place at the interface of system and context. It highlights how interactions develop into feedbacks and how changes in the context and system co-emerge. Thus, the framework guides analysis of this particular kind of socio-technical change by specifying the interrelated and continuous sub-processes of system formation in decentralized RE; and relating these to society, technology and nature interactions taking place at the interface of system and context.

In relation to the literature on human–technology interactions and infrastructure in S&TS, the framework captures three dimensions that have been identified as critical areas of S&TS research, namely: the political shaping of technology and the way artefacts influence behaviour of actors; the importance of the social setting; and the ways the shaping of the process influences the outcomes (Nahuis and Lente 2008). These three dimensions are embedded in the framework and reflected in the questions regarding: the consequences of design and system configuration; how existing social relations influence the formation process; and the critical role of the strategies, goals and actions of the dominant actors.

Finally, in relation to the literature on power as capacity and constitutive power (Allen 2008, 2014; Lukes 2005), the formation process is conceptualized as inherently political and an arena where individuals and collectives negotiate their place-in-the-world, and where relations of power are contested, destabilized and re-established. By iterating between theory and empirical cases, I have identified the following points of intersection between system and context as critical to shaping emerging outcomes: mobilization and redistribution of resources; enhanced productive powers and changing relations between time, work and resources; changing social organization around work; shifting meaning of places and strategic making of (new and existing) identities in relation to electricity. In this multiplicity of interactions, human agency and constitutive power interplay and shape the direction of societal development.

6.4.1 Areas for further research

The application of socio-technical systems approaches to research on energy system transitions in poor, rural contexts provided me with an opportunity to develop and refine my theoretical and empirical understanding of socio-technical change. From the combination of in-depth case studies at the local level and comparison between countries' energy sectors many questions for further research emerge.

Together, the findings point to the importance of careful and iterative design of socio-technical systems, including models for financing flexible implementations, and embedded learning processes in order to create a link between (lack of) societal impact, revised strategies and design. This seems to me a promising area for empirical investigation and conceptual development, which requires a dialogue between engineers and social scientists, between scholars and practitioners. Further work in this area has policy relevance, because deeper understanding of how systems and their context co-emerge can lead to innovation and learning on how to reduce barriers to access among people who are currently excluded from services.

This thesis has applied socio-technical approaches and systems thinking to a new context – decentralized RE processes in poor rural areas of Tanzania. The results indicate that this approach can fruitfully assist scholars in analysing the way new energy technologies become embedded in local economies (which differ in their ecological base, livelihood strategies, value-chain structures and barriers to economic growth), welfare systems and natural resource exploitation. The two in-depth case studies have provided insights on system dynamics in decentralized systems, but to what degree are these unique and case-specific? Are the combinations of factors that explain outcomes in respective case of more generic character? If we continue exploring, will we find that these processes unfold according to theoretical expectations? For example, as decentralized renewable energy systems develop over time, can we identify the development of self-organizing properties, the system gaining momentum and changing its context significantly? What factors become bottlenecks in individual systems and how are these linked to blocking mechanisms at higher levels of organisation?

The thesis has highlighted how RE processes provide us with opportunities to study the (re)production, contestation and shifting of power relations. The discussion on power and electricity has helped identify some points of intersection where development outcomes are produced, but the discussion was by no means exhaustive.

There may be other critical shifts brought by electricity beyond the ones related to work organisation, resource distribution, place and identity. What does it mean to be increasingly connected via television, mobile phones and internet in this type of social setting? What does it mean for people's mobility? One interesting dimension particular for decentralized RE processes that are funded and implemented by external actors is the moments occurring when projects end and dominant actors leave the scene, where remaining actors adjust their relations to one another and non-human system elements. Are these moments where destabilization occurs once more, where power struggles intensify? A different type of shift occurs when decentralized systems become connected to national grids. Such processes can be expected to involve confrontation between different rationalities and 'modes' of governance, with implications for the power dynamics between actors, control over and access to the system.

Given the historical role that large-scale electrification programmes have played in many countries in building, legitimating and (re)producing the power of the (welfare) state and centralized control over resources of 'national interest', the failure of most African states to extend national grids throughout their territory and 'reach' the majority of citizens raises a number of questions: What will be the role of the state in future energy systems on the African continent? What does the decentralized energy path imply for the welfare state as a legitimate democratic project? Will new 'polycentric' governance structures (i.e. governance across multiple scales and engaging multiple stakeholder groups (Goldthau 2014; Wolsink 2012)) emerge around decentralized energy systems, in ways similar to how district-level government is involved in Mawengi? What are the areas of alignment and 'mismatch' between the scales of technical systems and the social organization required to sustain well-functioning service provision? Attempts at answering such questions need to include an analysis of the different interests, visions and actions of actors at different organizational levels. The findings point to the importance of deconstructing the 'state' and exploring the multiplicity of actors, interests and rationalities within 'government' (Sharma and Gupta 2006). Inspiration can come from previous IS research, such as the historical study by Jacobsson and Lauber (2006), as well as other resource contexts (Hansson 2013; Li 1999). As highlighted in this thesis, formal legal frameworks, administrative procedures and roles of actors are not necessarily reflected in practice. In fact, the informal aspects of the working cultures of

implementing organizations are poorly understood. A fruitful approach to the 'inefficiency' of bureaucracy would investigate the adopted strategies and behaviours, the actions taken and the rationale for these among staff (Hansson 2013; van den Bergh et al. 2011), and identify strategies for improvement based on contextual understanding, rather than assume the problem is a 'lack' of good governance.

The value of in-depth case studies is, in my view, that they expand our knowledge, lead to new insights and open up to sets of new questions. Case studies help build our shared experience and theoretical abilities. For this reason, it would be fruitful to both probe different dimensions of the systems framework and to continue building it through more case studies and conceptual work. Already, the analytical approach developed in this thesis can provide some assistance in thinking through some of these questions and identifying studies at particular scales of observation that can help fill current knowledge gaps.

7 Conclusions and recommendations

This thesis has explored processes of rural electrification in Tanzania that aim to catalyse social and economic development and reduce rural poverty. In addition to large-scale infrastructure development, decentralised energy systems are increasingly seen as a suitable alternative for electricity provision in rural communities. However, there is a gap between ambitions and practice, desired and actual outcomes. Motivated by this divide, the thesis has scrutinized the assumption that electricity brings development, and approached the situation in Tanzania from the perspective of multiple actors. The three conceptual starting points for the work are socio-technical systems approaches, philosophical debates on human power and understandings of scale as a critical dimension in research and in interactions between society, technology and nature. Together, these perspectives help us see how electrification processes are embedded in inter/national development processes; how small-scale systems in rural areas are subsystems in emerging innovation systems; and how local systems for electricity supply co-emerge with local contexts. The analyses of system dynamics have revealed how complex, intersecting and cross-scale processes at the interfaces between society–technology–nature drive RE processes in a certain direction.

RE processes are inherently political and based on theoretical discussion of power relations and the empirical studies, the conclusion is that RE (re)produces existing social hierarchies and dominance. However, despite this general pattern, the changes involved – in the social organization of work, in resource distribution, the meaning of places and identities, the relationship between time, resources and labour – together destabilize relations of power and expand the space for agency in tension with structures. Hence, RE processes provides us with a possibility of studying how people react to the occurrence of perceived opportunities to escape from subordinate social positions. By studying such moments, we may be able to render visible the workings of power that were previously hidden from view (Lukes 2005: 50).

The thesis contributes to existing knowledge by developing conceptual tools for understanding the ‘messy’ human aspects of socio-technical change in relation to technical and ecological elements and processes. I present a framework for studying processes of system formation in decentralized electric grids, which can guide further research and assist interdisciplinary communication around the complex challenges

involved in similar processes. For the actors involved in RE processes, the thesis helps bring into view why conflicts of interest can be expected to emerge and where the possible points of friction occur. These are the points that require the continuous attention of actors involved in order to create positive feedbacks and avoid escalating conflicts or negative spirals. The findings are of general relevance for actors in the field and for other countries that face similar development challenges in that the systems perspective assists actors in asking the right questions, identifying critical factors and improving processes for working and learning.

Given the diversity of actors and their different roles in RE, I have pulled out some recommendations that begin from those different starting points.

Recommendations for actors who implement and operate decentralized energy systems

As the thesis has shown, actors involved in decentralized RE need contextual knowledge and broad competence to handle the challenges and uncertainties inherent in such processes. The process requires a flexible design and changes to system configuration, including technical and organisational change, in order to maintain and develop the system in a changing environment. This is likely to require the mobilisation of additional resources. A general lesson is that in order to catalyse economic diversification, expand the customer base and enhance demand, there is a need for strategies and investments that aim: to facilitate access for a larger part of the population, to enhance the capacity of individuals and groups to make use of the new opportunities and to support uses of electricity that create economic and social values for the community at large. From a strategic point of view, successful outcomes are more likely when working processes allow for longer presence, mutual learning and dialogue with stakeholders in order to solve emerging problems. Conflicts of interest between stakeholders, and attempts to exercise control over important resources should be expected to emerge because electrification destabilises social hierarchies and relations. Therefore, managing relations to stakeholders and negotiating between interests will be as important as technical and financial management.

Recommendations for donors

When RE is considered from a socio-technical approach then it becomes apparent that donors need a combination of contextual knowledge and theoretical understanding of

how energy systems are embedded in local society, in order to judge the feasibility of RE programmes and activities, support implementers and evaluate outcomes. The large degree of uncertainty that is inherent in processes of socio-technical change requires flexibility in financing and provision of additional funds to operational actors in order for them to be able to seize arising opportunities and handle emerging problems. In parallel to electricity provision, funding is needed for investments in human capacities. Current conditions for financing do not adequately reflect these needs. Also, each energy system will develop a unique interaction with its context. Therefore, solutions that work well in one context can seldom be transferred directly to other contexts. Focus should be on putting processes in place that allow actors to handle uncertainty, embed the system in local society and continuously act upon and learn from emerging system dynamics. Given that electrification processes are inherently political, donors should push for communication, dialogue and negotiation and insist that 'technical' implementations integrate processes for social learning.

Recommendations for government

The current energy sector structure does not provide local actors with an obvious counterpart in government for collaboration on energy-related issues and cross-sector linkages. Given how local energy systems overlap in multiple ways with local economies, livelihoods, ecosystems and social relations, the findings in this thesis indicate that RE processes create new intersections between sectors, which bring opportunities and challenges. There is a need for a local arena where stakeholders can meet and communicate, to identify and act upon emerging problems. By engaging in and supporting the learning processes in relation to RE, government actors can achieve better development outcomes in rural communities and strengthen its legitimacy among the public. Decentralized energy systems potentially open up a new role for government, new partnerships between actors and a stronger local engagement in rural development. Higher levels of government can provide important support networks and legal protection for local suppliers and users against corruption, sabotage and other kinds of power exercise by local elites. Electricity should be seen as a resource of political relevance. The societal values associated with RE go beyond quantifiable economic measures. Electricity is different from many commercial services in its critical role in enhancing human capacities to carry out work, communicate, learn, live a healthy life and be innovative.

For all concerned actors, this thesis suggests that it is important to acknowledge the political dimensions of RE, rather than trying to 'avoid' politics by framing RE as only a technical and economic matter. Also researchers take part in producing RE as a discursive arena and thus our framings of RE are part of what these interventions 'do'. By rendering 'political' what is usually conceptualized as 'technical' we reshape the way we look at the world, and open up to new questions, new knowledge and ways of seeing oneself and others. The search for 'success' is then redirected from finding the right model for scale-up, to questions of how actors can contribute to long-term functioning of energy systems and positive outcomes by creating processes for dialogue, negotiation and collaboration. Power brings responsibility: there is a risk that external or local actors use their dominant positions to impose dominant discourses portraying a specific kind of development as the desired one. Based on the insight that perspectives are partial and limited, actors can instead use their capacities to enhance dialogue and learning if they deliberately allow for a multiplicity of stories and diverse interpretations to be part of the process. What is suggested here is an approach to RE that strives to engage the political dimensions, handle the tension between dominance and empowerment, and renew the collective attention to the *open* question of what kinds of development are possible and desirable.

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