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Pedersen, Mathilde Brix; Nygaard, Ivan; Wehrmeyer, Walter

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PHD THESIS

Rural electrification through private models: the case of solar-powered mini-grid development in Kenya

Exploring the hybrid nature of private business models and the interplay between new players and existing structures in the Kenyan rural electrification regime

Mathilde Brix Pedersen

UNEP DTU Partnership

Management Engineering
Technical University of Denmark

Copenhagen, Denmark, August 2017

Main supervisor:
Ivan Nygaard
UNEP DTU Partnership
Management Engineering
Technical University of Denmark

Co-supervisor:
Walter Wehrmeyer
Centre for Environment and Sustainability
University of Surrey

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List of Abbreviations

AfDB	African Development Bank
CAPEX	Capital Expenditure
DfID	Department for International Development
DTU	Technical University of Denmark
ERC	Energy Regulatory Commission
ERC	Energy Regulatory Board
GMG	Green Mini-Grids
ICT	Information and communications technology
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producers
KEEP	Kenya Electricity Expansion Project
KEMP	Kenya Electricity Modernization Project
KenGen	Kenya Electricity Generating Company
KES	Kenya Shilling
KETRACO	Kenya Transmission Company
KfW	KfW Development Bank
kWh	Kilowatt-hour
KPLC	Kenya Power (formerly Kenya Power and Lighting Company)
MLP	Multi-Level Perspective
MoEP	Ministry of Energy and Petroleum
NGO	Non-Governmental Organisation
O&M	Operations and Maintenance
GPOBA	Global Partnership Output Based Aid
PV	Photovoltaics
REA	Rural Electrification Authority
SE4ALL	Sustainable Energy for All
SHS	Solar Home Systems
SME	Small and Medium Sized Enterprise
SREP	Scaling-Up Renewable Energy Program
TIS	Technological Innovation System
UN	United Nations
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USD	US Dollars

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Abstract

In Sub-Saharan Africa more than 630 million people live without access to electricity. Access to modern energy services like phone-charging, electric lighting, cooling, heating, etc. is an important enabler of social and economic development and human well-being. Renewable energy-based electrification solutions that deliver power through a decentralised mini-grid to village communities have gained in prominence as a supplementary path to achieving universal access in the realisation that, in many developing countries, traditional utility-led grid-electrification efforts will not succeed in bringing electricity to everyone in the near future. In East Africa, mini-grid development has primarily been driven by NGOs or faith-based organisations. However, recent technological advances like mobile phone payment solutions and drops in solar PV prices are making solar-powered mini-grids a cost-effective alternative to traditional fossil fuel-based solutions like diesel generators in off-grid areas in many countries. This has made rural electrification through mini-grids an interesting area for private-sector firms looking to do mission-driven business in the growing African economies. This, in combination with the broader turn in international development cooperation towards supporting private sector- and market-based solutions to facilitate development goals, makes private sector-driven rural electrification an interesting area for investigation.

Against this background, the aim of the research presented in this thesis is to explore the processes behind the emergence of such private-sector engagement, as well as the functioning and effects of specific private-sector models. This research topic is explored through a qualitative multi-case study design to provide context-specific insights into the particularities of the Kenyan mini-grid niche. Dynamics of change in the Kenyan rural electrification regime is investigated through the lens of the multilevel perspective to explore how niche-level actors conduct institutional entrepreneurship to influence existing structures in the rural electrification regime. Furthermore, min-grid firms' practices are explored to understand how they respond to competing institutional logics made available to them due to their dual social and economic mission.

The research finds that mini-grid firms operating in Kenya contribute to system building in the sense of making private mini-grid development a viable and sustainable alternative to grid-extension in various ways by following different strategies. While some actors are seeking to strengthen the private mini-grid niche by actively seeking to change the 'rules of the game' in the broader rural electrification regime through negotiations, advocacy and other forms of institutional work, other actors are following a strategy of increasing cohesion within the niche by building partnerships and generating knowledge and learning. This shows how niches build and grow not only through niche-internal processes, but also through purposeful actor-driven work with the aim to create conditions that allows the niche and the regime to co-exist.

At the firm level, the research finds that mini-grid firms respond differently to the competing demands of the social welfare and economic viability logics available to them. While some firms enact the logic of economic viability as the predominant logic guiding their work, other firms combine and blend the two logics. Each of the two strategies of prioritising or blending is pursued with the conviction that the underlying practices and decisions made manifest in such strategies will benefit these firms. While it is too early to draw conclusions regarding the prospects for the long-term sustainability of these firms, the existence of these various strategies is significant in two ways. First, it suggests that mission-driven enterprises can be differentiated based on the way they enact logics in their work. Secondly, it opens up a path to further research into how each of these strategies may influence the long-term sustainability of these firms.

1 Introduction

Access to energy is a precondition for human and economic development, and affordable, reliable and sustainable modern energy services are fundamental to human well-being, reducing poverty, improving health and increasing productivity. In Sub-Saharan Africa, 632 million people live without access to electricity, twice the population of the entire USA (IEA 2016). In each of the East African countries of Uganda, Tanzania and Kenya, more than 30 million people live without access (ibid.), most of whom live in rural areas, where poverty is high. Increasing energy access in rural areas is therefore crucial in order to combat poverty, as well as other problems regarding health, hygiene, gender inequality and environmental degradation.

Although national grid-extension programmes, in combination with decentralised solutions, have increased electrification in many countries over the past decade, these new connections are primarily targeted at urban or peri-urban populations where the costs of grid-extension are lowest. This means that, over the past decade, due to a combination of a lack of investments in rural areas and population growth, the number of rural residents in many Sub-Saharan countries without access has either remained stagnant or increased. In Kenya between 2000 and 2014 the national electrification level increased from around 8% to 20%, while in the same period the number of people living without access rose from 28 million to 36 million (IEA 2016; IEA 2002). This electrification gap in rural areas points to the need for off-grid solutions.

Mini-grids are proposed as the missing link between grid-extension and individual, pico-scale solutions like solar home systems or lanterns, which cover only low wattage needs like lighting and phone charging. The International Energy Agency (IEA) suggests that seventy percent of all rural areas globally are not suited to electrification through grid extension and that mini-grids are estimated to deliver forty percent of the new capacity needed to meet the goal of universal access (IEA 2011). While much of this new mini-grid capacity is expected to be financed through government budgets, the gap in energy access is increasingly being seen as a market by private-sector players like international social enterprises, local and international small and medium enterprises (SMEs), domestic conglomerates and multinational corporations (IFC 2012; GVEP 2014). While prior to 2011 most private mini-grid firms were based in India or West Africa (Bardouille & Muench 2014; IFC 2012), such firms relying on solar-powered and highly technologically advanced solutions have since emerged and started operating in East Africa.

The topic of rural electrification and research into the role of mini-grids have been dominated by techno-economic and policy analyses based primarily on quantitative data and methods (Schmidt et al. 2013; Sovacool et al. 2015). Such studies include, for example, economic evaluation (Mbaka et al. 2010) or the modelling and technical design (Kimera et al. 2014) of specific mini-grid systems at specific sites, as well as geographical analyses identifying optimal locations for mini-grids based on economic and geographical conditions (Bertheau et al. 2012; Szabó et al. 2011). They also include policy-tailored studies of feed-in tariffs (Moner-Girona et al. 2016), as well as reviews of the drivers of and barriers to attracting private-sector financing (Williams et al. 2015; Schmidt et al. 2013; Bhattacharyya 2013).

A different stream of literature is engaged in more qualitatively driven research that seeks to understand the different organisational arrangements of mini-grid development. These studies are dominated by a focus on the so-called community-based model, in which individual projects are implemented by public or donor-driven institutions like universities (Ulsrud et al. 2015; Muchunku et al. 2014) and non-governmental organisations (NGOs) (Ahlborg & Sjöstedt 2015; Ilskog et al. 2005; Yadoo & Cruickshank 2012).

While studies of private business models are available, these include primarily generic descriptions of the energy service company model and comparisons of the strengths and weaknesses of, for example, fee-for-service versus franchise models (Krithika & Palit 2013; Bardouille & Muench 2014). Other studies conduct cost-benefit analyses of particular mini-grid projects (Khan et al. 2016) or assess lessons learned regarding the technical, social and policy aspects across a number of cases (Schnitzer et al. 2014). Eder et al. (2015) present a qualitative in-depth case study analysing a privately driven mini-grid in Uganda that focuses mainly on explaining the reasons behind the adoption of new technology.

However, there is currently little understanding of the processes of private-sector engagement in rural electrification in East Africa. There is little empirical knowledge of how private mini-grid firms engage in changing existing institutions to create a space for their business models, of how they do business in practice, or of how they respond to competing demands of earning a profit and providing social welfare in rural communities.

In a thematic cross-field between rural electrification and private-sector engagement, this thesis aims to fill this gap by exploring the following main research questions:

> What explains and conditions the emergence of private mini-grid firms in Kenya, and how do private mini-grid actors, through their work, influence existing rural electrification structures and balance social and economic purpose?

To answer this overall question, two subsets of questions have been formulated that are explored in the four articles constituting this PhD. The first set of sub-questions explored in Articles 1 and 2 are concerned with the regional characteristics of solar PV and mini-grid development in particular:

> Article 1: What are the status, trends and drivers of solar PV diffusion in East Africa, and how is disparate diffusion across the region explained?

Article 2: How is the popular concept of mini-grids understood and used in the current development discourse, and what does a typology of mini-grids based on an empirically based conceptualisation of mini-grids look like?

The second set of sub-questions aims empirically to unfold the particularities of private sector engagement in mini-grid development in Kenya:

Article 3: How and through what forms of institutional work are system builders within the Kenyan mini-grid niche transforming or influencing current institutional settings in the incumbent rural electrification regime?

Article 4: How are private mini-grid firms, through their practices, responding to the competing logics of social welfare and economic viability?

The rationale behind the study is that, by zooming in on decision-making and sense-making made manifest through firms' practices, insights are revealed about the particularities and complexities of private models of rural electrification. Through a multiple case-study design, the thesis thus seeks to gain insights into the micro-level processes of firms' business activities and to generate a broader empirical understanding of how private mini-grid firms operate in practice, including insights into the variations between different models and strategies as well as the effects of these practices and strategies.

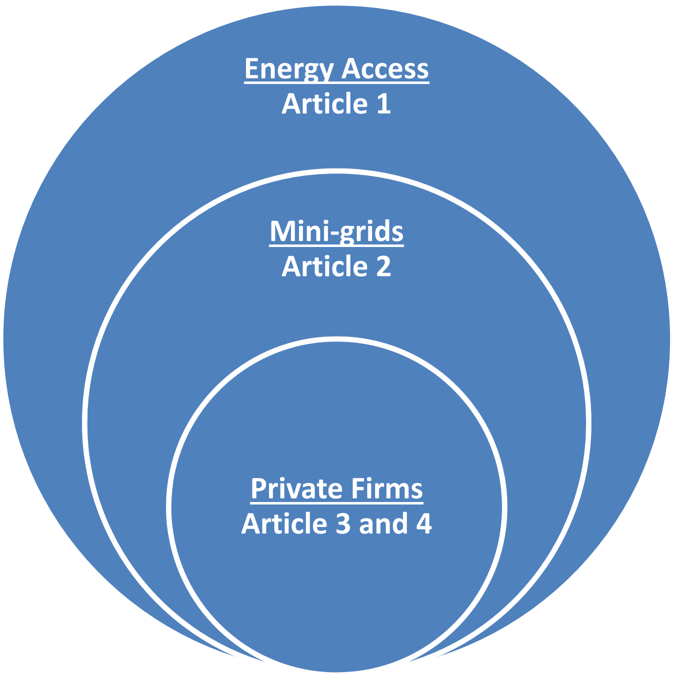
Articles 1 and 2 are contextual papers with a regional focus on Tanzania, Uganda and Kenya. Article 1 addresses the broader thematic field of energy access by providing a cross-sectoral analysis of the general solar PV industry in East Africa. Article 2 addresses the particular segment of renewable energy-based mini-grids and develops a framework to deconstruct the popular notion of mini-grids.

Articles 3 and 4 turn to explore agency at the firm level through case-specific, in-depth studies of four private mini-grid firms in Kenya. While Article 3 focuses on the interplay between the mini-grid niche and the broader electrification regime, Article 4 zooms in on the organisational model of private-sector mini-grids and takes an interest in the interaction between firms and the communities they serve. An overview of the four articles is provided in Table 1 and the thematic representation of the content in the four articles is illustrated in Figure 1.

Table 1: Overview of articles included in this thesis

#	Title	Authors	Status
1	Review of solar PV policies, interventions and diffusion in East Africa	Hansen, U.E.; Pedersen, M.B. and Nygaard, I.	Published in: *Renewable and Sustainable Energy Reviews,* (2015) 46, pp.236–248.
2	Deconstructing the concept of renewable energy-based mini-grids for rural electrification in East Africa	Pedersen, M.B.	Published in: *WIRE Energy and Environment,* (2016) 5(5), pp.570–587.
3	System building in the Kenyan rural electrification regime: the case of private mini-grid development	Mathilde Brix Pedersen and Ivan Nygaard	Re-submitted March 2017 to: *Energy for Sustainable Development*
4	Competing logics in rural electrification: the case of private mini-grid development in Kenya	Mathilde Brix Pedersen, Walter Wehrmeyer and Ivan Nygaard	Submitted March 2017 to: *World Development*

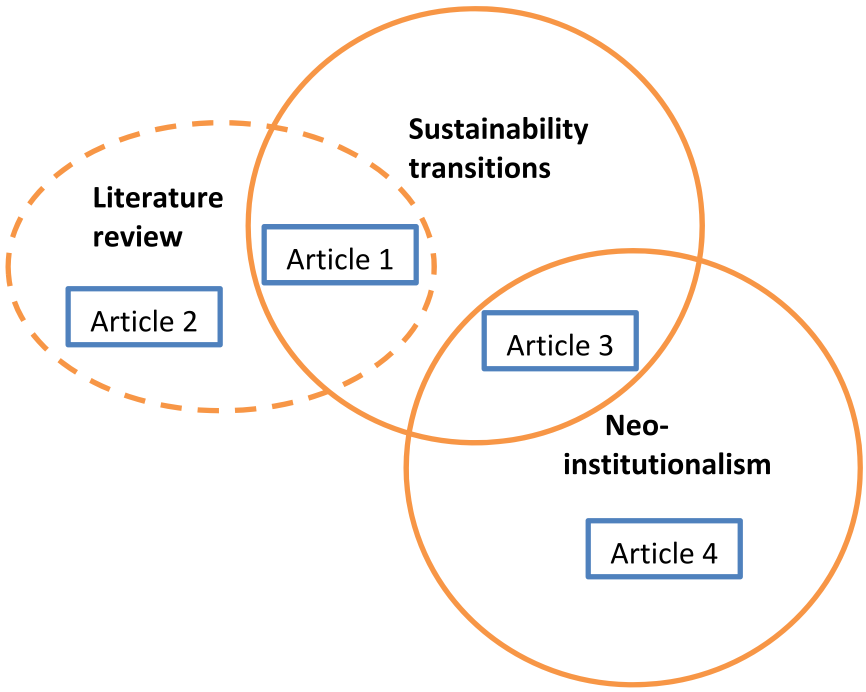
Figure 1: Thematic representation of the content in the four articles



2 Research fields and conceptual frameworks

This thesis draws upon the main research fields of sustainability transitions and neo-institutionalism to answer the research questions outlined above. The current section presents the particular strands of literature I draw upon, how they interlink and how particular concepts and frameworks have been integrated and applied in the analyses. Articles 1 and 2 are literature reviews. The analysis in Article 1 is guided by analytical concepts rooted in sustainability transitions, while the analysis in Article 2 is purely empirically founded. The analysis in Article 3 is based on an integrated framework drawing on sustainability transitions and neo-institutionalism, while Article 4 draws exclusively on analytical concepts rooted in neo-institutionalism. The links between the research fields and the articles constituting the PhD are illustrated in Figure 2.

Figure 2: Representation of the interlinkages between research fields and articles constituting the PhD



2.1 Sustainability transitions: innovation in socio-technical systems

Research on sustainable transitions is concerned with the dynamics and processes involved in the diffusion and uptake of new technologies to deliver societal services (like energy or transportation) in sustainable ways. Technological innovation and change are understood to happen as a result of complex and long-term processes that unfold in larger systems of innovation (Lundvall et al. 2002; Freeman 1995). Such systems consist of actors, technologies and institutions that, through experimentation, learning and interaction, accumulate capabilities that can foster technological innovation and change (Bergek et al. 2008; Edquist 2006). Technologies are understood not simply as hardware, but as reflections of the knowledge required to create it and the skills needed to adopt it (Geels 2002). Technologies are thus embedded in broader societal structures, (social, cultural and political) and a main challenge to achieving sustainable transitions is therefore to overcome the rigidities and path dependencies of existing institutionalised system structures. While this research field has been developed through Western-focused studies, primarily in areas such as energy, transportation (Geels 2005; Geels & Raven 2006) and policy (Jacobsson & Bergek 2011), recent research has contributed to the field by exploring and explaining transitions in developing country contexts (Ulsrud et al. 2011; Hansen & Nygaard 2014; Blum et al. 2015).

The current thesis draws primarily on insights from two strands of literature within transitions theory: the strand on technological innovations systems (TIS) as a framework with which to explore the properties of the East African solar PV technology innovation system (Article 1); and the strand on the multi-level perspective (Geels 2002; Kemp et al. 1998) with which to conceptualise and explain niche–regime dynamics in the Kenyan rural electrification sector (Article 3).

The technological innovation systems framework (TIS) emphasises the dynamic processes at play between the structural and functional components of an innovation system. The structural component includes: technology; actors (including organisations) such as firms, public agencies and end-users; networks among these actors; and institutions (formal and informal), for example, regulatory, political and cognitive frameworks (Markard & Truffer 2008). The functional component includes seven key functions: knowledge development and diffusion; entrepreneurial experimentation; the influence of the direction of search; market formation; resource mobilisation; legitimisation; and the development of positive externalities. The TIS thus provides a functionalistic approach to the analysis of technology diffusion by suggesting that these innovation and diffusion processes are key to the successful introduction of cleaner technologies (Smith et al. 2010; Hellsmark & Jacobsson 2009). As highlighted by Hellsmark & Jacobsson (2009) and Bergek et al. (2008), the functional focus of the TIS permits a systematic rather than ad hoc analysis of dynamics and interdependencies across the structural elements. Against this background, and following Tigabu et al. (2015), the functional component of the TIS framework is used in Article 1 to structure the analysis of the key factors highlighted in the literature to explain the differences in solar PV diffusion in the countries of Uganda, Tanzania and Kenya.

While technological innovation and change are a result of processes and dynamics between technology, actors, networks and institutions within an innovation system, as described above, it is also highlighted to be a result of dynamics between different levels of nested hierarchies within that broader socio-technical system (Geels 2002; Geels 2005; Rip & Kemp 1998). Rip & Kemp (1998) suggested that technological change be understood as processes happening at the three interlinked analytical levels of niches, regimes and landscapes. This *multilevel perspective (MLP)* conceives of technological transitions as path-dependent, non-linear, interdependent and interactive processes of change between these three levels (Markard & Truffer 2008). The levels are characterised by different degrees of structuration, the strongest being at the landscape level and the weakest at the niche level.

The landscape level is the overarching exogenous context consisting of slowly changing, strongly institutionalised social structures. These can include cultural values, political ideologies, climate change or demographic transitions. Landscape developments can influence or exert pressure on the regime and thus open up windows of opportunities for new innovations.

The socio-technical regime forms "the 'deep structure' that accounts for the stability of an existing socio-technical system" Geels (2011;27). The regime is made up of the shared beliefs and values, routines, regulations, artefacts, practices, actor-networks, capabilities, etc. that make up the dominant way of delivering a societal function such as energy provision. Regimes thus represent stability and resistance to change due to path-dependency and structural lock-in (Raven 2006).

However, transitions and change come about when new alternative socio-technical configurations start to compete with, become aligned with or transform the dominant design in the regime (Geels & Schot 2007). Breakthroughs of new innovations happen as a result of experimentation at the niche level. Niches are thus spaces where experimental projects take place and where the maturation of new socio-technical configurations can happen (Smith & Raven 2012). Experimentation at the niche level is dependent on protection and niches are thus referred to as protected spaces (ibid.). Protection can take different forms. New innovations can be shielded from the selection pressures of the regime through support programmes like technology policies, subsidised projects for research demonstration and learning or other regulatory support (Smith & Raven 2012). Niches, however, are also nurturing grounds for new innovations where the particular niche processes of articulating expectations, learning and network formation are instrumental in building the niche (Kemp et al. 1998; Smith & Raven 2012). Schot & Geels (2008) suggest that niches grow and become stronger when expectations are robust, are of high quality and are shared by many actors; when social networks are broad and deep; and when learning processes cover both facts and data, as well as second-order learning in the sense of alternative ways of supporting the niche.

Through experimentation, actors in the niche thus build up networks, generate learnings which are diffused throughout the actor-network that constitute the niche and generate alignment of expectations in the niche through interaction. Through these processes, niches can thus become more stable and drive change by becoming socially and institutionally embedded and either transform, out-perform or take over an existing regime (Kemp et al. 1998).

However, understanding transitions as a function of the interplay between these multiple levels and breakthroughs of new innovations as a result of niche-internal processes provides an overly structural framework for understanding change (Geels 2011). The MLP has thus rightfully been criticised for lacking agency as an explanatory factor in the transition process (Smith et al. 2005). Work by Raven (2006) and Geels & Schot (2007) shows how niche innovations do not always necessarily compete with or substitute the incumbent regime but instead can lead to reconfigurations in the prevailing regime. To understand these processes, recent work highlights the need to focus on niche-external processes in which actors engage in work to actively influence the dominating regime structures in which the niche is embedded (Raven, Kern, Verhees, et al. 2016). In order to contribute to this conceptualisation of the process of agency and the strategic work carried out by niche actors to actively influence the structures at the regime level, I now turn to the literature on neo-institutionalism.

2.2 Neo-institutionalism: institutional entrepreneurship

Neo-institutionalism provides a lens through which to understand social processes and human agency as conditioned, constrained and empowered by the structures within which they are embedded. Institutions are defined as "cognitive, normative and regulative structures and activities that provide stability and meaning to social behaviour" (Scott 1995). While early work on neo-institutionalism focused on explaining the stability and persistence of institutions (DiMaggio & Powell 1983; Meyer & Rowan 1977) and was thus aligned with a more structural view that social relations are patterned and constrain the free initiative of individuals and organisations, the post-structural turn reintroduced the role of agency to explain social change (DiMaggio 1988; Friedland & Alford 1991). Furthermore, influenced by a constructivist ontology, increased emphasis has been put on processes of contestation and struggle as drivers of institutional and organisational change (Garud et al. 2007). Central to the neo-institutional research agenda is the role of embedded agency. Embedded agency is concerned with the paradox of how actors that are subject to the regulative, normative and cognitive processes that structure their sense-making and define their identities are able to envisage and follow new practices and then subsequently get others to adopt them (Garud et al. 2007). The analytical concepts of the institutional entrepreneur (DiMaggio 1988; Battilana et al. 2009) and institutional logics (Friedland & Alford 1991; Thornton et al. 2002; Thornton et al. 2012), applied in Articles 3 and 4 respectively, originate from this strand of literature.

Institutional entrepreneurship refers to the strategic activities of actors who have an interest in particular institutional arrangements and who, by using their resources, create new institutions or change existing ones (DiMaggio 1988; Hardy & Maguire 2009). According to the institutional entrepreneurship perspective, embedding structures do "not simply generate constraints on agency but, instead, provide a platform for the unfolding of entrepreneurial activities" (Garud et al. 2007). According to this view, actors are knowledgeable agents with a capacity to reflect and act in ways other than those prescribed by taken-for-granted social rules (ibid.). The concept of institutional work thus highlights the effortful and skilful practices of actors (individuals and organizations) and provides an analytical tool with which to explore how actors purposefully seek to create, maintain or disrupt institutions (Lawrence & Suddaby 2006: 2015) .

While institutional entrepreneurship provides a framework for exploring the role of agency and the role of individuals in processes of institutionalisation, institutional scholars have cautioned against resorting to the 'hero-entrepreneur' in conceptualising institutional agency (Powell & Colyvas 2008; Hardy & Maguire 2009). This calls for a careful balancing of structural and agency-based explanations for transitions, an area where integration of the MLP and analytical frameworks from institutionalism may prove particularly fruitful. Although institutions and the dual subject-object relationship between actors and institutions are included in the MLP - referred to as mutual embeddedness (Markard & Truffer 2008), these aspects seem in MLP studies to be a conceptual assumption rather than an issue of empirical interest. However, a recent interest has emerged within transitions studies in integrating neo-institutionalism into the MLP to expand its explanatory power of agency in transitions (Fuenfschilling & Truffer 2014; Fuenfschilling & Truffer 2016; Jolly et al. 2016).

Neo-institutionalism is based on a phenomenological and constructivist ontology, where myths, symbols and meaning are of central importance to understanding social life. Furthermore, change is viewed as being driven through processes that take place in a context of contradictions and contested realities, rather than through evolutionary processes of selection, variation and retention. The MLP, on the on the other hand, has its roots in evolutionary theory with foundations in structuralism. With regard to ontological integration between the two perspectives, Geels (2010) claims that it is possible to use the MLP framework in combination with interpretivism and constructivism. Ontological contradictions therefore do not necessarily hinder the integration of neo-institutionalism and MLP, but rather offer another layer to the understanding of the process of change as explored though the MLP. As highlighted by Geels (2010) studies of transitions inevitably highlight certain aspects and background others. Bringing in neo-institutionalist perspectives can thus contribute to highlighting agency-driven processes, as well as the processes of contestation behind (re)production of the elements and links between sociotechnical configurations. It is in this cross-field between ontologies in particular that Article 3 is situated. Such cross-overs between ontologies are also found in research seeking to explain the role of power and politics in transitions (Raven, Kern, Smith, et al. 2016; Avelino et al. 2016).

System building as institutional entrepreneurship

In Kenya, the private mini-grid niche consists of a small number of private firms that are experimenting with a new socio-technical configuration characterised by high-tech, information and communications technology (ICT)-based technologies, demonstrations of commercial viability (including cost-recovery tariffs), in-house technological development, private ownership and strong international partnerships and networks. This niche is emerging within an incumbent rural electrification regime which historically has been dominated by national-led grid extensions. The niche is in its formative phase, being characterised by instability and fragility (Geels 2005) and a lack of proper institutional arrangements (Kebede et al. 2014). Thus the viability of the niche is contingent on the increased institutionalisation of cognitive, normative and regulative structures at the niche and regime levels in support of the niche.

Following (Geels 2004) and Fuenfschilling & Truffer (2014), Article 3 adopts an institutional perspective to explore change where stability and hence structuration at the different levels of the MLP are conceptualised as different levels of institutionalisation, with the strongest institutionalisation taking place at the landscape and regime levels and the weakest at the niche level. Strengthening and increasing stability at the niche level is thus viewed as a process of institutionalisation in which niche-level norms, rules and practices are gaining legitimacy at the regime level. The concept of system builders is used as a unit of analysis to explore agency in this process of institutionalisation. System builders are defined as key actors (individuals or organisations) that play a role in building functioning innovation systems by undertaking specific activities that contribute to the strengthening of innovation systems around such technologies (Ockwell & Byrne 2015; Byrne et al. 2014). The concept of *institutional work* (Lawrence & Suddaby 2006) is introduced to explore how system builders in the form of niche actors engage in specific work to create new institutions which favour the mini-grid niche through various strategies (ibid.). As a new organisational model in Kenya, the fully private mini-grid model represents a range of novel ways of doing things (e.g. charging cost-recovery tariffs, acquiring licences to operate, using mobile payment solutions, etc.) and hence a range of weakly institutionalised practices and norms. Institutional work aimed at *creating new institutions* (Lawrence & Suddaby 2006) in the sense of winning backing for new norms, practices and rules is therefore of particular interest in order to understand how niche-level actors are working to influence existing institutional settings at the regime level. Lawrence & Suddaby (2006) compiled a review of nine types of institutional work, presented in Table 2. Three are related to the regulatory pillar of institutions (Scott 1995), namely *advocacy, defining* and *vesting*, three to the normative pillar, namely *constructing identities*, *changing normative associations* and *constructing normative networks*, and three to the cognitive-cultural pillar of institutions, namely *mimicry, theorising* and *educating* (Perkmann & Spicer 2008; Lawrence & Suddaby 2006). The analysis in Article 3 found that four of them were applied by system builders in the Kenyan mini-grid niche: those of advocacy, defining, mimicry and changing normative associations.

Table 2: Institutional work aimed at creating institutions

Forms of institutional work	**Definition**
Advocacy	The mobilization of political and regulatory support through direct and deliberate techniques of social suasion
Defining	The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field
Vesting	The creation of rule structures that confer property rights
Constructing identities	Defining the relationship between an actor and the field in which that actor operates
Changing normative associations	Re-making the connections between sets of practices and the moral and cultural foundations for those practices
Constructing normative networks	Construction of inter-organizational connections through which practices become normatively sanctioned and which form the relevant peer group with respect to compliance, monitoring and evaluation
Mimicry	Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption
Theorizing	The development and specification of abstract categories and the elaboration of chains of cause and effect
Educating	The educating of actors in skills and knowledge necessary to support the new institution

Source: Lawrence & Suddaby (2006)

2.3 Institutional logics and hybrid organisations

The second neo-institutional analytical concept applied in this study is that of institutional logics. While Article 3 explores the interplay between the niche level and the regime level, Article 4 is primarily concerned with the firm and its organisational processes. This section therefore leaves transitions theory and turns exclusively to focus on the explanatory framework of institutional logics to explore organisational hybridity.

Rooted in the literature on public administration, the concept of organisational hybridity has emerged through the effort to understand and explain the increased "blurring of boundaries" between the state, the market and civil society in the delivery of public services (Billis 2010). Early work revolved around a conceptualisation of hybridity as a descriptor of an organisation that comprised two or more features of a state/market/community or government/business/non-profit triptych. In this strand of research, organisational forms arising from the integration of these traditional sectors have been presented as a spectrum or continuum with traditional non-profit and traditional for-profit at each pole, and with ambiguously defined hybrid forms like non-profits with income-generating activities, social enterprises, socially responsible businesses and corporations practicing social responsibility in between (Alter 2007).

However, increasing scholarly attention has been paid to exploring the managerial and organisational consequences of hybridity in organisations that adopt a for-profit strategy to tackle social or environmental problems (often referred to as social entrepreneurs or eco-entrepreneurs). The inherent organisational complexities of balancing social and economic aims (Battilana & Dorado 2010; Pache & Santos 2010) opens up for the conceptualisation of firms like mini-grid firms as hybrid organisations (Raynard & Greenwood 2014; Doherty et al. 2014; Skelcher & Smith 2015). In this strand of research, hybrid organisations are the carriers of multiple institutional logics, understood as taken-for-granted social prescriptions that guide actors' behaviour (Friedland & Alford 1991; Suddaby & Greenwood 2005; Thornton et al. 2012). Hybrid organisations thus play in two or more 'games' at the same time and "engage with multiple audiences that prescribe different and, at times, conflicting demands" (Raynard & Greenwood 2014:1).

The core idea behind the *institutional logics perspective* is that the interests, identities, values and assumptions of individuals and organisations are embedded within higher institutional orders, each of which has its own sense of logic and rationality (Thornton et al. 2012; Friedland & Alford 1991). Institutional logics thus represent "frames of reference that condition actors' choices for sense making, the vocabulary they use to motivate action and their sense of self and identity" (Thornton et al. 2012: 2). Actors' rationality, behaviour, interpretations and thus actions therefore depend on how individuals locate or reference their sense-making and decision-making within the context of particular institutional logics (Thornton et al. 2012). A family logic, for example, prescribes actions, sense-making and a sense of self tied to unconditional loyalty, patriarchal domination and family reputation, while a market logic follows social prescriptions tied to market capitalism, share price and self-interest. Importantly, however, embedded agency is only partially bounded by social structure, as plural institutional logics are made available to actors and organisations. As various logics place different demands on actors for them to respond to, it is the enactment of logics that reveals insights into how and why sense-making and decision-making occur within organisations (Thornton et al. 2012; Thornton et al. 2002).

As highlighted by Thornton (2010) the plurality of institutional logics and their availability for utilisation by actors allows this perspective to explain heterogeneity in an organisational field, as opposed to other theoretical concepts like that of isomorphism, which explains why organisations facing the same set of environmental conditions converge into organisational forms that resemble each other (DiMaggio & Powell 1983). This makes the institutional logics perspective of particular interest when studying firms that are operating within a presumably homogeneous organisational field, such as private mini-grid firms, while having to respond to the demands of competing logics, as analysed in Article 4.

Micro-level processes of institutional logics

Most research on institutional logics has focused on macro-level processes of institutional change at a sectoral level and within or between organisational fields (Powell & Colyvas 2008; Smets et al. 2012). This includes, for example, studies that explore change from one prevailing logic to another within the sectors of publishing and health care (Thornton et al. 2002; Reay & Hinings 2005). While micro-processes in the form of interpretation, translation and sense-making by actors have been highlighted as a central part of the framework from the very beginning (Friedland & Alford 1991), micro-level analyses of logics being enacted at the individual level have until recently been largely absent from theory building (McPherson & Sauder 2013). Micro-level analysis draws attention to everyday processes in which institutional logics are instantiated in and carried by individuals through their actions (Powell & Colyvas 2008). This agency-level focus understands institutions as being reproduced through the everyday activities of individuals and provides a perspective for interpreting action as a manifestation of logics. Following Powell & Colyvas (2008) and McPherson & Sauder (2013), the analysis in Article 4 thus draws upon this micro-level approach, where the actions and practices of actors within firms are interpreted through the lens of institutional logics to gain insights into the ways in which firms respond to the social and economic logics to which they are exposed. The study thus contributes an empirically based understanding of how mini-grid actors (firms and individuals) enact logics in concrete social situations as they engage in operational activities to achieve their goals.

With the aim of exploring the duality between the social and economic aims of commercial firms with a social mission, two ideal-type logics have been identified in the data, which have been termed the *economic viability logic* and the *social welfare logic*. The economic viability logic refers to the actions and practices of a firm that seeks to optimise the economic viability and efficiency of its business model. The enacted logic of economic viability is thus directed towards the good of the firm and is a manifestation of the market logic (see Thornton 2012). In enacting this logic, the focus of the firm is its own self-interest, its activities and practices being tailored towards increasing organisational efficiency and profit. This logic directs attention away from the customers, their circumstances and the wider community to focus instead on the firm itself and how its actions measure up to standards of economic efficiency.

The logic of social welfare, by contrast, is oriented towards the interests of the targeted community. Here the firm is accountable to the community it serves. This logic is enacted through the firm's activities and practices being directed at supporting and optimising social and human welfare and development. The logic represents the firm's actions and practices in seeking to increase democratic participation, increase the firm's accountability towards the community and ensure equal access. This logic is thus to some extent a manifestation of the state logic (Thornton et al. 2012), in which the cognitive attention of the firm's actors is directed towards the good of the community, democratic participation, citizens' rights and human rights.

3 Country context

Kenya is known for its vibrant private sector and entrepreneurial spirit and is ranked in the top five in Sub-Saharan Africa in terms of the ease of doing business (World Bank 2017b). Kenya’s position as the centre of East Africa’s banking, medical and trading sectors has turned Nairobi into a technology hub, and Kenya ranks high in terms of both foreign direct investments and business start-ups (Baker 2015). This has made Kenya an attractive place for private investors seeking to invest in Sub-Sahara Africa.

This private-sector activity makes Kenya an interesting country for studying processes of sustainable energy provision in rural areas led by private entrepreneurs. The rural electrification and solar PV technology sector in Kenya also demonstrates impressive entrepreneurship first and foremost in solar home pay-as-you-go systems (Rolffs et al. 2015; Hansen et al. 2015), but increasingly also in mini-grids, where three of the private mini-grid firms in this study raised more than USD 35 million in private investments between 2015 and 2017.

3.1 The history of rural electrification in Kenya

3.1.1 Up to the 1990s

Although a government-led rural electrification programme was established in 1973, the pace of rural electrification in the following decades was stagnant (Lee et al. 2016; Yadoo 2012). The rural electrification programme was the joint responsibility of the Ministry of Energy and its implementing arm, the Kenya Power and Lighting Company (KPLC), and was primarily driven by grant funds from donors (Barnes and Foley 2004). Electricity was prioritised for commercial use in the industrial and transport sectors (Byrne 2009), and the cost of grid expansion was considered prohibitively high and demand for energy in rural areas too low to be financially viable (Lee et al. 2016). Electrification efforts were consequently guided by the aim of electrifying industries and larger towns. Although USAID introduced their "New Directions" policy in the 1970s with the aim of targeting the poor more effectively, particularly the rural poor (Byrne 2009), the following decades did not improve rural electrification substantially. In 1990 rural electrification levels were at 3.5% (World Bank 2017a).

3.1.2 1990s to 2011

Like many other Sub-Saharan countries, Kenya went through a vertical unbundling of the national energy sub-sector in the late nineties (Kapika & Eberhard 2013). The unbundling of KPLC under the Electric Power Act 1997 led to the establishment of a public-sector generating company (KenGen), a transmission and distribution company (KPLC) and an Electricity Regulatory Board (ERB). Although this restructuring led to a semi-liberalisation of the sector, with independent power producers (IPPs) generating and selling power in bulk to KPLC through power purchasing agreements, transmission and distribution still fell under the KPLC monopoly.

Under the new Energy Act of 2006 an Energy Tribunal was established, and the ERB was turned into a fully independent Energy Regulatory Commission (ERC), with extended functions and powers to regulate the sub-sectors (KipKirui Karir 2009). The functions of the ERC include tariff setting and licencing. KPLC operates with cost-recovery tariffs approved and regulated by the ERC that are differentiated based on the level of voltage supplied to domestic users and commercial users. Tariffs are constructed using cross-subsidies so that consumers in rural areas, where the costs of provision are high, pay the same as consumers in urban areas, where the costs of provision are lower. The average retail tariff has been relatively stagnant. A significant change was introduced in 2009 however when the ERC approved KPLC's application for an upward adjustment, and the average tariff increased from 11.7 to 15.8 $cent/Kwh (Kapika & Eberhard 2013). KPLC, as the sole distributor, has been granted universal rights and a licence to distribute power to all areas across Kenya.

Like KenGEN, KPLC went public on the stock exchange in 2006, with the Government of Kenya being the company's principal shareholder, holding a 50.1% equity interest (Kenya Power 2016). Under the Energy Act of 2006 the functions performed by KPLC were opened up to other actors, paving the way for other players to enter the business of transmission and distribution of electricity. In 2008, the Kenya Electricity Transmission Company (KETRACO) was established to construct, operate and maintain high-voltage power transmission networks (Kapika & Eberhard 2013). However, distribution and retail still remained a de facto KPLC monopoly.

The Rural Electrification Authority (REA) was established the same year with a mandate to develop, manage and implement the rural electrification programme. After its establishment, REA drew up a three-phase Rural Electrification Master Plan (2009) with the aim of connecting 20,000 public facilities in the first phase (2009-2012), connecting households in the second phase (2013-) and achieving 100% connectivity in the third phase (-2030) (Kapika & Eberhard 2013). Connecting public facilities was pursued through two modes: grid extension, and the installation of solar PV, wind and biogas systems in public institutions (Ayieko 2011). In addition, decentralised generation and distribution systems were developed to supply remote urban centres. Although REA got off to a slow start, the strategy set out in the Rural Electrification Master Plan to connect trading centres, secondary schools and health centres has led to an increase in the electrification of public facilities from about 25% in 2008 to about 68% in 2016 (REA 2016b). Despite this progress, work by REA has been focused primarily on connecting public facilities, a policy that has left surrounding households unconnected and hence kept rural connectivity levels low.

After completion, projects developed by REA through government funding and international donor investments are handed over to KPLC for operation and maintenance based on a Service Level Agreement. However, the assets remain the property of REA, and project operations and maintenance (O&M) are covered through the electricity retail tariff (Ayieko 2011). This arrangement gives KPLC a de facto subsidy for capital expenses (CAPEX) and thus a competitive advantage in the market. REA and KPLC have a joint technical project committee whose members decide on the standards and specifications to be used in the electricity subsector (ibid.).

Being a publicly listed company owned by the government and private investors, KPLC has to take into account the interests of private shareholders, who are both seeking a profit and consuming electricity and hence expect a quality, reliable and competitively priced service. Their focus is therefore primarily on delivering power to industrial users and to optimise existing infrastructure by increase connectivity based on existing networks. 60% of KPLC's revenues come from fewer than two thousand industrial customers (personal interview). Despite a monthly fee on all domestic consumer bills of 150 KES[1] to cover O&M, connecting households with low consumption means increasing costs without increasing revenue, which has kept the incentives for including new low-consuming customers low. Furthermore their model of high connection rates (recently reduced from 70,000 to 35,000 KES) has left grid connection out of the reach of rural residents.

An effort has been made to increase connectivity levels and increase the customer base, driven primarily by USAID funding by subsidising connection fees. However initiatives like the "Umeme Pamoja" scheme, the Kenya Electricity Expansion Project (KEEP), the Kenya Electricity Modernization Project (KEMP) and Global Partnership Output Based Aid (GPOBA) schemes has primarily targeted peri-urban settings, not rural areas (Abdullah & Markandya 2009; Kenya National Audit Office 2015; Njoroge 2011). KPLC managed to reduce average connection fees under the Umeme Pamoja scheme to USD 550-700 to be shared by customers in 2011 (KPLC n.d.) and under the GPOBA to USD 174-462 per household with eligibility for loans (Njoroge 2011). However, many households were still left "below the grid lines", i.e. unconnected (Lee et al. 2016). National electrification levels increased in the period from 1990 to 2011 from below 8% to 19%, and rural electrification levels increased in the same period from 3.5% to 7%, indicating continued slow progress, as well as the prioritising of urban areas (IEA 2013; IEA 2002; World Bank 2017a).

3.1.3 2011 to the present

Windows of opportunity for private mini-grid development started opening around 2011. The Sustainable Energy for All initiative was launched by the UN Secretary-General in 2011 and was followed by the United Nations General Assembly declaring 2012 the International Year of Sustainable Energy for All and 2014-2024 the Decade of Sustainable Energy for All. These initiatives came out of an acknowledgement that sustainable energy

[1] Exchange rate as of May 2017: 100 KES = 0.98 USD

was central to achieving the post-2015 sustainable development goals (UN 2014). Mini-grids were given a central role, alongside grid extension and pico-systems, following estimates by the International Energy Agency in their World Energy Outlook (IEA 2011) that 40% of all new capacity needed to reach universal access by 2030 would be achieved most economically through mini-grids.

Concurrently, the African information and communications technology (ICT) revolution demonstrates its effects with evidence showing the economic gains made possible by greater ICT penetration and the increase in incomes of Kenyan rural households by 5%-30% due to mobile banking (Harding 2011). By 2011, 72% of the population living outside Nairobi on less than $1.25 per day were using the mobile money transfer service M-PESA compared to 20% in 2008, and the total number of subscribers had grown to 17 million (Suri & Jack 2012). This level of ICT penetration has provided a precondition for the backbone of the private mini-grid business models, namely the smart systems comprising mobile banking and telecommunications-based metering and monitoring solutions. Other forces creating windows of opportunity include the general fall in the solar PV price of 80% between 2009 and 2015, the increase in the quality of renewable energy technologies (IRENA 2016) and the climate change-driven focus on green and fossil-free investments from the private sector (Climate Change Support Team 2015; World Economic Forum 2013).

Following these developments, pressure has been increased on the Kenyan rural electrification regime, where grid extension and small-scale solutions like solar home systems and lanterns are increasingly being supplemented by mini-grid experiments. International development collaboration agencies like the World Bank and the African Development Bank (AfDB) are turning towards supporting mini-grid development as a natural extension of the poverty reduction discourse, while at the same time supporting the dominant regime of grid extension through major infrastructure investments and expansions of generating capacity. These initiatives include USAID-supported Power Africa and SREP, as well as AfDB-supported Last Mile and the African mini-grid facility (USAID 2016; GoK 2011; AfDB 2017). In addition, large financing projects directly targeted at developing the mini-grid niche include the UK Department for International Development (DfID) and the International Finance Corporation (IFC) in supporting the Green Mini-Grids Africa intervention initiated in 2016 with £30m to support project preparation and leverage private investment in Green Mini-Grids (GMGs), as well as £15m to support a regional facility for market preparation, evidence and policy development, and prepare for the wider scaling up of green mini-grids across Africa (DfID 2015). Also, the SE4All Africa Hub initiated in 2016 provides technical assistance to Green Mini-Grids developers (AfDB 2016). In 2015 the IFC commissioned a mini-grid study for the Energy Regulatory Commission to assess the potential market for privately operated mini-grids and identify some of the key challenges and possible approaches to expanding access to energy through mini-grids (Carbon Africa Limited et al. 2015). Donors involved in the Kenyan rural electrification regime are thus increasingly including mini-grids as part of their support to REA and KPLC. This is creating an increasingly diversified regime with a wide range of actors present and a large portfolio of ongoing projects.

KPLC's main focus on industrial users and grid-extension persists. However, its recently announced flagship, the Last Mile Connectivity Project, supported by the AfDB, represents a push to increase connectivity levels, including among low-consuming households. The project offers highly subsidised connection fees (fees of between USD 20 and 150 per connection depending on affordability) to people living within 600 meters of existing transformer stations and is an important part of the government goal to raise connectivity in Kenya to 70% by 2017 and achieve universal access by 2020 (MoEP 2017). While KPLC has enjoyed a de facto monopoly, despite the deregulation of the sector since 2006, this monopoly was broken when two IPPs were granted licences by the ERC to distribute and sell power directly to customers in 2015.

REA continues to focus on market centres, schools and health clinics, but its main mode of extending power lines to rural areas has recently been diversified to include village-size mini-grids to electrify rural areas, and the second phase of the rural electrification programme also includes connecting households. REA is working specifically with the KfW Development Bank (KfW) to develop three mini-grids rated at 100 kW (personal interview), and in 2016 it offered a public tender for twenty-five 60-kW mini-grids to be implemented through private-sector bidders (REA 2016a).

At the political level, following the post-2007 election processes, including the constitutional amendment and the introduction of a policy of devolution, MoEP drafted a new energy bill where decentralisation was increased and more authority was given to counties. The new energy bill of 2015, which has been sent to the Senate for review, supports private-sector involvement in distribution and sets out a more detailed framework for independent power producers (Shiundu 2016). The bill, however, has not yet been adopted.

According to IEA, national and electrification levels have been stagnant at around 20% and 7% respectively since 2011 up until 2014 when the latest figures were published (IEA 2016). Turning to national data sources, REA and KPLC state that approximately 1 million new connections were made between 2013 and 2015 (REA 2015) and another 1.2 million connections between mid-2015 and mid-2016 (KPLC 2016). These effort correspond to a national connectivity level of 42% reported by a KPLC staff member in mid-2015 (personal communication) and a level of 55% reported by KPLC and of 57% reported by the Government of Kenya in 2016 (GoK 2016; Moss & Portelance 2017). Although these figures cannot be reliably compared to the IEA figures presented above these developments represent an impressive effort towards reaching the national electrification goals.

4 Research Methods

In this thesis, solar-powered mini-grid development through private models is explored by means of a qualitative, country-specific, multiple-case study combined with regional reviews. As a sparsely researched topic with little empirical knowledge available, Articles 1 and 2 perform the function of establishing the context and foundations for the exploratory and empirically grounded work presented in Articles 3 and 4. The four private firms which constitute the case study in Articles 3 and 4 were selected based on their definition and context (Miles & Huberman, 1994) as private mini-grid developers operating in rural Kenya.

The process of selecting firms for the study was driven primarily by the aim of revealing new insights in an area that has not been studied before (Yin 1994). Due to the limited existing knowledge about this organisational form, the case of the four firms is considered to be of intrinsic interest and value (Stake 1995). The firms were thus chosen to generate data that would provide insights into particular firms, their business models and the experiences of their customers. In addition to generating case-specific knowledge, the multi-case design provides an opportunity to explore variations among cases and thus create complex yet conceptualised knowledge about the private-sector model in Kenya. While the research design does not facilitate generalizable knowledge per se, the findings may be of interest in terms of private mini-grid development more generally.

4.1 Data collection

Being literature reviews, Articles 1 and 2 are based on secondary data in the form of scientific publications, grey literature, popular media reports and information from firms' websites compiled through desk studies. In addition, supplementary data were generated from discussions, meetings and insights obtained during conferences in Copenhagen and Nairobi respectively. The data collection method for Articles 3 and 4 consisted of qualitative, in-depth exploratory interviews combined with observations at field sites. Primary data consists of transcribed interviews and notes from non-recorded interviews, as well as field notes documenting observations, reflections and thoughts. The research is based on a total of eighty-five interviews. Twelve interviews were conducted with staff from four mini-grid firms, four with key informants with knowledge about the firms and the sector in general, and eight with government representatives, including representatives from the Energy Regulatory Commission (ERC), Kenya Power (KPLC), the Rural Electrification Authority (REA) and the Ministry of Energy (MoE). These interviews lasted between thirty minutes and two hours and were recorded and subsequently transcribed. Sixty-one interviews, using an interpreter, were conducted with mini-grid-connected end-users and their non-connected neighbours during four site visits. The interviews were captured through notes taken at the time of the interview and elaborated further through extended field notes at the end of each day. In addition Articles 3 and 4 draw upon secondary data in the form of scientific publications, grey literature such as donor and NGO reports, annual statements, strategy and policy documents from governments, popular media reports retrieved from the internet and text from firms web pages.

Primary data was gathered during a two-month period from July-September 2015. Interviewees from firms included senior staff with key roles in the firms' daily operations and staff with on-site operational responsibilities. Interviews with firms were planned at the outset of the fieldwork, whereas actors from government agencies, donors and other key informants were selected using a snowball sampling method, which enabled access to relevant and knowledgeable actors (Atkinson & Flint 2004). Here senior experts directly involved in decision-making processes were targeted, as well as actors who had specific and practical knowledge of the sector.

Expert interviews conducted with firm staff, government officials and other key stakeholders were semi-structured and hence designed to act as a 'conversation with a purpose' (Mason 2002). Interviews were guided by a protocol that evolved from interview to interview as insights were gained and new themes emerged. The protocol or interview guide was developed prior to the fieldwork by operationalising the central analytical concepts. This work included formulating relevant questions to ensure that the analytical concepts were covered and hence to improve validity in data collection.

Interviews with firm actors were guided by a focus on how they 'do business'. In addition to questions on the processes and functions of the firm, questions were designed to reveal and gain insights into the everyday work of actors (Jarzabkowski et al. 2009) through the intelligent activities of individuals and organizations (Lawrence & Suddaby 2006). Firm staff were, for example, asked to describe the ways in which they collaborate with other firms, select new sites, engage with customers and interact with regime actors. This included probing for their views on regime actors' opinions of them, as well as their own views of regime actors and regime structures. This focus on practice was instrumental in creating data on the awareness, skills and reflexivity of actors, which is a key element in studying institutional work (Lawrence & Suddaby 2006).

A second strategy in the data generation process was to focus on conflicts, as suggested by Olivier de Sardan (2005;189) to "penetrate the intricacies of society, of revealing its structures, norms and codes, or of highlighting the strategies and logics of actors or of groups". Firm actors were asked, for example, to reflect on the tensions between their social and economic aims, as well as to share examples of difficulties in their work. Regime actors were asked, for example, about the expectations of mini-grids, the perceptions of mini-grid actors, their views on competition between regime and mini-grid developers, the attitudes to the barriers to private mini-grid development and suggested support measures. At the village level, customers were asked, for example, for their opinions of the firms, as well as to elaborate on their interactions with firms and examples of firms' practices and operations. Exploring conflicts, tensions, inconsistencies and contradictions with firm actors, regime actors and customers and non-connected neighbours was a way to gain insights into the semi-coherence of the regime, as well as to triangulate data generated from interviews with different actors.

Interviewees from villages with installed mini-grids were selected inspired by Bierschenk and Olivier de Sardan's method for identifying strategic groups in fieldwork (Bierschenk & Olivier de Sardan 1997). The notion of a strategic group, according to Olivier de Sardan (2005), is "built on the simple supposition that all actors in a given community do not share identical interests or concepts and that, depending on the problem, their interests and concepts produce different combinations, but not haphazardly so" (ibid.: 191). Following this reasoning, data were collected with the aim of identifying and covering as many strategic groups as possible. The two main strategic groups to be identified were those of connected and non-connected households. In order to identify further strategic groups, initial interviews were made with key persons in the village (shopkeepers, landlords, influential persons, etc.), who could be expected to possess information that could lead to the identification of further strategic groups. Identified strategic groups included (in addition to connected and non-connected households): i) landlords ii) tenants, iii) affluent households (owners of restaurants, hotels, shops, etc.) and iv) poor households. The aim of the data generation process was thus to represent respondents from each of these groups and to shift between the groups from one interview to the next in order to cover and possibly expand the number of strategic groups along the way. A second aim, facilitated by this approach, was to keep changing perspectives in the quest to explore conflicts without becoming attached to the viewpoints of particular strategic groups (Bierschenk & Olivier de Sardan 1997). This approach made possible the ongoing triangulation and validation of answers, as well as adjustments and elaborations of issues en route.

4.2 Data analysis

The reviews for Articles 1 and 2 were conducted by following a hermeneutic approach in which the search for relevant literature was guided by a continuous open-ended process (Boell et al. 2010). This search tactic was used to create target searches where a small number of highly relevant publications were identified, which in turn provided the foundation for additional searches. This approach acknowledges that "there is no final understanding of *the* relevant literature, but a constant re-interpretation leading (ideally) to deeper and more comprehensive understanding of relevant publications" (Boell et al. 2010:130). The reviews thus evolved over time, and understanding obtained in each new reading informed the continuous search.

In addition to a review of country-specific policies and activities related to each solar PV segment, the review in Article 1 consisted of a cross-country analysis of the key factors explaining differences in the diffusion of solar PV. The TIS framework was adopted to guide this analysis and thus structure the review. In Article 2, ongoing mini-grid activities in the three countries were mapped. This process included a review of existing mini-grid activities, followed by an empirically driven categorisation of these activities, leading to a proposed mini-grid framework based on mini-grid type and ownership. This categorisation partly informed the selection of case firms for Articles 3 and 4.

In Articles 3 and 4 transcripts, notes and documents were subjected to qualitative thematic analyses (Braun & Clarke 2006) using theoretically informed coding schemes. In this way, data were coded for emerging patterns and themes as well as for pre-established codes. The analysis in Article 3 went through the following steps. The first step sought to bring out the unique patterns of each firm, as well as differences and similarities among the firms by combining in-firm analysis with a search for cross-firm patterns (Eisenhardt 1989). Here the tool of tabular display was used (Miles et al. 2014). Following the insight of Fuenfschilling & Truffer (2014) that conflicts and tensions can help expose and reveal the instabilities of a regime in which old ways of doing things are being challenged by new actors in the space, the second step analysed issues of particular centrality with regard to the emergence of the new niche. These "hotspots" were analysed by identifying "issues that have not yet been settled" in the matter of private mini-grid development within the incumbent regime of grid-extension (ibid; 781). Interviewees were probed, for example, regarding challenges and barriers for private mini-grid development, the most important constraints for firms and possible policy solution. Six issues related to i) licencing, ii) grid-integration, iii) tariffs, iv) connection fees, v) who to connect and vi) subsidies were identified and verified by triangulating the data from the various groups of informants. The third step was guided by a theory-informed coding scheme which was used to analyse how firms and firm actors conducted institutional work. Codes corresponding to the nine forms of institutional work to create new institutions were applied to the data. The analysis identified four ways in which niche actors sought to influence the regime level directly, namely through advocacy, defining, mimicry and changing normative associations.

The analysis in Article 4 went through the following three steps. The first step included an open and inductive coding exercise to explore how firms were constructed discursively. This included firms' representations of themselves, as well as how mini-grid development was represented by actors within the broader environment, including, for example, development practitioners, policy-makers and the public media. Furthermore, firms' practices were coded according to aspects of their business models. This first step led to the development of two ideal-type logics: the logic of economic viability, and the logic of social welfare. The second step included an analysis of how firms enact these two particular logics through their practices and in their interactions with customers. The analysis focused on relations between the firms and their respective customers and was therefore organised according to the business-model aspects of customer segments, channels and customer relationships (Osterwalder & Pigneur 2010). With respect to these business-model aspects, each firm's practices were coded according to the prevailing logic underpinning their actions. The analysis was based on both reflexive and non-reflexive representations of these two logics, taking into account both how firms talked about their practices and how the identified logics became manifest unintentionally through their practices. The third stage identified the effects of various practices in the communities served by the firms.

5 Article summaries, findings and contributions

Article 1 addresses the broader topic of solar PV development in East Africa. While this topic has been dominated by single-country and single market-segment foci, Article 1 contributes a multi-country analysis cutting across the various market segments of solar PV technology in Uganda, Tanzania and Kenya. The article describes the historical context and current status of solar PV technology in the East African region and provides an analysis of the various markets of pico-PV systems, institutional systems, mini-grid systems and large-scale solar projects. The article points to a general trend away from donor-based support towards the private-driven diffusion of solar PV, as well as increased private-sector engagement in the mini-grid and large-scale grid-connected solar power plant segments. Solar PV diffusion in the particular segment of solar-home-systems (SHS) is explained by reference to a decline in the world market prices for PV modules, prolonged support from international donors and the supportive framework conditions provided by national governments. The article also identifies five key factors that explain the higher level of SHS diffusion in Kenya compared to Tanzania and Uganda. These include i) a growing middle class with purchasing power and knowledge about SHS, in combination with the slow pace of grid extension; ii) geographical conditions like the geographical proximity of actors combined with better transportation and distribution infrastructures and less dispersed populations; (iii) local solar PV sub-component suppliers, leading to cost reductions and fruitful interaction between different industries; (iv) local champions, who, through demonstration projects, have attracted the interest of donors and government; and (v) a strong entrepreneurial culture explaining the widespread opportunism and risk willingness of local firms in Kenya to enter the PV market during its initial development.

Article 2 turns to investigating the particular segment of mini-grids in the same three countries. The article makes two contributions. First, it provides an empirical review of activities on the ground, through which it suggests a typology of mini-grids based on types of ownership and types of mini-grid. Secondly, this framework is used to point out that the majority of national mini-grid initiatives in the three countries are targeted at urban and productive centres and only contributes towards rural electrification to a limited extent. This point presents a conceptual and practical contradiction between the discourse of the perceived positive benefits of mini-grids proposed as a solution for delivering rural energy access and the actual country-level priority placed on mini-grids powering large towns. The article thus highlights a need to deconstruct the popular and all-inclusive notion of mini-grids to create a more specific and differentiated language in order to capture better the different purposes, constraints and requirements of various types of mini-grids and their organisational arrangements. The article concludes by laying out a detailed research agenda for generating knowledge about the particular type of mini-grid being targeted at rural villages and implemented by means of a private model. The article calls for research into the innovation system of which mini-grid firms are a part, as well as into the operational and managerial aspects of how firms balance social and economic purpose in their business models and the practical effects on the ground. This research agenda is pursued through the cases studies described in Articles 3 and 4.

Article 3 contributes an empirical account of agency within the multilevel perspective by applying the concept of institutional work to explore how niche actors engage in system building to influence and change institutions in the Kenyan rural electrification regime. Findings show how strategies differ among private-sector actors. While some rely primarily on internal niche processes like network building and partnership development to build the niche, others engage in external niche processes to create change at the regime level more directly. These external processes include regulatory work in the form of advocacy and producing definitions in order to influence both the legal and economic instabilities within the regime; cognitive work in the form of mimicry to create links between taken-for-granted practices in the current regime and new practices associated with the min-grid niche; and normative work in the form of changing normative associations to create positive associations in regards to the private mini-grid model. By looking at system building through the lens of institutional work, Article 3 brings out the less visible ways in which, through their actions and practices, private actors seek to influence their environment and thus strengthen the niche. The article demonstrates the value of integrating the concept of institutional work with MLP to expand the understanding of processes at play at the niche level in transitions and to capture the role of (organisational) agency in these processes.

Article 4 examines the ways in which private mini-grid firms respond to the competing logics that are available to them. Its findings show how, through both a broader global narrative and their own self-representations, private mini-grid firms are embedded in a hybrid reality in which the logic of social welfare and the logic of economic viability are both available to them. By analysing the patterns of how these particular logics are enacted through firms' practices on the ground, the firms are condensed into two main groups. The first group enacts primarily the logic of economic viability, which is prioritised over the logic of social welfare in their work, while the second group of firms combines and blends the two logics. Enactment of the economic viability logic seems to be pursued by firms that need to conform to resource constraints and thus prioritise the economic logic over the social welfare logic in their actual business activities. This can be seen as way for such firms to respond to pressures from investors to prove the economic viability of projects in the short term in order to secure resources. The blending strategy, by contrast, seems to be pursued by firms that do not have the same resource constraints and that, due to access to large-scale funding, can pursue a long-term strategy in which synergies are sought from blending the logics of social welfare and economic viability. These findings open up an interesting avenue of research into the specific conditions under which blending as a firm strategy leads to successful long-term organisational outcomes for the firms and how this strategy can be supported.

In addition to the four articles constituting this thesis, the publications of thematic relevance listed in Table 3 were prepared in conjunction with preparation of this thesis.

Table 3: Additional publications of thematic relevance to this thesis

#	Title	Authors	Status
1	Review of Solar PV Market Development in East Africa.	Hansen, U.E.; Pedersen, M.B. and Nygaard, I	Presented as poster at 1st Africa Photovoltaic Solar Energy Conference and Exhibition, 27-29 March 2014, Durban, South Africa. Published as a UNEP Risø Working Paper, 2014.
2	Prospects for investment in large-scale, grid-connected solar power in Africa.	Hansen, U.E.; Nygaard, I and Pedersen, M.B.	Published as a conference contribution to the conference: "Opportunity Africa: Sustainable Energy Investments in Africa - Engaging the Private" Sector" June (2014), by UNEP Risø Centre.
3	Measures for the Diffusion of Solar PV are Aligned in Technology Action Plans for Six Countries in Africa.	Nygaard, I.; Hansen, U. E.; Pedersen, M.B and Mackenzie, G	Published as conference proceedings at 1st Africa Photovoltaic Solar Energy Conference and Exhibition, 27-29 March 2014, Durban, South Africa.
4	Measures for diffusion of solar PV in selected African countries	Nygaard, I.; Hansen, U. E.; Pedersen, M.B and Mackenzie, G	Published as peer reviewed article in: *International Journal of Sustainable Energy*, (2015) Oct, pp. 1–15.
5	Enhancing Access to Electricity for Clean and Efficient Energy Services in Africa	Christensen, J. M.; Mackenzie, G. A.; Nygaard, I.; Pedersen, M. B.	Published as a report by UNEP DTU Partnership, (2015).

6 Conclusion

This thesis sets out to explore the emergence of private sector-led mini-grid development in Kenya, as well as the way in which mini-grid firms, through their work, influence existing rural electrification structures and balance social and economic purpose. This overall aim was pursued by answering four interlinked research questions:

1. What are the status, trends and drivers of solar PV diffusion in East Africa, and how is disparate diffusion across the region explained?
2. How is the popular concept of mini-grids understood and used in the current development discourse, and what does a typology of mini-grids based on an empirically based conceptualisation of mini-grids look like?
3. How and through what forms of institutional work are system builders within the Kenyan mini-grid niche transforming or influencing current institutional settings in the incumbent rural electrification regime?
4. How do private mini-grid firms, through their practices, respond to the competing logics of social welfare and economic viability?

These questions are addressed separately in each of the research articles, and the findings were resumed in Section 5. I will conclude this thesis by returning to the overall research aim and provide a wider conclusion to each of its three elements, including theoretical reflections and proposals for further research.

What explains and conditions the emergence of private mini-grid firms in Kenya?

Rural electrification as a market place for private mini-grid developers and the emergence of private mini-grid firms in Kenya within the past five to six years have been highly reliant and conditioned by the digital transformation that has happened in the country within the past decade. High penetration rates of mobile phones, mobile payment solutions (M-PESA) and high-quality mobile coverage in rural areas, combined with technological advances in solar PV technologies and cost reductions, are the main drivers behind these new business models. Especially highly technologically advanced monitoring and metering software and hardware are central for understanding the emergence of rural electrification through mini-grids as a market for private firms. This specific technology provides several advantages to such firms, including automated and remote control over individual usage at the household level and effective payments collection based on actual consumption. It gives customers full control over their spending, and it provides firms with an overview of their actual revenue stream, as well as security of payment, as only electricity which has already been paid for is available for use. Furthermore, it provides firms with real-time access to information about operational and management issues related to the mini-grid, allowing them to make well-informed decisions and take immediate action to improve performance and fix problems in the mini-grid system. Lastly, it allows firms to generate valuable data from their experimentation, from which they can generate learnings about their particular mini-grids, as well as building convincing business cases based on real-life data to attract investors and upon which to base negotiations with regime actors. While the technology itself plays an important role in the emergence of private mini-grid firms, equally important is the fact that these firms are able to tap into an already established awareness, acceptance and trust on the part of their consumers towards the central part of their business model, namely the concept of mobile-based systems and pre-payment for services.

While the digital and high-tech solutions underpinning mini-grid business models also provide unique opportunities for potential future integration with the main electricity grid, and thus a unique opportunity for creating synergies between the two modes of electrification in the country, such integration would require clear policy frameworks, as well as standardisation across the sector, which is currently lacking. This leads to the specific regime-level stabilising factors that constrain niche development. The thesis points to two main aspects which are constraining the upscaling of experimentation in the niche. The first is related to rules and regulations with regard to tariffs and subsidies, the second to a lack of clear policies to guide the integration of grid-extension and mini-grids, including institutionalised norms and practices among regime actors resulting in resistance to change.

The national uniform electrification tariff of approximately 20 US cent / kWh represents a deeply institutionalised structure in the current electrification regime. While mini-grid firms are currently operating legally under the status of pilot projects, which allows them to charge cost-reflective tariffs at levels five to twenty times higher than the national uniform tariff level, the lack of a formal tariff approval from the ERC[2] is impeding firms in scaling up their operations. Although the ERC is an independent regulator, it relies on policy guidelines from the Ministry of Energy in order to make rulings of precedence in this area. And although cost-reflective tariffs may be accepted by consumers due to the fact that mini-grid firms provide a better service at a lower cost than the currently available alternatives (diesel, kerosene, batteries), approving higher tariffs for rural populations is a politically sensitive issue. While the Ministry of Energy is generally positive towards the prospects of attracting private-sector finance to rural electrification through private mini-grid firms, it is facing a dilemma in defending a policy which leaves rural populations paying higher tariffs than their urban neighbours. A subsidy scheme like that recently implemented in India, in which the government provides a 30% CAPEX subsidy while restricting tariffs (Government of Uttar Pradesh 2016), could provide a solution to the problem of bringing down tariffs for mini-grid power. However, government subsidies for rural electrification are currently being channelled through two regime-level actors, REA and KPLC, which simply erects a second

[2] None of the studied firms have had their tariffs approved at the time of writing.

barrier to private mini-grid development, namely unclear polices with regard to the co-existence of private mini-grid operators and the national utility KPLC, as well as resistance to change from incumbent actors.

While the process of licencing gives private actors legal access to operate within a certain area, it does not necessarily give them exclusive rights to serve the area if that area were to be absorbed by the national grid in the future. This lack of clear policy frameworks laying down the conditions for potential future integration between the mini-grid and the national grid presents a threat to firms with regard to their ability to safeguard their investment, a barrier similarly reported by Comello et al. (2016) in India. Furthermore, KPLC is currently pushing to increase connectivity drastically in the country over the next few years through the Last Mile project. The fast pace of the KPLC grid extension programme presents a situation in which private mini-grid developers may end up competing with KPLC for the most densely populated rural areas to electrify. This, in combination with KPLC's status as a national utility with a historical monopoly of electrification, leaves it reluctant to view private-sector mini-grid development as a favourable supplement to grid-extension or to back a solution involving subsidising the mini-grid sector.

These regime-level stabilising factors shows that, while mini-grid firms may be successful in designing and operating commercially viable businesses, their business cases rest on conditions that are not (yet) aligned with the current policy framework in the country, which is primarily tailored towards grid-extension. Whether the market for mini-grid development, due to fast grid-extension, will start closing before it has really taken off or whether electrification via mini-grids will become a supplementary mode of electrification is still to be seen. However, as neither the technologies nor the firms are restricted by national borders, the Kenyan mini-grid niche may end up as an important incubation room from which firms could bring their learnings into other markets in the region. Three of the firms are already operating in other countries globally.

While it is still uncertain whether alignment between the mini-grid actors and the existing structures will materialise and thus encourage growth of the niche, it is clear from the findings here that mini-grid firms are reliant on improved protection of the niche in order for it to grow and for mini-grids to become a sustainable supplementary electrification approach to grid-extension. Turning to the next section, the thesis finds that, while mini-grids are unlikely to become competitive to grid-extension by conforming to existing regime-level conditions, niche actors are found to actively seeking to influence and transform institutions at the regime level in order to change conditions, including mainstream selection environments, in ways that are favourable to mini-grid development (Smith & Raven 2012).

How do private mini-grid actors, through their work, influence existing rural electrification structures?

The research presented in this thesis has shown how system builders in the Kenyan mini-grid niche apply different strategies in their work to strengthen and grow the niche. While some actors through their work are focusing on traditional niche-internal processes in the form of generating learning and expanding networks and partnerships in support of the niche, other actors are engaging in niche-external work in order to transform the constraining environment in which they operate. The first type of system builders are seeking protection from selection pressures by, for example, experimenting in areas far from existing infrastructure, which protects them from engaging in resource-demanding negotiations with regime actors. This provides these firms with room for manoeuvre in what they find important for growing their businesses, namely focusing on generating and disseminating learnings from their work in order to grow and build networks and partnerships in support of their businesses. The second type of system builder, in contrast, works directly towards creating an empowering environment for private mini-grid development by targeting openings in the existing regime and thus reducing the pressures on the niche. System building of this kind is thus a result of specific actors working to change the current rules, norms and behaviours in the regime and to become more aligned with those of the niche, as well as to win backing for new rules, norms and behaviours in favour of the niche. While most such work towards transforming regime structures is targeted directly at the mobilization of political and regulatory support through direct meetings and negotiations with regime actors, the study highlights some interesting and less visible forms of institutional work in which actors rely on cognitive and normative work to create change. This work includes associating private mini-grid development with existing and accepted sets of practices, like mobile payment solutions, as well as modes of standardisation. Although current rules, regulations and practices in the regime do not support or encourage integration between mini-grids and the national grid, by mimicking national grid standards firms seek to create the right conditions for this to be possible in the future. Following grid standards represents high upfront investments for firms. However, by doing so firms create a situation in which they reduce rather than emphasise the gaps between the regime and the mini-grid niche and thus create a platform for the regime to re-structure the rules and practices to become more favourable to the niche. Lastly the thesis identified how system builders are seeking to change normative associations within the existing regime towards private mini-grid development. This is done by targeting taken-for-granted assumptions about what is a 'just' price for electricity and by questioning the normative assumptions underpinning the traditional connection model, used by regime actors and private firms alike, of connecting only the most affluent households in an area. In this way, firms create positive normative connections between their sets of practices, including the moral and cultural foundations of these practices (e.g. the connect-all strategy), and the mini-grid model, thus reformulating the normative associations within the regime related to that model. While the effectiveness of these system building strategies in growing and stabilising the niche is as yet unknown, it provides an interesting avenue for further research into the role of and interdependence between niche-internal and niche-external processes in driving the expansion and scaling up of new niches. The focus in this thesis has been on the role of niche actors to facilitate change by *creating* new rules, norms and practices in favour of the niche and to win backing for these at the regime level. Further research is needed to understand other aspects of the role of institutional work in system building. This includes research into the importance of institutional work done by regime actors to *maintain* existing rules, norms in the regime. Such research could also focus on the dynamics between institutional work done to create institutions in favour of the niche and work done to maintain institutions at the regime level. Furthermore research could address whether niche actors engage I work to actively *disrupt* institutions at the regime level to create openings for the niche. Research into these aspects would align with the work on outward-oriented processes as proposed by Raven, Kern, Verhees, et al. (2016).

How do private mini-grid actors, through their work, balance social and economic purpose?

While entrepreneurship in Africa targeted at areas like rural energy provision is often labelled social entrepreneurship due to its association with improving the lives of the poor (e.g. IRENA 2017), this thesis highlights the need for a more diversified interpretation of this type of business. Emerging markets in Africa with low-income yet high-volume consumers are being pursued not only by so-called social entrepreneurs with a primary mission to create social value by providing solutions to social problems (Dacin et al. 2011), but also, and increasingly so, by traditional entrepreneurs with a primary mission to capture value and secure a return on investment.

The research presented here found that, while these mini-grid firms are mission-driven, they do not necessarily identify themselves as social entrepreneurs, nor do they pursue business models that qualify them as such by prioritising the creation of social value over the capture of monetary value (Santos 2012). However, the findings point to some interesting variations across the spectrum of private mini-grid firms in terms of how they rely on the competing logics of economic viability and social welfare in their work. In this thesis it is shown how one group of firms thought their practices prioritise the logic of economic viability over the logic of social welfare in their decision-making and day-to-day operations, while a second group of firms combine and integrate the two logics in their work. Economic and social outcomes of private mini-grid development is often communicated as a given by external actors like donors, the media and governments. When we turn to examine firms' practices, however, this duality in specific business models becomes more multifaceted, and variations between models start to emerge. The existence of these various strategies is thus significant from the perspective of differentiating among mission-driven private enterprises.

Enterprises that do not necessarily self-identify as social enterprises might actually in practice employ strategies of integrating social and economic logics while enterprises that identify and are discursively constructed by others as social enterprises might rely predominantly on a logic of economic viability in their work.

These insights lay out an interesting path for further research. First, it highlights a need for further empirical knowledge about what explains and drives the various strategies firms employ. Further it highlights a need for research on the conditions under which the strategy of integration leads to successful outcomes in the form of synergies and firms' long-term sustainability. Previous work has pointed to positive outcomes in terms of organisational robustness and long term sustainability as a result of organisations seeking synergies from integrating social and economic logics (Battilana & Dorado 2010). However such studies have focused on internal organisational aspects such as hiring practices and financial and human resource acquisition (Doherty et al. 2014). This thesis points to a need of further research into understanding the aspects related to the firm's practices targeted towards their customers. This can create insights into the areas of strategy and management decision-making for private sector players who operate in the cross-field of social and economic purpose (Ocasio & Radoynovska 2016).

While it is desirable for governments to attract private sector investments and private sector actors into areas like public service delivery, the identified variation across private sector models opens up for policy discussion as to what type of private sector engagement government policies should support. Research into the conditions under which the identified strategies of integration or prioritisation between logics thrive can contribute to better understanding of how policy interventions and donor policies can be effectively tailored towards desired outcomes of private sector engagement.

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Article 1

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Review of solar PV policies, interventions and diffusion in East Africa

Ulrich Elmer Hansen [1], Mathilde Brix Pedersen *, Ivan Nygaard [2]

UNEP DTU Partnership, Department of Management Engineering, Technical University of Denmark, UN City, Marmorvej 51, 2100 Copenhagen Ø, Denmark

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ABSTRACT

Previous research on the diffusion of solar PV in Africa has mainly focused on solar home systems (SHS) in individual countries and thus overlooked developments in other PV market segments that have recently emerged. In contrast this paper adopts a regional perspective by reviewing developments in supportive policies, donor programs and diffusion status in all PV market segments in Kenya, Tanzania and Uganda, as well as identifying the key factors put forward in the literature to explain differences in the diffusion of SHS in these three countries. The paper finds two emerging trends: (i) a movement from donor and government-based support to market-driven diffusion of solar PV; and (ii) a transition from small-scale, off-grid systems towards mini-grids and large-scale, grid-connected solar power plants. The paper points out three generic factors that have contributed to encouraging SHS diffusion in all three countries: (i) the decline in world market prices for PV modules; (ii) the prolonged support from international donors; and (iii) conducive framework conditions provided by national governments. The paper also identifies five key factors that have been elaborated in the literature to explain the higher level of SHS diffusion in Kenya compared to Tanzania and Uganda: (i) a growing middle-class; (ii) geographical conditions; (iii) local sub-component suppliers; (iv) local champions; and (v) business culture. Finally, the paper discusses the lack of attention in the literature given to analysing the amount, nature and timing of donor and government support across countries, processes of learning and upgrading in local PV industries and the interaction between the different explanatory factors.

Contents

* Corresponding author. Tel.: +45 45 33 53 26.
E-mail addresses: uleh@dtu.dk (U.E. Hansen), brix@dtu.dk (M.B. Pedersen), ivny@dtu.dk (I. Nygaard).
[1] Tel.: +45 45 33 52 98.
[2] Tel.: +45 45 33 52 97.

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1. Introduction

For a long period, the diffusion of solar photovoltaic (PV) in Africa has been promoted through government and donor-funded projects as a means to provide electricity to remote rural populations in off-grid areas. Solar PV has been considered an appropriate option in cases where grid-extension is not feasible and where other energy sources, such as biomass and hydropower, are not readily available or economically viable. Underlying the programs and projects implemented to support solar PV have been a number of perceived developmental benefits, which include improved air quality in households by reducing the use of polluting fuels for cooking, lighting and heating, better nutrition from access to refrigerators, and educational benefits from increased study time and the provision of electricity-dependent equipment in schools [1,2].

Recently the rapid and substantial decrease in the price of solar PV panels, in combination with rising oil prices, has made solar PV increasingly competitive with conventional technologies, such as diesel-fired generators, which are widely used throughout Africa [3]. Due to the foreseen business opportunities, this has led to a mushrooming of local providers of solar PV components and systems and to the establishment of solar panel assembly plants in a number of African countries [4]. Additionally, solar PV has attracted renewed interest among policy-makers, energy planning agencies and donors, which has resulted in the adoption of supportive incentives in the form of financing schemes, exemptions from VAT and import taxes, power-purchasing agreements and feed-in tariffs (FITs).

Previous research undertaken on the effects of these supportive measures in terms of installed solar PV capacity have mainly focused on the diffusion of solar home systems (SHS) in individual countries, for example, in Kenya [5]. This means that there is currently only limited understanding of developments in other solar PV market segments beside SHS that have recently emerged, such as mini-grids and large-scale solar power [3]. In addition, the predominant focus in the literature on the specific conditions underlying the diffusion of SHS in the context of individual countries implies that findings are particularistic and therefore less generalisable. Hence, there is a need for broader cross-country comparisons of patterns of solar PV diffusion. As a contribution to filling this gap in the existing literature, this paper adopts a regional perspective, focusing on the diffusion of solar PV in different market segments across three countries in East Africa: Kenya, Tanzania and Uganda. To guide the analysis, the focus is on addressing three interrelated questions: (i) the current status and emerging trends concerning the diffusion of solar PV in different market segments within these countries; (ii) which donor programs and national polices have been adopted to promote the diffusion of solar PV; and (iii) what may explain the disparate patterns of solar PV diffusion in the three countries? These questions will be analysed in two steps. First, the development and current status of solar PV diffusion in the three countries and the policies and programs implemented to support different solar PV market segments will be reviewed. Second, the technological innovation system framework of Bergek et al. [6] will be used to identify the key factors provided in the literature to explain the different patterns of solar PV diffusion in the three countries. This analysis focuses on the SHS market segment, as this has been the dominating area of analysis in the existing research.

The paper is structured as follows. Sections 2 and 3 presents the research methods and analytical framework adopted. Section 4 provides a review of the developments and status of solar PV diffusion in Kenya and the government policies and donor programmes that have supported the different solar PV market segments. Sections 5 and 6 conduct a similar review for Tanzania and Uganda, respectively. Section 7 presents a crosscutting discussion of the findings across the three countries. Section 8 provides an analysis of the key factors highlighted in the literature to explain differences in solar PV diffusion in Kenya, Tanzania and Uganda. Finally the conclusions of the paper will be presented in Section 9.

2. Research methods

This paper mainly draws on empirical research published in the peer-reviewed literature and sources in the grey literature, such as donor reports, consultancy and policy documents, and occasional use of media reports, where relevant. To supplement the review,

Table 1
Characteristics of five different solar PV market segments. *Source*: [7,8].

Market segments	Market characteristics	Installed capacity/ size	Owners and buyers
Small pico-systems: solar lanterns, LED lamps, solar chargers	Lighting and charging of batteries and mobile phones in mainly non-electrified areas	1–10 W_p	Private (over the counter) consumer devices
Solar home systems (SHS)	Off-grid electricity demand in private homes in dispersed settlements, in smaller non-electrified villages and on the outskirts of electrified towns and villages far from existing distribution lines	10–100 W_p	Residential SHS (private households), ESCOs
Stand-alone 'institutional PV systems'	Institutions located in villages without grid or mini-grid, or on the outskirts of grid-electrified villages	50–500 W_p	Government/municipal procurement for public institutions (schools, hospitals, health clinics)
Telecommunications and tourism	Powering telecom base receiver stations (BTS), link sites, and remote tele-centres, and basic electricity supply (mainly lighting) for rural lodges and hotels	0.2–15 kW_p	Procurement by commercial companies in the telecom and tourism sectors (e.g. telecom service providers, hotel owners, etc.)
Mini-grids (e.g. hybrid PV-diesel)	Villages and towns located far from existing grid	5 kW-1 MW_p	Utilities, cooperatives (community-based), ESCOs (village electrification projects)
Large-scale, grid-connected PV systems	Expansion of production capacity in existing grid	1–50 MW_p	Utilities, IPPs (incl. foreign investors)

the paper includes information from interviews conducted in January 2014 with solar PV industry stakeholders in Uganda, such as local PV suppliers, industry experts, representatives of donor programs and government officials. Topics discussed during interviews included historical developments and the diffusion status of different solar PV segments, local industry and SME business development, factors encouraging and discouraging solar PV diffusion in Uganda, and the relevant political and regulatory frameworks. With respect to large-scale, grid-connected solar PV, the paper also relies on feedback on a paper on prospects for investment in large-scale solar power in Africa, which was distributed and presented orally at a recent conference in Copenhagen in June 2014[3]. This allowed inputs from the presentations and discussions with stakeholders from the three countries to be incorporated. This procedure for the collection of data was used to triangulate information obtained from the documentary sources.

3. Analytical framework

To structure the analysis of the policies, programs and diffusion of solar PV in Kenya, Tanzania and Uganda (presented in Sections 4–6) a distinction between five types of PV segments has been developed and presented in Section 3.1. In addition, the technological innovation system (TIS) framework was used to structure the analysis of the key factors highlighted in the literature to explain differences in solar PV diffusion in the three countries (presented in Section 8). The operationalisation of the TIS framework involved the categorisation of specific factors that were found to resonate across research papers according to the particular functions suggested by Bergek et al. [6].

3.1. Solar PV market segments

Solar PV systems range from the smallest pico-applications, such as solar lanterns and small mobile-phone chargers, via solar home systems (SHS) installed in private households and mini-grids at village level, to utility-scale, grid-connected plants. Therefore, although solar PV is often considered a distinct type of technology, it is clear that solar PV systems are quite different in terms of scale, capital-intensity, technological characteristics, target groups and competing technologies. Accordingly, it is crucial to distinguish between the different market segments in which these PV systems are being diffused, as these are characterised by fundamentally different dynamics. In Table 1, a fivefold categorisation of solar PV market segments is presented, which will be used to guide the subsequent review.

The 'small pico-systems' segment has been excluded from what follows, as this market segment is substantially different from the other segments. While the latter comprise fixed installations based on standardised PV panels, controllers and batteries installed by skilled technicians, pico-systems are integrated products which are more similar to other appliances such as lanterns or torches and are therefore usually bought over the counter. In the description of the five market segments of interest to this paper, the focus will be on assessing the scope for public intervention by governments and donors in order to promote the development of specific market segments.

The market for solar home systems is similar to that for various types of over-the-counter consumer products, such as air-conditioning, that need to be installed by a technician, but that are readily available in specialist shops [7]. Governments and donors may provide indirect support to this mainly private market through various measures, such as (i) exemption from import duties on PV components, (ii) enforcing systems of product quality standards, and (iii) supporting specific credit schemes to suppliers and customers.

The 'institutional PV systems' segment is different not only because of its larger scale and capital-intensity, but also because of the supporting instruments and typical interventions that are used to promote this segment. Most interventions in this segment are direct, as institutional PV systems are usually procured directly by donors or government agencies (often in combination) to provide electricity in schools or public buildings located in off-grid areas.

The 'telecommunication and tourism' market segment is characterised by PV systems procured directly by private, commercial actors in the communications technology industry (e.g. telecom service providers) and the tourism sector (e.g. hotel owners and rural entrepreneurs). These PV systems are typically installed at remotely located base transceiver stations in order to reduce operating costs or in rural lodges to cover basic lighting needs. As this segment is purely market-based, government and donor support are limited to providing broad enabling incentives, such as general VAT and duty exemptions for PV components.

The 'mini-grid' segment includes new hybrid PV-based plants and the hybridisation of existing, conventional diesel-fired power plants with solar PV, which are typically installed in larger towns far from the national grid [8]. Mini-grid systems can range from

[3] Information and presentations from this seminar can be found at: http://www.unepdtu.org/PUBLICATIONS/Workshop-Presentations/Workshop-Presentations—Sustainable-Energy-Investments-in-Africa.

Table 2
Functional components of technological innovation systems. *Source*: [9,6,13].

Functions	Description
Knowledge development and diffusion	The generation of breadth and depth of the knowledge base of the TIS, and the diffusion and combination of knowledge
Influence on the direction of search	The existence of incentives/pressures (and expectations) for actors to enter the TIS, and to direct their activities towards certain parts within the TIS (e.g. technologies, applications, or markets)
Entrepreneurial experimentation	The probing into new technologies and applications, unfolding a social learning process reducing uncertainty
Market formation	The timing, size and type of markets that have actually formed, including customer demand and user preferences
Legitimation	The extent to which the new technology and its proponents are considered appropriate and desirable by relevant actors in different parts of the TIS to acquire political strength
Resource mobilisation	The availability of human resources (e.g. skilled labour), physical resources (e.g. infrastructure, material, etc.), financial resources (e.g. investments, venture capital, subsidies, etc.) and complimentary products and services
Development of positive externalities	The interconnectedness between different parts of the TIS, and between the TIS and the external environment, in fulfilling the other functions

covering a relatively small number of households and commercial consumers to providing whole villages or groups of villages with electricity over a local distribution grid. They can be owned and operated by local cooperatives in so-called community-based systems, by national utilities or by foreign or national energy service companies (ESCOs). In some cases, mini-grids are also established in connection with cell-phone towers, factories or plantations with support from donors or governments. Rural electrification is in general heavily subsidised, either through rural electrification agencies or cross-subsidisation within utilities. The scope for government and donor interventions to support PV in rural electrification can be directly by providing project development support, subsidies and finance and, more indirectly, by providing the necessary regulatory set up for operators.

Finally, the 'grid-connected' PV market segment is characterised by large-scale capital-intensive plants, which can be owned and operated by utilities and private operators, so-called independent power producers (IPPs), often involving foreign investors [3]. Government interventions to support this segment may consist of indirect measures, such as feed-in tariffs, but may also be more direct through the management of bidding rounds and contractual arrangements with operators.

3.2. Technological innovation systems

The technological innovation system (TIS) framework has been developed as a heuristic tool to study the conditions under which the generation, diffusion and utilisation of a specific technology unfolds under particular institutional circumstances [9]. While in principle the TIS for a specific technology is global in nature (see Carlsson and Stankiewicz [10]), this paper follows the approach adopted in Schmidt and Dabur [11] to have an increased focus on the national TIS for solar PV. The study of TIS generally proceeds by exploring two main components. The first component involves an analysis of the structural composition of the TIS around a specific technology, which focuses on the actors and organisations involved, such as firms, public agencies and end-users, the networks among these agents, and the formal and informal institutional structures involved, for example, the regulatory, political and cognitive frameworks. The second component focuses on the overall functioning of the TIS in question, which involves an analysis of the specific functions that, depending on their strength, may impede or encourage the development and diffusion of a new technology. Following the approach adopted in Tigabu et al. [12], the analysis in Section 8 makes use of the functional typology developed in Bergek et al. [6], which comprises a list of seven functions that determine the ability of a specific TIS to promote the diffusion and adoption of new technologies (see Table 2).

4. Kenya

4.1. Development and status for different PV segments

While Kenya today boasts a solar market that is one of the most mature and well-established in Africa, its origins date back to the 1970s, when the Kenyan government started to use solar energy as a means to power signalling and broadcasting installations in remote areas. Subsequently, from the 1980s onwards, international donors and NGOs began to play a greater role, as they included solar in their development programmes by means of workshops, training programmes and demonstration projects that contributed to generating a demand for PV in Kenya [13,14]. While government and donor programmes have continued to play an important role in promoting PV in the country, this support has gradually been phased out in parallel with the establishment of a private market, which slowly started to emerge during the 1980s with the first established suppliers of solar equipment to customers in rural areas [16].

During the 1980s and 1990s, this private market grew rapidly along with a continued reduction in PV system prices, which led to a genuine boom period during the late 1990s [17]. Thus, while overall installed PV capacity was estimated at around 1.5 MW peak (MW_p) in the early 1990s, by 2000 it had more than doubled to approximately 3.9 MW_p [17,18]. A decade later, total installed capacity had reached between 8 and 10 MW_p of installed capacity according to the comprehensive market review undertaken by GTZ in Kenya in 2009 [17]. Although information about subsequent developments in installed PV capacity has been sporadic, Ramboll [20] estimated that at least 320,000 SHS were in operation in 2010. Similarly, Meza [21] claimed a figure of 16 MW_p for 2012, and Tobias Cossen of GIZ a figure of 20 MW_p in November 2013 [22].

During the initial development phase in the late 1980s and early 1990s, the Kenyan solar PV market was dominated by donor-funded projects and the public procurement of systems to provide electricity to schools, health centres, missions and other social institutions in rural off-grid areas. According to Acker and Kammen [14], this 'institutional PV system' market segment amounted to approximately two thirds of total installed capacity in the early 1990s, when it was overtaken by the increasing market for residential SHS, which, according to Ondraczek [19], amounted to around 75% of installed capacity in 2000. In 2009 the installed capacity of residential SHS and institutional market segments was about 80% and 20% respectively (corresponding respectively to 6–8 MW_p and 2 MW_p of the total installed capacity of 8–10 MW_p) [17]. Recently, annual sales of solar PV systems have reached 1–2 MW_p, with much of the market dynamic stemming from demand for residential SHS [19]. In 2009, installed capacity in the telecommunications and tourism segment was estimated at

150 kW_p, a relative low share of total installed PV capacity in Kenya [17]. The emergence of new mini-grid PV installations in rural Kenya has appeared to be limited until now [4], although Muchunku [23] estimated that six out of twelve existing diesel mini-grids in the country (with a total installed diesel-based generating capacity of 7.7 MW) had been hybridised with PV (see also Hankins [24]). Four grid-connected PV plants have evidently been installed in Kenya so far: one plant in the UN compound in Nairobi with an installed capacity of 575 kW_p, another at the SOS Children's village in Nairobi with an installed capacity of 60 kW_p [24,4], a third, 72 kW_p system installed at a flower farm in central Kenya in early 2013 [22], and a fourth, 1 MW_p plant at a tea-processing facility, also installed in 2013. While the first two plants were financed mainly by international donors, the other two were financed by the industrial users themselves and delivered by the Kenyan-based company East African Solar Ltd. under turnkey contracts [26].[4]

4.2. Policies and donor programmes supporting different PV market segments in Kenya

4.2.1. Solar home systems (SHS)

According to Hankins [15], the Kenyan government has generally adopted a 'light touch' regulatory approach to supporting the development of a private (i.e. household) market for SHS and thus resorted mainly to the use of indirect policy measures. This has primarily taken the form of exemption from value-added tax (VAT) and duties on imported PV products and components, enacted in 1986. Government targets or legislation designed specifically to increase the uptake of SHS have been absent [16,26,27], as market development in Kenya has been driven mainly by commercial and private-market actors [14]. Nevertheless, a number of international donor organisations have been active in supporting the development of the private SHS market segment in Kenya through various programmes, especially in the period from 1995 to 2007 [29]. Of particular importance was the photovoltaic market transformation initiative (PVMTI) implemented by the World Bank in the period 1998–2008, with a total budget of US$ 5 million. By providing favourable loans to consumers and suppliers of SHS in Kenya, PVMTI was instrumental in improving financial conditions for the diffusion of SHS. The German development organisation GTZ[5] has also been active in supporting the diffusion of SHS in Kenya in many cases, with the objective of exploiting commercial opportunities for German suppliers of SHS [17].

4.2.2. Stand-alone 'institutional PV systems'

The development of the institutional PV market segment has been led by various international donors and development agencies, particularly during the initial stage of market development during the 1980s [29,28]. These have focused mainly on providing lighting to schools through individual projects in rural areas. Kenya also has many active NGOs and missions providing services in the remote off-grid parts of the country, such as solar PV-powered water pumps, and vaccine refrigerators in health clinics. More recently, the government's so-called Solar Energy Development project aims to electrify 500 rural institutions through solar PV systems [31], and the National Energy Policy has set out to install solar PV systems in 50% of all the remaining public facilities in the off-grid areas by 2016 [32].

4.2.3. Telecommunications and tourism

The information and communications technology (ICT) sector, especially mobile telephony, has grown substantially in Kenya since 2002. Indeed, subscriber growth in the period from June 2007 to June 2008 alone reached 39%, a trend that has continued since. This has led to a substantial expansion of base transceiver stations (BTS) in rural areas, and a number of telecom operators have begun implementing PV systems at these sites [16,18]. PV installations have also been increasing in the tourism sector, mainly to covering lighting and basic electricity needs in rural lodges and tented camps [29].

4.2.4. Mini-grids (e.g. hybrid PV-diesel)

Support for the establishment of mini-grids, either fully powered by solar PV alone or in combination with diesel generators, is a fairly recent development in Kenya [22]. The Kenyan government's rural electrification master plan from 2008 supports the retrofitting of existing diesel-based decentralised power stations into hybrid schemes with solar PV, which, according to Gichungi [33], is motivated by a wish to reduce operating costs (see also Moner-Girona et al. [17]). International donors have also been supporting PV-powered mini-grids in Kenya, most importantly the World Bank's Scaling-Up Renewable Energy Program (SREP), which aims to install 3 MW of (PV and wind) in hybrid with the existing diesel generators in 12 isolated grids with a total installed capacity of 11 MW [34]. Likewise, through the so-called Energy for Development (E4D) project, the Department of International Development (DFID) in the UK has supported PV-powered community based mini-grids in Kenya [35]. The revision of the FiT tariff scheme in 2012 (see below) introduced a FiT of 0.20 USD/kW h for mini-grids [36]. Within the past one and a half years a few private companies have started implementing village-level mini-grids based on a commercial business model. However, installed capacity within this category is at this stage still low (approx. 100 kW).

4.2.5. Large-scale, grid-connected PV systems

In 2008, the Kenyan government launched a feed-in tariff (FIT) policy to support grid-connected renewable energy, which was later revised in 2010 to include solar PV and again in 2012 to adjust tariff prices [36]. The current FiT price for grid-connected solar PV is 0.12 USD/kW h (ibid.). Given the increasing demand for energy in Kenya, fuelled mainly by rapid economic growth, a main objective of the FIT policy is to contribute to expanding capacity in the existing grid in order to maintain an adequate reserve margin and ensure security of electricity supply. According to Willis [37], 25 projects with a total installed capacity of 750 MW are currently proceeding from the initial feasibility stage towards the power purchasing agreement stage under the FIT policy. Although this would seem to suggest substantial interest from private investors, in 2013 some observers are stressing that PV tariff rates are too low to attract domestic and foreign investors [20,21]. Nonetheless the Government of Kenya has high expectations regarding the future of grid-connected PV in Kenya. According to the National Energy Policy [32], Kenya expects installed capacity to grow as follows: to 100 MW_p by 2016, 200 MW_p by 2022 and 500 MW_p by 2030. Recently, foreign investors have apparently being entering the Kenyan market for grid-connected plants. According to Finkelstein [38] and Woods [39], two plants of 50 MW_p are currently in advanced stages of planning.

5. Tanzania

5.1. Development and status for different PV segments

Tanzania, like Kenya, started using PV for the government-financed electrification of rural institutions, such as schools, churches

[4] See also http://www.eastafricansolar.com/.
[5] Now GIZ.

and health centres, in the 1970s. Since then the PV market has continued to be dominated by government procurement projects and donor-supported programmes for such rural institutions. A consumer market for PV in Tanzania started to evolve from the late 1990s and early 2000s onwards, mainly as a result of the expansion of the solar PV industry in Kenya into Tanzania [40]. The development of this private market for solar PV evolved from an installed capacity of 300 kW_p in the late 1990s to approximately 1.2 MW_p in 2003 to around 3–4 MW_p in 2009 [19] and to more than 5 MW_p in 2012 [41]. During this development, annual sales grew from 70 kW_p in 2002 to 200–300 kW_p between 2003 and 2007. Recently, Meza [41] has estimated sales of solar energy to have reached 2 MW_p in 2011, and they are thought to have been higher in 2012 and 2013 due to large-scale project initiatives and continued SHS demand.

SHS and small-scale commercial systems make up around 75% of installed capacity in Tanzania and are hence the biggest segment in the country's solar market [19]. This capacity was installed in an estimated 40,000 SHS by the end of 2008, with annual sales of at least 4000–8000 systems, which, according to Hankins et al. [40], translates into an annual increase of around 200–300 kW_p. The remaining 25% of installed PV capacity in Tanzania largely consists of institutional PV systems in schools, health centres, missions and government offices, while the telecommunications and tourism segments (and other uses of PV, such as in game parks) only play a minor role in comparison. Currently the mini-grid market segment in Tanzania is also limited, and although Ondraczek [19] claims that a few PV mini-grid installations do exist, information about these are scarce. To the authors' knowledge there are currently no grid-connected PV plants in operation in Tanzania.

5.2. Policies and donor programmes supporting different PV market segments in Tanzania

5.2.1. Solar home systems (SHS)

In 2005 the Tanzanian government took steps to support the SHS market segment by exempting solar systems from 20% of VAT and reducing import duties to 5% [42]. Besides this, two larger programmes have been implemented to increase demand by lowering consumer costs.

From 2007 the so-called Tanzania Energy Development and Access Project (TEDAP) (earlier known as Energizing Rural Transformation) reduced consumer costs by providing a subsidy to qualifying companies of US$ 2/W_p per sold system for systems below 100 W_p. TEDAP was a World Bank/GEF-funded programme implemented by REA, one objective of which was to promote SHS uptake in Tanzania. The total budget for the off-grid component was 22.5 Mn USD [39,42]. Since 2008 REA has lowered consumer costs through the so-called PV Clusters Project, which supported private households in buying and installing SHS collectively (bulk purchasing) to reduce the overall cost. The project targeted clusters consisting of organised labour or farmers' groups with a minimum of a thousand members. These clusters engaged in annual wholesale procurements of solar PV systems through tendering, and REA provided subsidies for systems procured (20% of the cost) [44].

Beside these demand-side interventions, international donor agencies have focused on supporting the supply side, that is, the private solar PV market actors. From 2004 to 2009, UNEP led an initiative entitled Transformation of the Rural Photovoltaic Market in Tanzania with a specific focus on using the 'private sector as a vehicle for providing basic services from PV' [45]. The programme included business and technical skills training for private-sector merchants, as well as the establishment of financing mechanisms to provide consumers with access to SHS. The SIDA /MEM Solar Energy Project was implemented in 2005–2011 with a budget of USD 3.2 million to provide technical, business and sales support to PV businesses, with the aim of improving the market for solar power and building up the solar industry in the country [46].

Another supply-side support project is the Developing Energy Enterprises Project East Africa (DEEP EA), a five-year initiative established in 2008 by the Global Village Energy Partnership (GVEP) focusing on micro- and small energy enterprises in Kenya, Uganda and Tanzania. DEEP EA supported the development of energy enterprises formed by, and for, rural and peri-urban entrepreneurs by assisting them with the identification of viable energy market opportunities, technology options and service structures to generate revenue and sustain businesses [46].

5.2.2. Stand-alone 'institutional PV systems'

The main driver for institutional PV systems in Tanzania is direct procurement through REA, together with international donor programmes and development organisation projects (such as TEDAP). One element of this is the Sustainable Solar Market Packages Project (SSMP), implemented by REA from 2007 and designed to establish a functioning institutional framework for commercially based service delivery for rural electrification [47]. Each SSMP arranges the supply of solar PV energy equipment with long-term maintenance contracts to rural institutions such as schools, clinics and other community facilities in a defined rural area, together with requirements and incentives for commercial sales to households in the same area. Another programme, the Transformation of the Rural Photovoltaic Market in Tanzania, resulted in the installation of solar PV systems in more than a hundred public institutions, such as health facilities and schools [45]. The programme also facilitated the inclusion of PV in the local authorities' annual budget plan in Mwanza and in three other regions: Kagera, Mara and Shinyanga.

5.2.3. Telecommunications and tourism

Although this segment only played a minor role in the solar PV market in Tanzania in 2008, Hankins et al. [40] estimated this sector to be growing substantially, mainly due to an increasing use of solar-powered base stations in mobile-phone networks and PV in eco-tourism establishments and rural tented camps and lodges.

5.2.4. Mini-grids (e.g. hybrid PV-diesel)

Through the newly established Scaling Up Renewable Energy in Low Income Countries Program (SREP) funded by the Climate Investment Funds, the government of Tanzania aims to provide electricity to 400,000 off-grid households and other consumers using renewable energy mini-grids, micro-grids and SSMP projects [48]. Further, the Ministry of Energy and Minerals (MEM) has established simplified procedures for private-sector investment in solar, wind and micro-hydro projects, including a 100% depreciation allowance in the first year of operation [46]. According to Tenenbaum et al. [49], the government of Tanzania is applying light-handed regulation for Small Power Producers (SSP). SPPs operating on an isolated mini-grid generating less than 1 MW are required merely to register with the regulator, instead of applying for a license, which, unlike registration, entails approval by the regulator. For very small power producers (VSPPs) with an installed capacity of 100 kW or less, the Tanzanian regulator requires no prior regulatory review or approval of proposed retail tariffs (ibid.). On that basis, Tenenbaum et al. [49] argue that Tanzania has made more progress than any other African country in developing a comprehensive regulatory system to supporting SPPs. Moreover, TEDAP provides two types of subsidy to project developers: performance grants and matching grants [43]. For rural mini-grid projects under the performance grant, a subsidy of US$ 500 is provided for each new connection, with a maximum amount of up to 80% of total investment costs. Matching grants include primarily training and consultancy services. Such initiatives may have contributed to spurring investment interest in mini-grids, as reflected in two recently announced PV-powered mini-grids to be developed by private investors under power purchasing agreements with the Tanzanian utility TANESO [41]. Private sector-led initiatives are in their infancy, with only a few operating mini-grids (< 100 kW). However, in October 2014 REA announced the winners of their Lighting Rural Tanzania Competition, where half of the 20 winners where solar PV-based mini-grids [50].

5.2.5. Large-scale, grid-connected PV systems

The Ministry of Energy and Minerals (MEM) has established a framework for the development of renewable energy power projects ranging from 100 kW to 10 MW, which includes the introduction of standardised power purchasing agreements for wind, hydro, PV and co-generation with standardised FITs [46]. According to Ondraczek [19], however, there are no signs that the government is intending to include solar PV in the national electricity mix in any significant way in the years to come. In the long-term plans for the energy sector and the state-owned utility's pipeline, the focus is almost exclusively on the expansion of natural gas, coal and hydro power [19]. One policy potentially supporting grid-connected solar PV is the FIT policy introduced in 2009. Tariffs are differentiated depending on whether the small power producer is connected to the main grid or to a mini-grid. In 2012 the average tariff for grid-connected electrification was 0.095 USD/kW h (152.54 TZS/kW h). For mini-grids in 2012 the tariff was 0.30 USD/kW h (480.50 TZS/kW h). This is a common FIT for all technologies, and consequently the majority of projects currently under development and in the pipeline are mini-hydro. The lack of technology-based payment differentiation is, according to Nganga [51], one of the greatest weaknesses of Tanzania's FIT policy.

6. Uganda

6.1. Development and status for different PV segments

The PV market in Uganda started to develop from the early 1980s, and, as in Tanzania and Kenya, it was initially driven mainly by government and donor-funded programmes along with NGO projects, mainly for lighting and vaccine refrigeration in health centres [52].

The study of solar PV markets in Uganda from 2009 estimates total installed capacity to be 1.1 MW_p, with annual sales of about 200 kW_p [53]. According to the study, SHS only comprised 20% of total installed capacity (300 kW_p), while the institutional segment at the time comprised 45% of installed capacity (470 kW_p). PV applications in the institutional segment were mainly utilised in the health (e.g. rural health clinics), water (e.g. pumping systems), education (e.g. off-grid boarding schools) and local government sectors (e.g. public agency offices). The combined telecommunications and tourism segment took up the remaining 35% of installed capacity (340 kW_p). PV in this segment is mainly used for powering telecom BTS and link sites, remote telecenters and remote tourist lodges.

While the SHS segment only took up 20% of total installed capacity in 2009, this share seems to have increased substantially in the last 5 years. According to different sources, the number of installed SHS has risen from 3000 in 1999 [54], to 10,000 in 2004 [55], to 20,000 in 2007 and to 30,000 in 2012 [56]. According to an interview in 2014 with 'SolarNow'[6], the largest players in the SHS market in Uganda, installed capacity increased by 12,000 SHSs in 2013 and 15,000 in 2013[7], raising the number of SHS to 45,000 in the latter year. This increase in SHS units sold in Uganda added around 0.9 MW to installed capacity of SHS in 2009–2013 [57], reflecting very high growth after 2009.

Only a few hybrid solar PV and diesel-powered mini-grids have been installed so far in Uganda, including one at a rural boarding school in Bulyansungwe south-west of Kampala [58]. Grid-connected, utility-scale PV power plants have not been put into operation in the country.

6.2. Policies and donor programmes supporting different PV market segments in Uganda

6.2.1. Solar home systems (SHS)

The Ugandan government has stimulated the private market for SHS both through indirect measures, such as exemptions from import duties and VAT on PV products and components, and directly, by providing a subsidy of 5.5 USD/W_p (with a maximum system size of 50 W_p) on solar equipment purchased by households and 4 USD/W_p (for systems below 500 W) for businesses and institutions [53]. The subsidy was funded partly by the World Bank's Energy for Rural Transformation (ERT) programme and implemented by the Rural Electrification Agency in Uganda in the period 2002–2013 (in two phases between 2002–2009 and 2009–2013) [59]. ERT also aimed at stimulating the SHS market by reducing costs for end-users through rural-based micro-financing institutes and by providing business start-up support and technical training to PV suppliers. Despite high ambitions at the outset of the programme, only 7000 of the 80,000 initially planned PV installations had actually been installed when the programme was terminated [60]. A precursor of the ERT programme was the so-called Uganda Photovoltaic Pilot Project for Rural Electrification (UPPPRE), which was funded by the United Nations Development Programme (UNEP) and implemented in 1998–2002 [61]. Similarly to ERT, UPPPREE targeted the development of the SHS market by providing finance to PV suppliers and credit guarantees to local banks so that they could provide loans at favourable conditions to end-users.

Programmes targeting the supply side were also implemented in Uganda. The so-called Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP), funded by GTZ during the period 2007–2011, was aimed at strengthening the SHS market segment by supporting Kampala-based solar companies with branches or agents in rural areas, local solar dealers and microfinance institutions [62]. A similar project entitled Providing Access to Energy in Northern Uganda (PAMENU) provided training to local technicians and supported local PV suppliers. This project was also implemented by GTZ during 2008–2011 [63].

6.2.2. Stand-alone 'institutional PV systems'

According to Hankins et al. [53], the ERT programme has been the main driver behind most of the direct public procurements of PV systems in the institutional market segment in Uganda. However, other international aid programmes and NGOs have also targeted the institutional PV market segment. For example, the PREEEP programme mentioned above was specifically aimed at electrifying government institutions (such as health centres, boarding schools, vocational training centres and local government offices) with solar PV systems by providing an 80% subsidy for the procurement of a PV system, the institution being

[6] Interview with Willem Nolens, Managing Director, and Ronald Schuurhuizen, Business Development Manager, 16 January 2014.

[7] SolarNow alone installed 3600 SHSs in 2012 and 4500 in 2013. According to SolarNow they control about 30% of the established market, indicating total sales of 12,000 SHSs in 2013 and 15,000 in 2013. Given that the smallest modules are rated at 50 W_p, this amounts to 600 and 750 kW_p, in 2012 and 2013, or four times annual sales in 2009.

responsible for providing the remaining 20% [64]. This segment is therefore still strongly influenced by donor support, although this support is channelled through the Ugandan rural electrification agency.

6.2.3. Telecommunications and tourism

The market for PV systems in the telecommunications and tourism sector in Uganda has rapidly increased during the past decade and comprises a relatively large share of the country's total installed PV capacity. Driven mainly by an increase in the use of mobile phones in Uganda, the telecommunications sector has grown rapidly, resulting in a substantial increase in national coverage through the widespread establishment of base transceiver stations (BTS) and link sites in rural areas [53]. As most of these BTS facilities operate on diesel-based generators, PV has been implemented to reducing operating costs for telecom operators at these rural sites. To support this development further, in 2012 GIZ launched a programme entitled 'develoPPP.de' aimed at supplying telecommunication masts with PV and at the same time electrifying off-grid villages close to the masts. The project, which has a scope of 250 masts, is being carried out in partnership with a German supplier of solar systems, one of the telecompanies in the country and GIZ [65],[8]. In the tourism sector, PV systems have mainly been implemented to provide basic electricity supply (mainly lighting) for remotely located lodges and hotels.

6.2.4. Mini-grids (e.g. hybrid PV-diesel)

Through the ERT programme, the rural electrification agency in Uganda has promoted the establishment of isolated mini-grids (including PV), for example, by providing investment subsidies to investors [53]. The Rural Electrification Strategy Plan (RESP) from 2012 (covering 2013–2022) also specifically prioritises rural electrification through PV-powered mini-grids and has set a goal of reaching 140,000 additional off-grid installations of solar PV systems and mini-grid distribution service connections in 2022 [60]. Beside this, a recently announced agreement with the East African Chamber of Commerce indicated that foreign investors are also becoming interested in developing mini-grids in Uganda [66], though only a few have been installed so far. These include four set up in connection with the telecommunication masts described above and a PV-powered mini-grid financed by Together: Assistance for Uganda, a German aid organisation [58].

6.2.5. Large-scale, grid-connected PV systems

Under the Renewable Energy Policy adopted in 2007, the Ugandan government introduced the first phase of the Renewable Energy Feed-in tariff (REFIT) programme to encourage grid-connected bagasse co-generation and hydropower plants. A second phase of the REFIT programme, implemented in January 2011, introduced a PV tariff rate at 0.362 US$/kW h (for systems below 2 MW_p), along with changes in tariff rates for the other eligible technologies under the programme. Later, in 2012, PV was removed from the REFIT programme after a tariff revision had identified that the drop in PV system prices was deemed to have made large-scale, grid-connected PV plants competitive without subsidies [67]. This led to a greater focus within the government on tendering and soliciting bids from private investors to develop grid-connected PV systems. To meet this demand, the so-called GET FIT programme introduced in 2013 established a special window for support to an auction process for grid-connected PV. Under this reverse bidding process, selected developers will receive a premium payment to bridge the gap between a predetermined tariff set by the Ugandan Electricity Regulatory Authority and their own offers [68]. The funds for the GET FIT programme are being made available from a number of international development organisations. As of June 2014, 9 companies were prequalified for the first bidding round for 4 plants of each 5 MW_p. The deadline for bids was fixed at 8 August 2014, and the plants are expected to be in operation by mid-2015[9]. Furthermore, a feasibility study is being completed for a 50 MWp plant. Negotiations about the terms of a power purchasing agreement are awaiting the outcome of the bidding round mentioned above[10]. Further, according to the press, in late 2013 a memorandum of understanding (MoU) was signed between the Government of Uganda and a private company for building further capacity of 500 MW_p [66].

7. Cross-country discussion of developments in PV market segments

It is evident that Kenya has taken a lead position in terms of total installed solar PV capacity compared to Tanzania and Uganda. As the market in Kenya started earlier, it seems that the subsequent development of PV markets in Tanzania and Uganda was influenced greatly by a gradual expansion of PV suppliers into neighbouring countries and by the spilling over of policy experiences from Kenya. While Tanzania and Uganda seem to be rapidly catching up, Kenya will most likely remain at the forefront in terms of solar PV diffusion for some time to come.

It was found that SHS play a major role in Kenya and Tanzania, currently accounting for around 80% and 75% of total installed capacity, respectively. In Uganda, in 2009 SHS accounted for around 20% of installed capacity, but this share has increased considerably recently. This market segment is generally encouraged by a growing demand from private households with increasing purchasing power, but it has also been supported through VAT and import duty exemptions for imported PV components and various government and donor programmes. The institutional PV segment also accounts for a large share of total installed PV capacity in all three countries, especially Tanzania and Uganda, and has mostly been driven by direct government and donor procurement of PV systems for rural schools, health clinics and public buildings. The telecommunications and tourism segment is expected to increase in all three countries, but while this segment is relatively large in Uganda, it seems to play a smaller role in Kenya and Tanzania. While the market for PV-powered mini-grids currently only comprises a limited number of installations, this is expected to increase in the future, as is reflected in the increasing number of planned mini-grids in all three countries. Similarly, a growing number of grid-connected PV plants are currently in the pipeline and have yet to materialise.

Two interesting trends are apparent from the above. The first is a movement from donor-supported initiatives towards commercially based market development. From PV being mainly a small niche for government and donor procurement, it has increasingly become a viable alternative for consumers and private investors across PV market segments. Not only has the commercial part of the SHS market segment gained an increasing share of total installed capacity in all three countries, private investors are also playing a bigger role in the other segments, such as telecoms operators and foreign IPP investors. The second trend is the movement that is currently taking place from off-grid to mini-grids and large-scale, grid-connected PV plants. Whereas the off-

[8] Four of these installations were in operation in January 2014.

[9] Personal communication with René Meyer, consultant for KfW/GET-FIT Uganda, 25.06.14.

[10] Personal communication with Benon Mutambo, Energy Regulatory Authority, 25.06.14.

grid market for SHS and institutional systems is dominated by small-scale systems for individual consumers or a relative small community, the increasing focus on mini-grids and grid-connected plants comprises a significant increase in the scale and reach of PV installations.

8. Key factors put forward to explain differences in the diffusion of solar PV

This section explores the generic aspects that are conducive to the diffusion of solar PV, as well as examining the main underlying reasons for the different levels of solar PV diffusion in Kenya, Tanzania and Uganda, as illuminated in the literature. The aim is not to provide a comprehensive explanation of this highly complex issue, but rather to draw out some of the key factors that resonate across papers. This discussion focuses mainly on the diffusion of SHS because the literature has concentrated on this PV segment and because SHS has the dominant share of installed capacity in Kenya and Tanzania, and increasingly also in Uganda.

8.1. Generic aspects conducive to the diffusion of solar PV in all countries

The main generic aspects emanating from the literature fall within the TIS functions (i) influence on the direction of search, and (ii) resource mobilisation. These are discussed in further detail below.

8.1.1. Influence on the direction of search

Underlying many government and donor initiatives over time to stimulate PV markets has been a continuous expectation that module prices would be reduced and thus enable PV to compete with conventional technologies. Often based on so-called learning-curve projections and actual prices, in some cases this understanding has led to over-optimistic goals to be set regarding what can realistically be achieved from policies and interventions. In the literature, it is evident that the price reduction in PV modules that has occurred, especially since the 1990s, was ascribed a key role in explaining the accelerated diffusion of solar PV in the three countries. Acker and Kammen [14], for example, pointed to falling world prices for PV modules as a main reason for the growth in the Kenyan PV market. As PV module prices continued to decline from the 1990s, several papers engaged with exploring the economic feasibility of solar PV compared to traditional electricity-generating technologies. Gullberg et al. [69], for example, demonstrated that PV generation was able to compete with diesel generation in Tanzania, while Ondraczek [18], p. 41 more explicitly stated that ‘the price of equipment is perhaps the single most important factor in the growth of solar markets in Africa’. Later, Twaha et al. [70] concluded that grid-connected solar PV had greater feasibility than diesel as a source of electricity in Uganda. In a similar vein, Ondraczek [20] recently found that the price level for grid-connected PV was competitive with diesel generators and gas turbines in Kenya, a finding the author contrasted with the prevailing understanding in the donor community and many African country governments that PV is suited only to remote off-grid and small-scale applications. These analyses showed the increasing competitiveness of PV, especially in the period since 2009, when the PV module price per watt has been drastically reduced.

8.1.2. Resource mobilisation

It is widely recognised in the literature that international donor programmes have been a key driver in stimulating solar PV uptake in all three countries examined, primarily through support to the institutional PV segment [5]. Various papers describe such donor-funded projects aimed at electrifying social institutions in rural areas. Kivaisi [71], for example, investigated a PV project designed to provide power to key functions in a large village in Tanzania, such as a school, a mosque and a health centre (see also Hogarth [72]). In their analysis of the development of the Kenyan PV market, Hankins [14], p. 88 highlighted the importance of donor interventions by stating that ‘not only did their funding create a demand for PV that allowed the private market subsequently to develop, but the donor agencies supported workshops, training and demonstration projects as well [which] played a vital role in educating the first Kenyan solar technicians, sparking an initial interest among Kenyan consumers, and proving the viability of the technology in Kenya’s conditions’. Hence donor programmes provided direct financial resources to promote PV market development, but also contributed to creating the supporting industry and supply-side conditions for this [73].

The literature has also identified government support to promote PV in all three countries as important for promoting solar PV uptake. Eliah and Louineau [53], p. 1, for example, stressed that the historical increase in the diffusion of solar PV in Uganda was accounted for mainly by ‘conducive regulatory policies that encourage investment and trade in the solar sector [and] government projects that specifically promote the use of solar in rural electrification’. This is similar to Kenya and Tanzania, and in all three countries governments have stimulated the diffusion of solar PV indirectly through feed-in-tariff systems, subsidies, and exemptions from import duties and VAT on PV components, as well as directly via public procurement projects. Some of these changes in government support may be linked to donor support, as many donor programs directly aim at influencing policy through capacity-building and providing technical support to develop specific policy measures and legal frameworks such as FIT.

In summary, three main generic aspects seem to have been conducive to the diffusion of solar PV in all three countries: (i) the decline in world market prices for crystalline silicon-based PV modules; (ii) the substantive and prolonged support for solar PV from international donors; and (iii) the conducive framework conditions provided by national governments. The decline in world market prices influenced the direction of search, while support from donors and governments mobilised human, financial and technical resources for project developers, public agencies and PV system suppliers.

8.2. Specific factors explaining the relatively more advanced position of Kenya

While the broad trends mentioned above are common to all three countries, other factors have been used to explain the relatively more advanced level of solar PV diffusion in Kenya compared to Tanzania and Uganda. The main aspects in this regard emanating from the literature falls within the TIS functions (i) market formation, (ii) resource mobilisation and iii) entrepreneurial experimentation. These are discussed further below.

8.2.1. Market formation

An often repeated explanation for the growth of the SHS market segment in Kenya is the general rise of an affluent rural middle class from around the 1990s, which increasingly demanded electricity to power televisions, radios, cell phones and other modern electrical appliances [18,72]. According to Jacobson [74], the increasing incomes from tea-growing were particularly important in improving the purchasing power of these rural customers. Indeed, Moner-Girona et al. [17], p. 2 state that the development of the SHS market segment was mainly attributable to ‘high incomes among farmers (coffee, tea, horticulture), rural teachers, civil servants and businesses with a strong demand for consumer electronics (TV's, radios, cell phones)'. Consequently, the business model of many PV system suppliers in Kenya was to target this growing rural middle class that lacked access to electricity [30]. Further, Bailis et al. [15], p. 92 argued that, 'most buyers are rural, middle-class households that lack confidence that the power grid will be extended, are knowledgeable about photovoltaic system performance, and want to make existing battery systems less maintenance intensive. Local entrepreneurs have played a key role in the process by aggressively moving photovoltaic systems to market and by downsizing the product to the needs of the lower-income market'. This would indicate that, besides the effects of the demand from the rural middle class, the lack of prospects for grid connection was an important factor for customers in deciding to purchase SHS. At an early point in the market's development, Hankins [14], p. 90 stressed that 'an enormous demand for electricity in rural areas has gone unsatisfied because they cannot count on grid connection [and so] rural households have increasingly turned to photovoltaics to meet their electrification needs'. More recently, Kivaisi [70], p. 416 also stressed that 'a major characteristic that probably helps to explain the high adoption rate of PV systems in rural Kenya is the slow pace of the grid extension', which the author associates with the ineffective rural electrification programme in Kenya.

8.2.2. *Resource mobilisation*

A number of papers employ a geographical explanation for the disparate patterns of SHS diffusion in Kenya, Tanzania and Uganda. Ondraczek [19], for example, argues that the Tanzanian population is more geographically spread compared to Kenya, where a majority of the population is concentrated in the central and western parts of the country [39,74]. Coupled with a relatively well-developed transport infrastructure in terms of road and rail links, establishing effective distribution channels and a PV supplier network has therefore been easier in Kenya. This is reflected by Woods [38], p. 3, who points out that 'distribution linkages are poorly established across Tanzania, partly due to the geographical size of the country [and] the geographical distance between players [being] a major barrier to the development of the market'. Byrne [30] also points to the geographical proximity between the PV industry, which is concentrated mainly in Nairobi, and market demand, as the customers, in living mainly on the southern and eastern sides of Mount Kenya, were located relatively close to the suppliers. Indeed, Ondraczek [19] considers the close distance between the PV supplier industry and the end-market to be a key explanation for the initial growth of the commercial SHS market in Kenya during the 1990s.

Hankins [14], p. 88 highlights the development of a local battery supplier industry during the 1990s in Kenya as a key factor in accelerating the diffusion of solar PV and in particular emphasises that 'technical modifications, known and utilised in the manufacture of batteries for other applications for years, improved PV system performance'. This points towards cross-fertilisation of the technical development mainly of car batteries to suit PV systems and thus a fruitful interaction between two emerging industries in Kenya. This is supported by Moner-Girona et al. [18], who stress that increases in the local availability of components such as batteries, wiring, circuitry and charge controllers in Kenya led to substantial decreases in PV system costs, as this reduced the need for imports, which contributed to stimulating solar PV diffusion. Similarly, Moner-Girona et al. [17], p. 2 stress that 'the successful development of the household and small commercial system markets is attributable to the availability of balance of systems components [and] local battery manufacturing'. Finally, Ondraczek [19], p. 409 too highlights that 'along with South Africa, Kenya is therefore the only African country with a sizable production capacity for solar modules, balance of system (BOS) components and lead acid batteries, and serves not only as an import hub, but also as a manufacturing centre for the wider region'.

8.2.3. *Entrepreneurial experimentation*

Various papers have accentuated the importance of particular individuals who have worked to support the overall development of the PV market in Kenya. Two expatriate engineers in particular – Harold Burris and Mark Hankins, both ex-Peace Corps volunteers – have been widely cited as playing a key role in the initial development of the SHS market segment in Kenya (see e.g. Duke et al. [5]). Indeed, Hankins [14], p. 87 states that 'the private market's genesis may be roughly dated as 1984. That year, an American engineer, Harold Burris, founded a small company called Solar Shamba'. According to Kivaisi [70], p. 417, 'Burris trained a group of about a dozen local technicians to market and install PV lighting systems. By reaching out to the high-income households on the southern and eastern sides of Mount Kenya, the rich white coffee and tea farms [and] Burris' successes attracted other local entrepreneurial groups and individuals to join the rural PV market'. After meeting Mark Hankins in the early 1980s, these two individuals provided training to local technicians in PV systems, as well as preparing various PV-related technical tools and guide books and broader consultancy and promotional activities. Through Burris's company, they also engaged in a number of demonstration projects showcasing PV systems in Kenya, which, according to Byrne [30], was instrumental in attracting interest from donors and the Kenyan government.

Ondraczek [19], p. 414 ascribed a generally enabling business environment in Kenya a key role in stimulating the SHS market by pointing to 'a strong entrepreneurial culture in Kenya and openness to foreign investors and business practices/ideas', while also deploring that 'the lack of entrepreneurs hindered the emergence of successful solar companies in Tanzania during the 1980s and 1990s. Similarly, Byrne [29], p. 207 highlighted that the 'opportunistic behaviour of entrepreneurs once the demand had been demonstrated' was a key to promoting market development, thus pointing to the widespread opportunism and risk willingness of local firms in Kenya to enter the PV market during its initial development (see also Hankins et al. [17]). These findings link the emergence of a PV market mainly with the existence of a particularly dynamic and entrepreneurial business attitude in Kenya compared to Tanzania and Uganda.

In conclusion, five key points have been identified in the literature as primary explanations for differences in the diffusion of solar PV. The first factor identified is the importance of the growing middle class in Kenya. The second and third factors are the favourable geographical conditions and the existence of a local sub-component supplier base, which are related to mobilizing resources in the innovation system. The fourth and the fifth factors are the importance of local champions and the of a vibrant business culture in Kenya, which relates to the conditions for entrepreneurial experimentation.

8.3. *Crosscutting discussion of findings and gaps in the literature*

The discussion presented above gives rise to a number of reflections about the explanations provided in the literature to account for the generic factors encouraging SHS diffusion and for the reasons behind differences in the levels of SHS diffusion in the three countries. On the basis of the TIS framework, the following will point out elements missing in the existing literature and sketch out areas of further research.

It seems reasonable to assume that the continued support from donors and governments, highlighted in Section 8.1, has generally contributed to encouraging solar PV diffusion in all three countries. However, previous research has paid limited attention to addressing whether differences in the amount, nature and timing of the technical, human and financial resources provided over time may help to explain differences in solar PV uptake across the three countries. This analysis would be interesting in order to increase the understanding of the effectiveness of different instruments and measures to creating an enabling environment for the diffusion of solar PV.

Existing research has only addressed the 'knowledge development and diffusion' functions to a limited extent, even though these are key elements of interactive learning, knowledge creation networks and technology development in TIS (see, however, Byrne [30]). This means that there is currently a limited understanding of how local learning, the development of technological capability and the upgrading of local solar PV SMEs have emerged as part of the accelerated diffusion of solar PV systems in these three countries. Issues that need further attention in this regard include how local entrepreneurs obtain access to PV technology and which sources and networks of learning they draw on to build technical and business competences. These issues should preferably be understood in the light of ongoing processes of incremental learning in the local PV industry, which relies less on formal R&D and more on trial and error and gradual experimentation.

A related issue that has also received little attention so far in the literature concerns the dynamic interaction between different TIS functions. The existing literature seem to focus more on the identification of distinctive, individual factors than on how the interaction among these factors has influenced the diffusion of solar PV in the three countries. For example, it is evident that geographical proximity between supply and demand provided a conducive infrastructure that encouraged solar PV diffusion in Kenya. Yet, it is less clear whether and how this 'resource mobilisation' function was conducive to facilitating the cross-sharing of experiences in the PV industry and hence contributed positively to the 'knowledge development and diffusion' function by facilitating learning through local labour turnover, imitation and knowledge sharing.

In addition to these three missing elements, the existing explanations provided in the literature to account for differences in the level of SHS diffusion in the three countries identified in this paper may also need further analysis. For example, concerning the explanations stressing the existence of a local sub-component supplier base in Kenya, an interesting analytical endeavor may be to address in greater detail the conditions under which the local production of PV components may be established in the first place. An interesting area for further research may involve addressing the barriers to entry for establishing local PV module assembly production lines and how and why local industries may diversify into new branches, as in the case of the Kenyan battery industry. Similarly, it would be interesting to analyse in greater detail the role local champions play once the commercial PV market reaches a certain scale. For example, it would seem logical that their influence on promoting knowledge sharing would gradually be reduced when competition in the local industry increases. With regard to explanations highlighting the growing middle class in Kenya, further research may also analyse in greater detail the importance of income relative to other influential factors, such as level of education, awareness and so-called neighbor effects (see Lay et al. [76]).

9. Conclusion

This paper has reviewed the development and status of different solar PV market segments in Kenya, Tanzania and Uganda and the support from donors and governments to promote different PV segments. Further, the paper has also analysed the key factors put forward in the literature to explain the disparate patterns of solar PV diffusion in the three countries.

The paper finds that, although Kenya currently has the highest (total) installed solar PV capacity, Tanzania and Uganda are rapidly catching up. The SHS market segment dominates in Kenya and Tanzania and in the past five years has also increased significantly in Uganda to comprise a larger share of total installed PV capacity. The institutional PV segment is larger in Tanzania and Uganda compared to Kenya. In all countries the telecommunications and tourism segment is increasing, as are the mini-grid and large-scale solar power segments. The paper identified two emerging trends across PV segments: a movement from donor and government-supported initiatives towards commercial-based solar PV diffusion, and a movement from off-grid to mini-grids and large-scale, grid-connected PV plants.

The review also reveals that donor programs and national policies have used a combination of direct and indirect measures to promote the diffusion of solar PV. The SHS market segment has been supported mainly through indirect measures, such as VAT and import duty exemptions for imported PV components and favourable loan and credit schemes for SHS suppliers and customers. The institutional PV segment has been supported through direct procurement of systems in rural schools and health clinics. The tourism and telecommunications segment is driven mainly by private investors. The mini-grid segment is supported by private investments, government subsidies and donor programs, while the large-scale solar power segment is driven by international investors and supportive government instruments, such as feed-in tariffs.

The TIS framework enabled the paper to identify three factors that have been stressed in the literature as encouraging the diffusion of SHS in all three countries. These include the decline in world market prices for PV modules, the prolonged support from international donors and the conducive framework conditions provided by national governments. Beyond these generic aspects, the paper pointed to the following five key factors that have been elaborated in the literature to explain the relatively higher level of SHS uptake in Kenya compared to Tanzania and Uganda: (i) a growing middle-class; (ii) geographical conditions; (iii) local sub-component suppliers; (iv) local champions; and (v) business culture. The paper further discussed the lack of attention in the literature towards analysing the amount, nature and timing of donor and government support across countries, processes of learning and upgrading in the local PV industries, and the interactions between the different explanatory factors. These issues offer promising areas for further research, which should preferably go beyond SHS to include other emerging PV market segments, such as mini-grids and large-scale solar power.

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Article 2

Advanced Review

Deconstructing the concept of renewable energy-based mini-grids for rural electrification in East Africa

Mathilde Brix Pedersen*

The goal of providing universal energy access to all by 2030 under the UN-led SE4ALL initiative calls for new and innovative solutions to rural electrification and is fuelling the recent interest in mini-grids. Mini-grid solutions are emerging as a third alternative to rural electrification, coming between the option of large-scale grid extension and pico-scale stand-alone solutions like solar home systems or solar lanterns. International expectations of mini-grids are high, with the International Energy Agency suggesting that they will play a significant role in reaching the goal of universal access. Based on a detailed review of past, ongoing, and planned mini-grids in East Africa, this study seeks to deconstructs the popular notion of mini-grids for rural electrification in East Africa. The study reveals that so far activities carried out under the heading of mini-grids to a large extent consist of the hybridization of existing utility-owned electricity systems for medium-size towns located far from the grid, which does not necessarily contribute to rural electrification. However, limited but increasing activity is identified regarding the use of mini-grids to bring electricity to rural villages and smaller rural towns. This is of specific interest because it is for this type of mini-grid that the main challenges are to be found with respect to identifying and testing adequate financing, ownership, and business models. Based on the trajectories identified for mini-grids for rural electrification and the challenges identified in the literature, the study concludes by proposing three avenues for further research.

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INTRODUCTION

Attention to mini-grids as a way of accelerating energy access in unserved rural areas has grown rapidly in the past few years. With the announcement of 'the international year of sustainable energy for all' (SE4ALL) by the UN Secretary General in 2012, the issue of energy poverty was raised high on the international development agenda. Although the issue of energy poverty is not new and has been recognized by governments and development agencies for decades, the SE4ALL initiative is the first time the issue has been addressed in a coordinated manner. The goal of universal access to all by 2030 under the SE4ALL initiative calls for new and innovative solutions and is fuelling the recent interest in mini-grids.

Mini-grid solutions are emerging as a third alternative to rural electrification, coming between the option of large-scale grid extension and pico-scale stand-alone solutions like solar home systems (SHS) or solar lanterns. The International Energy Agency

*Correspondence to: brix@dtu.dk

DTU Management Engineering, UNEP DTU Partnership, Copenhagen, Denmark

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(IEA) suggests that 70% of all rural areas globally are not suited to electrification through grid extension, and that renewable energy-powered mini-grids will therefore play a significant role in reaching the goal of universal access.[1] At the same time, there are strongly voiced expectations that the private sector will play a major role in upscaling mini-grids in respect of both financing and implementation.

Expectations regarding mini-grids are based partly on an indispensable need for alternative solutions to slowly growing national grids and the low-quality options of individual solutions, and partly on a highly positive narrative about their advantages. Characteristics such as greater flexibility than the main grid, modularity, and better quality electricity than individual systems are emphasized. Furthermore, recent technological advances, especially in solar PV, and the resulting lower prices, greater efficiency, and greater reliability have led to a situation in which renewable energy-based mini-grids are cost-competitive with other decentralized electrification solutions like diesel generators.[2,3] Finally, the possibility of grid-readiness and smart solutions drawing on information and communication technology provide promise of new opportunities for both mini-grid developers and rural consumers.

However, the concept of mini-grids in the current international development discourse is a highly popular notion without a commonly adopted conceptualization of the large variety of systems. The positive narrative of mini-grids has developed a considerable degree of international hype, with mini-grids being put forward almost as a panacea for fulfilling the SE4ALL goal of universal access by practitioners and researchers. As highlighted by ARE, mini-grids ‘have the potential to become the most powerful technological approach for accelerated rural electrification’ (Ref 3, p. 11).

In Asia the mini-grid experience is fairly well-documented, particularly in India, with a growing body of literature documenting operational experience (case studies and lessons learnt) with mini-grids. Topics in the literature include: (1) reviewing current experience from the angle of technology, business models, policies, financing, and opportunities and challenges[4–7]; (2) evaluation of the impact of mini-grids on rural electrification[8,9]; (3) comparative analysis of specific organizational mini-grid models[10]; and (4) analysis of specific mini-grid systems from the angle of economic viability,[11] household preferences,[12] and socioeconomic aspects.[13] Studies using specific theoretical lenses such as transitions theory[14,15] are also emerging.

Turning to Africa the literature is mainly addressing rural electrification in general. Topics in the literature include: (1) generic business models[16]; (2) country specific case studies[17,18]; (3) policy-tailored analyses targeting country-scale institutional environment and enabling frameworks[19–22]; (4) financing[23,24]; and (5) planning and scale.[25–27]

But interestingly, on the continent where the challenges of achieving universal access are the greatest, only limited research has been carried out on practical experience with renewables-based mini-grids for rural electrification.[10] Three pieces of work, all project-specific single-case studies using a narrative style to describe the organizational arrangement of the mini-grid, are highlighted here. Ilskog et al. describe an organizational model of a mini-grid in Tanzania where a cooperative owns and manages the system.[28] Eder et al. describe a particular mini-grid project in Uganda through a technological innovation system lens,[29] while Kirubi et al. evaluate to what extent a specific mini-grid project contributes to rural development.[30] There is thus a need to understand current trends in mini-grid development in an African context and to set a relevant research agenda.

Against this background, this study sets out to answer to the following research questions:

- How is the concept of the mini-grid understood and used in the current international development discourse?
- What are the status and current trends in the application of organization models for renewable energy mini-grids in East Africa?
- What are the implications for setting a relevant research agenda?

The article is structured as follows: *Methods* section presents the research methods; *Analytical Framework* section presents a framework for deconstructing the concept of mini-grids; *Current and Planned Mini-Grid Installations in East Africa* section maps existing mini-grids in Kenya, Uganda, and Tanzania according to this framework and highlights country priorities and directions; and *Discussion and Conclusion* section provides a discussion of identified trends and concludes by providing suggestions for further research.

METHODS

The article is based on a desk study comprising a review of peer-reviewed and gray literature supplemented by information retrieved from the internet from mini-grid developers, development agencies, governments, and NGOs.

The mini-grid types in *Mini-Grid Types* section are derived inductively from the available information on mini-grid cases described in the literature. Ownership models in *Ownership Models* section, however, are based on an already well-established categorization of ownership structures in the literature.

In addition to the above-mentioned sources, to identify existing mini-grids systems in Tanzania, Uganda, and Kenya in *Analytical Framework* section, information was gathered through participation in the Africa Mini-grid Summit held in Nairobi on 18–19 November, 2014. In addition, e-mail correspondence with mini-grid developers has been used as a source of confirmation and elaboration and of snowballing to reach further informants.

ANALYTICAL FRAMEWORK

The aim of this section is to deconstruct the popular notion of mini-grids in order to arrive at an empirically based conceptualization of mini-grids broken down into subcategories.

Definitions of mini-grids in the literature range very broadly. Some definitions are all-encompassing, with no defined size limit and with the only defining characteristic being an off-grid generation and distribution system.[31–33] Other authors use the defining characteristic of size and define mini-grids to be in the capacity range of 5–200 kW[14] or up to 300 kW.[34] Schnitzer et al. uses the term micro-grids, which they define as ‘systems up to roughly 100 kW’.[10] Tenenbaum et al. also distinguish between micro- and mini-grids and use targeted markets as a defining characteristic, mini-grids being ‘isolated grids (typically ranging in power output from tens of kilowatts (kW) to tens of megawatts (MW) and serving several hundred customers) in rural areas of developing countries,’ while micro-grids are ‘systems of very small scale, with power output ranging from hundreds of watts to a few kilowatts, and typically fewer than 150 household customers’ (Ref 35, p. 44). Yet others include the term pico-grid to describe systems below 1 kW.[36] UNEP, in its ‘Clean Energy Hybrid Mini-Grids in Remote Areas: An Investment Opportunity?’ program uses ‘sufficient scale for investment’ in defining mini-grids for inclusion in the program and focuses on systems >100 kW.[37]

These various definitions point to different perceptions of what a mini-grid is and what the concept entails. In the context of the goal of universal access to energy, a broad definition of mini-grids encompassing all mini-grid types could be appropriate to some extent, as all mini-grids are likely to create positive social impacts in the form of general increases in electrification. However, too broad a definition also masks the fact that some mini-grids are implemented in order to provide energy access directly benefiting rural poor populations, whereas other mini-grids are implemented in order to increase energy supply in urban or peri-urban settings without increasing rural energy access. Business models in pursuit of these different aims are bound to differ, with one end of the spectrum targeting rural populations and requiring long-term and less financially lucrative investments, while the other end of the spectrum depends on easier, quicker and more financially profitable opportunities targeting broader segments of society. Furthermore, a broad definition also masks the fact that different policy frameworks and financing mechanisms are needed to promote different types of mini-grids and business models. Against this background, an attempt is made in *Mini-Grid Types* section to deconstruct the concept of mini-grids to arrive at more detailed categorization of them.

Mini-Grid Types

Table 1 presents an overview of the different methods of rural electrification, with mini-grids placed in the spectrum between pico-sized household systems and large-scale grid extension. Rural electrification is divided into four overall categories according to the systems used: off-grid household systems, off-grid stand-alone systems, mini-grids, and grid extension. These four categories are further divided into a subsystem typology which makes it possible to differentiate between various mini-grid types.

Mini-grids as presented in Table 1 are defined as decentralized energy systems consisting of power generation assets (hydro turbine, solar panels, batteries, inverters, etc.) and distribution assets (the wires, poles etc.) with power capacity between 0.2 kW and 2 MW connecting two or more individual households. This definition covers the majority of systems called mini-grids in the literature. The three characteristic features of mini-grid subsystems are: (1) the nature of the power supply (AC/DC); (2) the targeted market; and (3) the size of the system. Mini-grids are divided into the following four subsystems: ‘DC village mini-grids,’ ‘ABC mini-grids,’ ‘AC village mini-grids,’ and ‘Large mini-grids.’ The

TABLE 1 | Characteristics of Electrification Methods

Rural Electrification System	Subsystem	Nature of Power Supply	Market Description	Capacity/ approximate Size[1]
Off-grid household systems	Small pico-systems: solar lanterns, LED lamps, solar chargers	DC	Lighting and charging of batteries and mobile phones in mainly nonelectrified areas	1–10 W
	Home systems (e.g., SHS)	DC	Off-grid electricity demand in private homes in dispersed settlements, in smaller nonelectrified villages and on the outskirts of electrified towns and villages far from existing distribution lines	10–100 W
Nonhousehold stand-alone off-grid systems	Stand-alone 'institutional systems'	AC	Institutions located in villages without grid or mini-grid, or on the outskirts of grid-electrified villages and basic electricity supply for the tourism sector (mainly lighting) for rural lodges and hotels	50–500 W
Mini-grids	DC village mini-grids (e.g., modular PV systems). Also referred to as micro-grids by some.	DC	Single village (up to hundreds of HH) located far from existing grid	0.2–5 kW
	Anchor-business-community (ABC) mini-grids (e.g., telecom towers or lodges)	AC	Powering an anchor costumer, combined with supply to nearby villages	0.2–15 kW
	AC village mini-grids (e.g., hybrid PV-diesel, hydro schemes)	AC	Single or plural villages (up to hundreds of HH) and small towns located far from existing grid	1–300 kW
	Large mini-grids (e.g., diesel powered)	AC	Large towns located far from existing grid	>300 kW to 2 MW
Grid-connected mini-grids	SWER (single wire earth return)	AC	SWER connection to private and cooperative owned mini-grid	0.2–500 kW
	Agro-business (a larger version of the ABC mini-grid)	AC	Own generation combined with whole sale to utility (sometimes also combined with distribution to local community)	1–5 MW
	Connection of existing mini-grid	AC	Any of the above (except DC Village mini-grid)	0.2 kW to 5 MW
Grid-extension	Electricity generation	AC	Expansion of production capacity in existing grid	>4 MW

[1] Terminology in regards to capacity differs depending on technology. For solar PV technology, as maximum electric load depends on solar irradiation levels and therefore cannot be expected at all times, kW or MW peak (p) is used to describe the potential maximum capacity. For other technologies, such as diesel or biomass generators, kW or MW is used for the maximum load, which in this case can be delivered at any time. In this study, kW and MW are used as maximum load for all mini-grid systems regardless of technology.
Source: Adapted from Ref 38.

characteristics and definitions of these four mini-grid types are described in detail in the following sections.

The classification in Table 1 is not assumed to be definitive or exhaustive, and the various electrification systems listed may overlap between the various categories. However, the table is meant to situate mini-grids in the wider context of rural electrification alternatives and to present a breakdown and hence a better overview of the mini-grid alternatives currently identified in the literature.

DC Village Mini-Grid (0.2–5 kW)

The 'DC village mini-grid' provides DC power at a low voltage of between 12 and 48 V and for a limited number of hours, usually 5–7.[5] The DC village mini-grid system consists of a DC power-generating unit (e.g., one or more solar PV panels), wires for distribution, a control unit, and an electrical storage unit.[39] As the name suggests, the DC village mini-grid supplies power to a village (or a cluster of villages), the off-takers of electricity being people living in the village either for private use or for low-voltage appliances in shops. The DC village mini-grid can supply power for appliances like LED lighting, cell phone charging, radios and DC TVs, or fridges. The sizes of DC village mini-grids range from about 0.2 kW to about 5 kW.

DC village mini-grids provide power that is comparable to pico-systems like SHS and cannot support productive uses to the same extent as AC-driven systems. DC village mini-grids can, however, provide cheap and reliable power in areas where the main demand is for lighting and mobile phone charging. Because of the restricted applicability of DC power, some authors refer to DC village mini-grids as micro-grids[7] or as skinny-grids.[40]

Anchor-Business-Customers Mini-Grid (0.2–15 kW)

The Anchor-Business-Customers (ABC) mini-grid supplies power to three different groups of targeted customers, namely an anchor client, who is ensuring a steady revenue for the developer; small village businesses or institutions with a greater load demand than regular households; and lastly rural household customers.[41] ABC mini-grids supply AC power through an AC low-voltage network (e.g., 230 V/50Hz, 120 V/60Hz). The system consists of a generating unit, distribution wires, storage unit, load controller, and inverter. The heart of the AC-coupled system is the bi-directional battery inverter, which provides the voltage and frequency control of the grid.[42] The size of ABC mini-grids are between 0.2 and 15 kW.[38]

Currently, the ABC mini-grid is associated particularly with the telecoms sector and greening of the current diesel-fired generators used to electrify remote mobile masts. Implementation of ABC mini-grids is driven primarily by cost savings potentials for power delivery companies, as solar PV-driven power stations for telecom base stations are increasingly competitive with conventional diesel-driven ones.[43]

AC Village Mini-Grid (1–300 kW)

The technical specifications of an AC village mini-grid are the same as those of ABC mini-grids. Like the DC village mini-grid, the AC village mini-grid supplies power to people living in rural villages as well as local businesses, however without an anchor customer. The defined target market is hence a whole village, a subgroup in a village or a cluster of villages. Systems are of sizes between 1 and 300 kW, with the upper limit being highly indicative.

AC village mini-grids have the potential to deliver three-phased grid-quality power with high reliability. They can power high-power devices such as fans, agricultural machines, pumps, and so on, and can thus support productive uses. Furthermore, they can be designed to be grid-ready, which means that they can be integrated into the national grid in the case it arrives at the location. However, there are no standards for mini-grid systems, and AC village mini-grids are built according to individual specifications. Accordingly, AC village mini-grids are not necessarily designed to provide three-phased power or to be grid-ready.

Large Mini-Grid (>300 kW to 2 MW)

Large mini-grids differ from AC village mini-grids in having a higher installed capacity, otherwise the technical components are the same. Mini-grids of this type usually range above 300 kW up to several MW. However, the limit between AC village mini-grids and large ones is somewhat arbitrary, and when tested empirically it can prove difficult to distinguish AC village grids from large mini-grids solely on the basis of capacity size. However, instead of being targeted at the rural population on the village scale, large mini-grids are targeted at urban centers located far from the main grid or at powering a factory or large agribusiness.

In Africa, large mini-grids have traditionally been installed by the utility as a supplement to ongoing grid-extension, simply as a least-cost option for electrifying urban centers lying out of the reach of the main grid. Large agribusinesses that produce electricity for their own consumption and supply power to nearby communities are also examples of large mini-grids.

Ownership Models

A second dimension by which to categorize mini-grid systems is according to the organizational model. Ownership of the assets, responsibility for implementation, responsibility for operation and maintenance (O&M), and financing the system all form part of the organizational model for implementing and running a mini-grid.[3] These four aspects can be divided between various actors in complex ways, which makes the definition and classification of such organizational models challenging.

In the effort to define and classify organizational models, some authors refer to business models,[3] other to operator models,[41] and yet others to ownership models.[44] According to ARE, 'ownership is clearly the dominant and most decisive element on which to base a typology of business models' (Ref 3, p. 21). However, as Hazelton et al. has pointed out, the term 'ownership' is interpreted differently in the literature.[45] Some authors define the owner of a mini-grid 'as the entity that initiates the project and finances its delivery […]' (Ref 45, p. 2). Other interpretations of ownership include those responsible for the O&M of the system (ibid.) (e.g., Ref 41).

In order to establish a clear defining parameter on which to classify organizational models, this study defines ownership models based on actual and legal ownership of assets. The focus on legal ownership has been chosen to make a clear distinction between who owns, implements, operates, and finances the mini-grid. It is argued here that actual ownership of assets deserves more attention than it currently receives, and that legal ownership can serve as a more accurate parameter when categorizing organizational models.

The four ownership models adopted here are the following: utility ownership, hybrid ownership (a combination of private/utility/community), private ownership, and community ownership.[3,41]

Particularly in relation to community ownership, a clearer distinction between the four aspects of an organizational model could prove valuable, as the current terminology on community ownership is vague. The term 'community ownership' is used in the literature to refer to a wide variety of organizational models, including arrangements in which legal ownership does not lie with the community.[17,46,47] The term 'ownership' is hence used in a broad sense to describe both legal ownership, i.e., cooperatives,[48,49] and to describe a *sense* of ownership in the meaning of a local buy-in. This study therefore suggests that the specific terminology of community ownership be broadened to adopt a new term that covers the specific type of community ownership in the meaning of local buy-in, namely 'symbolic ownership'. In the classification below, community ownership is thus further subdivided into legal ownership and 'symbolic' ownership.

Ownership of assets does neither determine the responsibility for operation and management (O&M) nor for the financing of the system. These aspects therefore have to be elaborated separately under each ownership model. Each of the four ownership models can depend on one or more of the contractual arrangements highlighted below in Table 2 in relation to O&M, commercial risk and capital investment.

The most typical combinations of ownership model and contractual options are elaborated further in the following sections.

Utility Ownership

Utility ownership is where a utility owns both generation and distribution assets. O&M and financing can be split between public and private entities in various ways. These organizational arrangements take the form of public–private partnerships (PPP) with different contractual arrangements. PPP contracts include service contracts, management contracts, or long-term leases. With a service contract, the public entity remains the primary service supplier, but subcontracts specific activities to a third-party operator. This can include some of the functions of O&M. Commercial risk and capital investment lie with the public entity. A management contract between a public entity and a private entity will usually cover all the functions of O&M, as well as

TABLE 2 | Contractual Options for the Four Ownership Types

Contractual Arrangements	Operation and Maintenance	Commercial Risk	Capital Investment	Contract Duration (Years)
None	Owner	Owner	Owner	N/A
Outsourcing	3rd party	Owner	Owner	1–2
Management contract	3rd party	Owner	Owner	3–5
Long-term lease	3rd party	3rd party	Owner	8–15
Concession	3rd party	3rd party	3rd party	25–30
Build, operate transfer	3rd party	3rd party	Owner	20–30
Build, own, operate, transfer	3rd party	3rd party	3rd party	20–30

Source: Adapted from Ref 50.

several management functions, such as equipment management, staff management, accounting, or marketing services.[50] Also here, commercial risk and capital investment lie with the public entity. An example of a management contract between a public entity and a private entity is the Santo Antâo Island solar PV hybrid mini-grid in Cape Verde.[51] Through a long-term lease, the commercial risk is transferred to a private entity. Under such a contract the contractor agrees to manage a public service, at his own risk, for a consideration paid by consumers.[50] An example of a long-term lease is the SPUG project in the Philippines.[3]

Hybrid Ownership

Hybrid ownership is where ownership of generation assets and distribution assets is divided between two or more entities. In this model, specific contractual arrangements between different actors apply. The most common of such arrangements is the power purchase agreement (PPA), in which a small power producer who owns the production assets sells power to a distributor who owns the distribution network, usually the utility. O&M and the financing of such systems are usually also hybridized in nature. For example, in a Build, Operate, and Transfer Contract, investment charges, O&M, commercial risk, and asset ownership for the duration of the contract are shared between the public and private entities as part of a mixed enterprise corporation.[50] An example of hybrid ownership is the Tanganyika Wattle Company Ltd (TANWAT) in Tanzania, which, in addition to generating power for its own consumption, also sells power through a PPA to a national utility-owned mini-grid.[52]

Private Ownership

Private ownership refers to cases in which a private entity plans, builds and owns both production and generation assets. Funding depends on private equity and commercial loans, as well as, in some cases, on some form of government support, e.g., grants, subsidies, results-based financing, or public-sector loan guarantees.[41] Fully privately financed mini-grids are rare but do exist (e.g., Powergen and Powerhive in Kenya, Mesh Power in Rwanda and India). O&M usually lies with the private business itself, but it can also be outsourced to a third party. O&M is in some cases handed over to a community-based organization in order to increase local buy-in and the local 'sense of ownership'. This particular arrangement is referred to in this study as 'symbolic' community ownership and is elaborated further below. A private company can also Build, Own, Operate, and later Transfer ownership (BOOT) to, e.g., a local cooperative or village group. An example of this is DESI Power in India.[11] In the case of the concession, investment charges, O&M, commercial risk, and asset ownership for the duration of the contract are fully born by a private contractor. An example of privately owned mini-grids being operated through a concession is the Yeelen Kura solar hybrid mini-grid in Mali.[51]

Community Ownership

In an attempt to add clarity to the terminology on community ownership, I distinguish in this article between legal ownership and 'symbolic' ownership. Legal ownership entails full ownership by a communal institutional entity (e.g., a cooperative) of production and distribution assets. O&M activities can be outsourced to a third party or remain with the owner (the communal institutional entity). Examples include Thiba in Kenya[53] and Urambo in Tanzania.[49] In these cases, financing usually comes from donors and implementation support from NGOs or REAs.

'Symbolic' community ownership entails an institutional arrangement whereby legal ownership of the assets remains with the implementer or the investor, whether an NGO, a private company, REA, or municipal utility, whereas 'symbolic' ownership is transferred to the community through the formation of, e.g., an energy committee, which then owns responsibility for the O&M of the system. Especially in relation to community ownership, ownership structures are often so vaguely described in the literature that it is difficult to describe the institutional arrangements involved. Therefore, the prevalence of symbolic ownership is unknown, and more research will be needed to understand what role this ownership type plays in the field of what the literature refers to as community-based mini-grids.

CURRENT AND PLANNED MINI-GRID INSTALLATIONS IN EAST AFRICA

Section *Current Mini-Grid Installation* provides an overview of currently operating mini-grids in Tanzania, Uganda, and Kenya based on the framework outlined in the *Analytical Framework* section and provides an overview of the policy environment and planned mini-grids in the tree countries (*Policy Environment and Planned Mini-Grids* section). This will be followed by a discussion of identified trends in the market in *Discussion and Conclusion* section.

Current Mini-Grid Installations

Because of the limited availability of information on organizational models and ownership models, this section does not claim to be exhaustive. However, it presents a broad and inclusive picture of the current mini-grid landscape in East Africa illustrated by examples of mini-grid types and ownership models in the region. These examples of currently operating mini-grids are presented in Table 3 based on the classification in the *Analytical Framework* section and are organized according to ownership model, type of mini-grid, and country.

Utility-owned mini-grids are left out of this table, as they represent primarily 'large mini-grids' and have traditionally been implemented with the primary function of electrifying large towns or cities. For that reason, it can be argued that their role in rural electrification is limited.

The examples listed in Table 3 are described in detail in the following sections.

Hybrid Ownership

The only type of mini-grid identified with hybrid ownership is large mini-grids. There are no known examples of village mini-grids using this ownership structure. This does not, however, conclude that such systems do not exist. ABC mini-grids, as will be shown later, are implemented purely through a private ownership model.

Hybrid Large Mini-Grids

Ngombeni Power Ltd, Mafia Island, Tanzania, is an example of a large mini-grid with a hybrid ownership model. The production unit is a biomass unit, namely a steam turbine running on coconut wood privately owned by a company called Ngombeni Power Ltd. The distribution grid is owned and managed by TANESCO. Installed capacity is 1.5 MW, and the company sells power at 11 kV to the national utility TANESCO at $0.301/kWh.[54]

The forestry product company Tangayika Wattle Company Ltd (TANWAT), Tanzania, commissioned in 1995, is another example of a large mini-grid with hybrid ownership. TANWAT produces power using waste wood from production and has an installed capacity of 2.5 MW.[55] In addition to power generation for its own consumption, the plant sells surplus power to the Njombe/TANESCO-owned mini-grid through a power purchase arrangement (PPA) with TANESCO covering 1.4 MW.[52]

Private Ownership

The private ownership model is the most diverse model, and all four types of mini-grids are seen implemented through it.

Private DC Village Mini-Grids

This type of mini-grid represents a small part of installed systems. Devergy is a Tanzania-based private company which started installing a solar PV

TABLE 3 | Examples of Mini-Grids Types and Ownership Models

Ownership Model	Name of Owner	Mini-Grid Type	Country	System Size	Technology
Hybrid	Ngombeni Power Ltd/TANESCO	Large	Tanzania	1.5 MW	Biomass
	Tangayika Wattle Company Ltd/TANESCO	Large	Tanzania	2.5 MW	Biomass
Private	Devergy	DC	Tanzania	3 kW	Solar
	Sincro Sitewatch	ABC	Tanzania	Unknown	Unknown
	Kirchner Solar	ABC	Uganda	22.5 kW	Solar
	Carbon X	AC	Tanzania	11 kW	Solar
	Husk power	AC	Tanzania	32 kW	Rice husk
	Kisiizi Power Company	AC	Uganda	300 kW	Hydro
	Remergy	AC	Uganda	5 kW	Solar
	Powergen	AC	Kenya	1.4 kW	Solar
	Powerhive	AC	Kenya	20 kW	Solar
	Andoya Hydro Electric Power Company	Large	Tanzania	1.2 MW	Hydro
Community	Urambo Village Cooperative	AC	Tanzania	180 kW	Diesel
	Community of Thiba	AC	Kenya	135 kW	Hydro
	Cooperative in Kitonyoni	AC	Kenya	13.5 kW	Solar

Source: author's own elaboration.

mini-grid system in 2012 in the pilot village of Matipwili.[56] By October 2014, Devergy had electrified six villages with a total installed capacity of 18 kW (F. de Pascale, personal communication, November 2014). The mini-grid systems consist of connected individual solar panels with an associated battery for storage and a meter for each household that can be charged using prepaid electricity cards via mobile phones (ibid.).

Private ABC Mini-Grids

ABC mini-grids are purely operated through the private ownership model. However, this does not rule out subsidies or donor support. On the contrary, donor-supported initiatives have been launched in all three countries to develop the private market for the ABC model within the telecom sector.

Sincro Sitewatch Ltd is a privately owned Tanzanian company with majority Tanzanian shareholding. As its core business it maintains and fuels approximately 800 telecom towers in Tanzania using conventional diesel generators. According to their CEO, the company is in the process of changing from being solely a power maintenance subcontractor to being an energy service provider.[57] In the village of Mgera, the company has connected households and the school to the network, with support from the World Bank. Surplus electricity from the telecom station is used by rural customers.

Kirchner Solar, Uganda, is piloting the ABC model as a new market segment in Kabunyata village, Luwero district, with support from GIZ. Kirchner Solar has installed solar containers with a capacity of 22.5 kW and acts as an energy services provider for both the telecom operator and private households.[58,59]

African Solar Designs, Kenya, has recently received a seed grant under the joint IFC–GSMA 'Green Power for Mobile' program[a] to provide renewable power to an Airtel base station and to electrify a nearby community though a mini-grid for businesses and an energy kiosk for households to access charging and solar products.[60] The seed grant and the project are functioning as a pilot to generate lessons about ABC mini-grid business opportunities for private companies.

No detailed information is available about the outcomes of these ABC mini-grid projects in the literature.

Private AC Village Mini-Grids

Carbon Energy X, in collaboration with the international renewable energy company Juwi, has installed an 11 kW PV-Module mini-grid serving 250 households in Masurura, Tanzania.[61,62]

Husk Power Systems is an India-based company with a total of 200 installed mini-grids (25–100 kW) serving 325 villages in India, Nepal, Uganda, and Tanzania.[63] According to AECF,[64] Husk Power Systems has installed five 32 kW rice husk biomass gasifiers in Tanzania. However, no detailed information about the company's East African operations is available.

The Kisiizi hydro-powered mini-grid is owned by Kisiizi Hospital Power Ltd, a subsidiary of Kisiizi Hospital, a private missionary hospital administered by the Church of Uganda.[65,66] The power station, with a capacity of 300 kW, was commissioned in 2009.[66] The power from the station is used by the hospital and its affiliated institutions, and its surplus is sold to the wider Kisiizi community, including businesses and private homes. The number of connections by 2012 was 300.[67]

Remergy, a Denmark-based company established in 2014, has so far installed one solar PV mini-grid in Kayanza village in Uganda. The mini-grid is a 5 kW system that provides electrical power to 120 households and businesses for the primary purpose of electrical lighting.[68] Remergy is, according to their website, preparing the implementation of similar systems in more off-grid villages (ibid.).

Powergen, Kenya, a Nairobi-based company, has implemented and owns four mini-grids in the Masaai Mare area in Kenya with a capacity of 1.4 kW each. Financing for the mini-grids was raised through the online crowd-funding source Kiva.[69] Powergen has in total installed more than twenty mini-grids in Kenya however most of them are owned by others.

Powerhive, Kenya, was founded in 2011. Although headquartered in the United States, operations are run from the regional office in Nairobi. They have installed and own four mini-grids of a total of 80 kW in the vicinity of Kisii[70] and is currently planning to upscale with hundred new sites (R. Wuts, personal communication, November 2014).

Private Large Mini-Grids

According to Adebayo et al.[71] and Msofe,[72] Andoya Hydro Electric Power Company has installed a 1.2 MW hydro-powered mini-grid in Mbinga, Mtambazi Tanzania (Ruvuma). Data availability and information about this project are very scarce, but according to Greacen the commercial operation of the plant was set for early 2015.[40] There is no documentation confirming that this mini-grid has become operational.

Community Ownership

The main type of community-owned mini-grid is the AC village mini-grid. There are no accounts of any community-owned DC village mini-grids.

Community-Owned AC Village Mini-Grids

The Urambo Electric Consumers Co-operative Society (UECCO), Tanzania, was set up in 1993. UECCO owns, operates, and manages the Urambo Power plant, which consists of three diesel gensets with a total installed capacity of 278 kW. By 2005, approximately 2000 people were being served through UECCO.[28]

The community of Thiba, Kenya, has initiated its own hydro project, partly in cooperation with a local NGO GPower, and has been running the 135 kW hydroelectricity mini-grid through a cooperative since 2005, with 180 HH connected.[32]

As part of it Energy for Development project, the University of Southampton has implemented a 13.5 kW mini-grid in Kitonyoni, Kenya. The mini-grid is owned and operated by a local cooperative.[73]

Symbolic Community Ownership

As already mentioned, information and data available about ownership models are in many cases scarcely available. It is therefore often challenging to determine the actual ownership of community-based mini-grids, and the prevalence of this ownership model is therefore unknown. However, one example of a case where community ownership is vaguely defined in the literature is the Mpeketoni Electricity project in Kenya. This is a diesel-powered mini-grid (initially 60 KVA, but later, with the addition of two generators, a total of 207 KVA) that began electricity production in 1994. Since then the mini-grid has been increased to a capacity of 960 kW.[74] Kirubi et al. present a well-documented analysis of the link between energy access and development from an empirical study of the Mpektoni mini-grid.[30] The mini-grid in the study is referred to as community-based, though without giving an actual account of the legal ownership arrangements. According to Ref 75, the Mpeketoni mini-grid is owned by the government and operated and managed by KPLC. According to Ref 76, it was 'handed over to the community in 2004,' which could indicate that there was a change in ownership and/or management structure in 2004. However, documentation is scarce, and the mini-grid may well have been owned by the community from the beginning or have a shared ownership structure (hybrid ownership) involving both the community and the government.

With reference to the point made earlier, regarding how the real ownership of assets deserves greater attention than they are currently receiving, it is worth noting how the term 'community-based' is used descriptively without defining what it refers to. 'Community-based' could in this case either refer to the typology of the mini-grid (that it is an AC village mini-grid) or to the ownership structure (that it is community owned).

Policy Environment and Planned Mini-Grids

In terms of government support for mini-grids, all three countries are highlighting them as an important area of development.[77–79]

Tanzania

In the Scaling-up Renewable Energy Programme (SREP) investment plan for Tanzania,[77] it is anticipated 'that mini-grids will be developed mostly in areas where there are one or more anchor commercial clients and/or TANESCO (that can be the buyer/seller of bulk power in conjunction with the renewable energy generation supplying the mini-grid) able to justify the bulk of the generation investment' (Ref 77, p. 56). This expectation is reflected in the electrification targets, where 25 large mini-grids with a capacity of 1.8 MW each are planned.

In addition to the large mini-grids, 50 village-sized mini-grids are planned (ibid.). Furthermore, all eight SPP projects on isolated grids with either signed SPPA or LOI by 2013 were in the range between 300 kW and 7.5 MW.[77]

The Tanzania Energy Development and Access Project (TEDAP), which was launched by the REA in 2011 with funding from the World Bank, has an off-grid component with three subcomponents. First subcomponent is the small power producer program, which supports grid-connected renewable energy projects, grid-connected mini-grids and isolated mini-grids up to 10 MW. The second subcomponent is Stand-alone Renewable Energy Electrification (using SHS and solar institutional systems) under which falls the 'Sustainable Solar Market Package' (SSMP) model, which bundles institutional systems with household electrification services; and the Cluster model, where market aggregation is achieved by working with local associations such as coffee, cashew and tea smallholder associations. The third subcomponent is the 'Lighting Rural Tanzania' competition.[77]

On the regulation side, the current legal framework in Tanzania removes barriers for developers up to 10 MW.[35] The Ministry of Energy and Minerals (MEM) has established simplified procedures for private-sector investment in solar, wind, and micro-hydro projects, including a 100% depreciation allowance in the first year of operation.[80] Also, SPPs operating on an isolated mini-grid generating less than 1 MW are not required to apply for a license and wait for approval from the regulator: a simple registration with the regulator suffices. Furthermore, for very small power producers (VSPPs) with an installed capacity of 100 kW or less, there is no requirement for regulatory review or approval of proposed retail tariffs (ibid.). On that basis, Tenenbaum et al. argue that Tanzania has 'made more progress than any other African country in developing a comprehensive SPP regulatory system' (Ref 35, p. 22).

When it comes to private-sector engagement, two US-based multinational corporations are involved in developing grid-connected mini-grids in Tanzania. Symbion, in partnership with KMR Infrastructure, is developing a biomass project in Kigoma that will replace diesel-based power for an existing TANESCO mini-grid. The signed PPA is for 3.3 MW, and commissioning was scheduled for December 2014.[54] However, there are no accounts of the status of the project. The other company, called NextGens, is preparing a 5 MW power plant supplying power to 150,000 rural HH through a PPA with TANESCO in Kigoma District, Tanzania. Commissioning is scheduled for January 2015.[54] Similarly, there are no accounts of the current status of the project.

Uganda

Very little information is available about planned mini-grids in Uganda. The Rural Electrification Strategy Plan (RESP) from 2012 (covering 2013–2022) specifically prioritizes rural electrification through PV-powered mini-grids. However, the goal of reaching 140,000 additional off-grid installation service connections by 2022 includes both individual HH systems and mini-grids, and hence no specific targets are outlined for mini-grids.[78] Although initiatives to support mini-grid initiatives have been taken [World Bank's Energy for Rural Transformation (ERT) programme],[81] alongside the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) implemented by MEMD and GIZ,[82,83] no information is available about the nature of these systems.

In 2011, the rural electrification sector received a 13 million Euro grant from the Dutch ORIO Infrastructure Fund for the development, construction and operation of ten hydro mini-grids of up to 1.5 MW each.[84,85] The total capacity of the ten mini-grids is 6.2 MW, and some of the mini-grids will be connected to the main grid.[84] The project is still in the development phase (ibid.).

Kenya

In Kenya, the government's rural electrification master plan from 2008 focuses on the retrofitting of existing diesel-based decentralized power stations in the form of hybrid schemes with solar PV and wind, which, according to Gichungi,[86] is motivated by a wish to reduce operating costs. This refitting is being pursued through international donor support from the World Bank's Scaling-Up Renewable Energy Program (SREP), which aims to install 3 MW of (PV and wind) in hybrid with the existing diesel generators in 12 isolated grids with a total installed capacity of 11 MW.[79] In addition, currently 15 mini-grids in the range of between 334 and 840 kW are under construction, and 44 sites have been identified for installing hybrid mini-grids. These are in the range between 284 and 1.3 MW and have a total capacity of 17.8 MW. According to AHK, these mini-grids are being installed to add capacity in order to cover electricity demand in towns that have grown along with population and economic activities, and are hence not contributing additional rural electrification.[87] The UNEP lead program entitled 'Clean energy hybrid mini-grids in remote areas: an investment opportunity?' is seeking through demonstration projects to test and prove business models for replication.[37] The program focuses on systems with a capacity greater than 100 kW. The latest flagship publication from the Frankfurt School is focusing on refitting mini-grids with capacity sizes of 0.8–9.5 MW.[88]

DISCUSSION AND CONCLUSION

The review of current and planned mini-grid interventions in East Africa undertaken in this study shows that mini-grids have become a catch-all phrase with many meanings. The term mini-grid is used to cover a broad range of systems ranging from a few kW up to 10 MW, which masks the fact that the purpose of these systems varies. An overview of the combinations of ownership models and mini-grid types in East Africa identified in this study is provided in Figure 1.

Large mini-grids are implemented through utility ownership, hybrid ownership or private

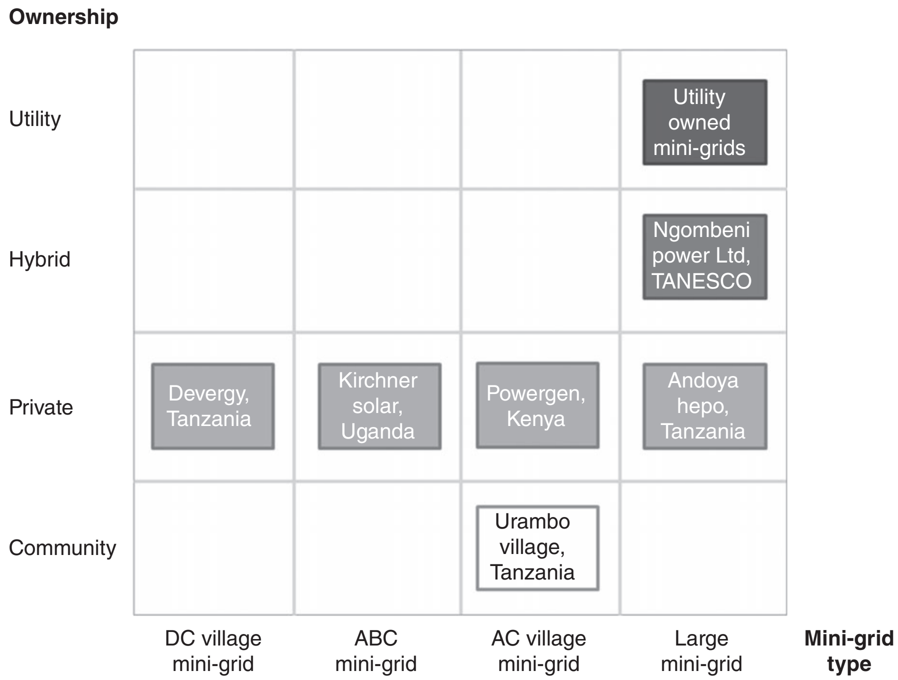

FIGURE 1 | Mini-grid types implemented through four ownership models. Source: author's own elaboration.

ownership models and are all characterized as supplying electricity to places with a large customer base and high levels of productive activity. As a means of increasing rural energy access, large mini-grids can therefore be discarded, as they do not supply electricity to remote rural populations. The particular mini-grids appropriate for the purpose of rural electrification are AC village mini-grids, whether privately owned or community owned, as well as ABC mini-grids and DC village mini-grids.

When analyzing government and donor initiatives through the framework presented in *Mini-Grid Types* section, it becomes clear that, although village-size mini-grids have a place in rural electrification targets and plans, large mini-grids feeding into either the national grid or existing utility-driven mini-grids are given a high priority by governments and donors.

In Tanzania, in both the SREP and the TEDAP programs, most initiatives are targeting large mini-grids. Specific programs, targeted at what in this article are called village-sized mini-grids, are limited to the 'Sustainable Solar Market Package,' the Cluster Model, and the 'Lighting Rural Tanzania' competition.

In Kenya, the government and donor support to large mini-grids is even more prominent than in Tanzania. All fifteen mini-grids under construction are large mini-grids, as are eight out of ten existing mini-grids where hybridization is being proposed. Furthermore, the 44 sites identified for future development lie in the capacity range of 179 kW to 1.3 MW, with the majority of systems >300 kW. Kenya, through its portfolio of mini-grids, is specifically working toward expanding mini-grid systems in towns where demand is growing due to population growth and increasing productive activities.[87]

In Uganda, although information is sparse, Bena[89] stresses that mini-grids are being targeted at areas that are far from the grid but have concentrated loads, such as trading centers and islands communities. Also, at least five of six government-owned mini-grids are larger than 300 kW (ibid).

Although large mini-grids can be expected to contribute with additional connections and hence increase electricity access, these new connections will be in towns and not in rural areas. Large mini-grids represent a very different business case compared to village sized mini-grids, with better investment opportunities being secured due to the predictable cash flows made possible with high demand and predictable consumption patterns, and with operations resembling utility operations in respect of technical operation, management structures, financing requirements, and bankability.

The literature review carried out in this paper and the discussion above show that, although the term 'mini-grid' covers a variety of systems in terms of technical features and organizational models, no specific language is available to differentiate between these systems in a systematic manner. This lack of terminology may present a barrier to increasing our understanding of the challenges to scaling up rural energy access through various organizational models as well as to creating appropriate policy measures. The framework developed in this paper might be useful in overcoming these barriers.

Based on the discussion above, we can also conclude that in East Africa there is currently a contradiction between the discourse that proposes mini-grids as a solution for delivering rural energy access and current country-level activities prioritizing large-scale mini-grids delivering power to large towns. The notion of the mini-grid has become what David Mosse has called a mobilizing metaphor.[90] It is an inclusive notion, which, due to its blurred definition and positive connotations regarding rural electrification, is used to mobilize funding to provide green electricity to larger towns.

Status and Current Trends for Mini-Grids for Rural Electrification

Community-owned AC village mini-grids, and to some extent privately owned AC village mini-grids, have in the past been the only types of mini-grids implemented for rural electrification. Community-owned AC village mini-grids have been and still are implemented through donor funding by NGOs and universities. However, when looking across the three mini-grid types appropriate for rural electrification, a trend toward increased private-sector involvement is emerging, with DC village mini-grids being the least prominent of the three. Only one privately owned DC village mini-grid has been identified in this study. Although this appears to suggest this type of mini-grid to be of lesser importance it would be premature to reject the potential of this solution. DC village mini-grids do not support productive uses. However, they do represent an important effort to provide power for low load services such as lighting and mobile phone charging which are the primary demands in large parts of rural Sub-Saharan Africa.[91] It is a solution that, in load potential, is comparable to SHSs and could therefore be seen as an appropriate transitionary solution in areas where local demand does not include productive loads.

The ABC mini-grid as a means to increase rural energy access is a relatively new phenomenon in Africa. Although delivering electricity to rural populations is part of the business model, the primary target end-users for the ABC mini-grid are anchor clients. The rationale behind the business model of ABC mini-grids is to ensure steady revenues from an anchor client, whereas providing energy access to those living near the anchor client is a secondary priority. ABC mini-grids with telecom towers as anchor customers have, according to Hankins et al., great potential in increasing energy access in rural communities.[92] However, the impact with regard to rural energy access will depend on how the company implementing ABC mini-grids sets priorities between the (C)ommunity, the (A)nchor customer and the local (B)usinesses.

Especially in Kenya, a growing private sector is delivering AC village mini-grid solutions. This currently emerging private sector is dominated by start-up small and medium-size enterprises (SMEs) with a core business consisting in delivering rural energy access through business models that are highly reliant on ICT and smart technologies. This is a diverse group of companies, but common features include the fact that they are mission-driven, that rural energy access is their core business and that they are implementing AC village mini-grids. Furthermore, their goal is to deliver rural energy access at scale rather than on a project basis. They are developing business models with the purpose of scaling up in order to deliver electricity to a large quantity of consumers through many smaller mini-grids.

This trend toward increased private-sector involvement follows a general trend identified by Hansen et al. that is specific to the solar PV market in East Africa.[38] Although private-sector involvement is growing, there are no signs of a reduction in NGO- and donor-driven community-owned mini-grids. As Hansen et al. also stress, in the past donor-driven initiatives in the SHS market in Kenya have played an important role through experimentation and piloting, which contributed to maturing the private sector.[38] Donor-driven community-owned mini-grids could serve the same purpose of delivering knowledge and market information and hence contribute to maturing the private market.

Future Research Suggestions

The fact that village-size mini-grids are particularly appropriate in the context of rural electrification, combined with the general expectation of private-sector involvement in driving the up-scaling of rural electrification, make privately owned AC village mini-grids a fruitful avenue for further investigation. One area for future research would therefore be empirically based analyses of concrete business models that pursue the dual objective of creating a social impact through the delivery of electricity and making a profit. A number of such private companies are developing AC village mini-grids in Kenya. However, very little is known about the performance of these private business models. Currently, private-sector implementation of village-size mini-grids is at an early stage, and business models are still in the piloting phase. No private company has so far been able to scale up its operations. It is therefore unknown whether these private business models will be able to contribute to increasing rural energy access figures on a larger scale. This situation leaves policy makers in a void with respect to research-based policy recommendation.

Against this background, it appears timely and appropriate to address the challenges of diffusion of private-sector business models for rural electrification at three different levels.

At the society social level, the diffusion of privately owned mini-grids could be analyzed from an innovation system perspective, according to which the privately owned mini-grid is seen as a sociotechnical innovation. One option in this regard would be to apply the multilevel perspective (MLP) as developed by Geels.[93] This perspective would permit a focus on the wider framework conditions for creating a viable niche for private-sector mini-grids while at the same time being sensitive to the role of networks and learning across multiple actors in the mini-grid sector. Also, by conceptualizing private mini-grid developers as a new niche, insights could be revealed about the processes through which private companies are acting as niche builders and possibly about how this knowledge could be used to support such processes elsewhere.

At the private company level, it is expected that companies will enter the market for rural electrification through for-profit business models, but there is also reason to believe that privately owned AC village mini-grids will be implemented by highly mission-driven companies who seek to balance social and economic value creation in developing and managing their business models. Insights into how this dual mission is balanced and managed are essential for the practical results on the ground, not least for the long-term sustainability of the business models. Insight into these issues can be gained by drawing on perspectives from the social entrepreneurship literature.[94]

At the village level, rural electrification interventions are not inserted into a void, but rather encounter a complex social reality.[95] It might therefore be a fruitful avenue to analyze private-sector interventions in rural villages through the perspective of the actor-oriented approach,[96,97] which allows the processes and dynamics at the interface between the private company and the recipients of electricity to be captured. Through this perspective, an intervention is viewed as an ongoing, socially constructed and negotiated process, and not simply as the execution of an already specified plan of action with controllable outcomes.[96] This perspective could thus reveal insights about the role of existing structures, interests and conflicts in the arena where the electrification system is situated and provide explanations for the resulting challenges for the company.

NOTE

[a] Promoted in partnership with the Netherlands Ministry of Foreign Affairs, the use of green power such as solar and wind at mobile network towers in remote, rural areas around the world.

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Article 3

System building in the Kenyan rural electrification regime: the case of private mini-grid development

Mathilde Brix Pedersen and Ivan Nygaard
UNEP DTU Partnership, DTU Management Engineering, UN City, Marmorvej 51, 2100 Copenhagen, Denmark,
brix@dtu.dk, +45 45335326

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Abstract

Given the growing interest in how the private sector can contribute to the goal of providing universal access to energy in developing countries, this study sets out to investigate the practices and strategies of private actors in the emerging niche of rural mini-grid development in Kenya. The paper raises a number of questions about the stability and sustainability of the current niche. It argues that, although instabilities can be identified within what is a relatively stable regime, it is too early to predict to what extent the current niche will be able to fundamentally challenge the regime and change the way of 'doing' rural electrification in Kenya. The paper's main analytical focus is how niche actors are influencing and creating change in the incumbent rural electrification regime of grid extension to strengthen and expand the niche for private mini-grids. The analysis shows that, in addition to internal niche processes like alignment of expectations, learning and network building, niche actors actively engage in various forms of institutional work. The greatest emphasis here is on regulatory institutional work such as advocacy and ruling in order to influence the legal and economic frameworks, but niche actors also engage in cognitive institutional work to enhance acceptance of the niche technology by constructing a shared world view between niche and regime actors. Interestingly, niche actors also engage in normative work to establish positive normative associations with the private-sector model, like equity and social justice. The research concludes that institutional work in this case is collective work drawing on different mandates and relying on different skills and resources. Overall the study provides insights into the practised work of system builders to create change, and contributes to the ongoing effort to conceptualise agency within the framework of transitions theory.

Keywords: institutional work; mini-grid niche; rural electrification regime; system building; Kenya

1. Introduction

As part of the current international push to eliminate energy poverty, decentralised options like mini-grids have become established as a crucial part of the effort to achieve universal access to modern energy services by 2030 (IEA, 2011; Wiemann and Lecoque, 2015). Mini-grids are highlighted as the missing link between large-scale national grid extensions and small-scale solutions like solar home systems and lanterns, being estimated to deliver forty percent of the new capacity needed to meet the goal of universal access (IEA 2011). Rural electrification has traditionally been a matter for state bodies. However, local government bodies and international actors are increasingly stressing the importance of private-sector involvement if the goal of universal access by 2030 is to be met (Bardouille and Muench, 2014; SE4ALL, 2012).

Mini-grid development has a long history in Sub-Saharan Africa. In Kenya, this means primarily diesel-driven systems set up by the government to connect rural market centres and towns far from the existing grid, as well as donor-driven, historically hydro-based projects introduced by NGOs, research institutions and faith-based organisations to connect selected communities (Pedersen, 2016). More recently, the technological focus has shifted toward solar-powered systems due to technological advances, price falls (Hansen et al., 2015; IRENA, 2016) and new mobile payment and monitoring solutions (Glemarec, 2012). However, the new aspect in this sector is the emergence of firms established with the single purpose of delivering power to rural communities through highly technologically advanced solutions using private business models. While village-based donor-driven mini-grids have been relatively well researched (Ahlborg and Sjöstedt, 2015; Ilskog et al., 2005; Ulsrud et al., 2015), knowledge of private-sector involvement in mini-grid development in Sub-Saharan Africa is limited. Although research is emerging on the barriers to attracting private-sector involvement in rural electrification (Schmidt et al., 2013; Williams et al., 2015), sector-wide empirical investigations into firm-level processes of technology diffusion are lacking.

Despite establishing a Rural Electrification Authority in 2006, rural electrification in Kenya has been slow, and only a few donor-initiated community mini-grids have been established since 2006. More recently, however, a number of private firms have started operating solar-powered, village-sized mini-grids in rural areas. These firms resemble each other in being small, start-up enterprises founded by expatriate engineers and business people with a core business of delivering power through mini-grid systems to rural consumers. The emergence of this niche of privately owned firms is starting to challenge established ways of planning, regulating and 'doing' rural electrification in Kenya, what we here call the 'rural electrification regime'. The aim of this study is therefore to explore the practices and strategies of these private firms, showing how they 'do business' and how, through their actions and practices, they engage in influencing the existing regime in order to diffuse their innovation and strengthen the niche of private mini-grid development.

The structure of the remainder of this paper is as follows. Section 2 presents an integrated analytical framework based on the multilevel perspective (MLP) and the concept of institutional work. Section 3 outlines the research methods that underpin the study. Section 4 presents the rural electrification regime and examines the semi-coherence and inherent conflicts in the regime. Section 5 presents empirical findings showing how system building takes place in the niche, while Section 6 discusses how the four niche actors are conducting institutional work and deploying different strategies and using different skills to influence institutional settings at the regime level so as to create change in the system. Section 7 concludes the paper.

2. System building as institutional entrepreneurship

The multilevel perspective (MLP) (Geels, 2002; Rip and Kemp, 1998) focuses on how transitions towards sustainability take place following complex, interacting processes at the three levels of landscape, regime and niche. In this paper, MLP provides a framework for exploring the processes at work in the Kenyan rural electrification regime and mini-grid niche. The MLP emphasises that the alignment of processes at these multiple levels is important for understanding transitions (Geels, 2005) and that "both niche processes [...] and changes in the incumbent regime are necessary for understanding the innovation journey of a new technology" (Raven 2006: 581). According to Raven (2006), the greatest prospect for niche expansion and up-scaling is when stability in the niche increases in combination with a situation of relative instability in the regime.

Following (Geels, 2004) and Fuenfschilling & Truffer (2014), this study adopts an institutional perspective to explore change where stability and hence structuration at the different levels of the MLP are conceptualised as different levels of institutionalisation, with the strongest institutionalisation taking place at the landscape and regime levels and the weakest at the niche level. Scott (1995: 33), defines institutions as "cognitive, normative and regulative structures and activities that provide stability and meaning to social behaviour". The process of institutionalisation can therefore be viewed as a process of gaining legitimacy for new norms, rules and practices.

Against this background, the current study takes a special interest in understanding i) the interplay between the niche level and the regime level and ii) the role of agency in the processes of increasing institutionalisation of the niche.

In order to zoom in on the processes of agency involved, the study looks at the strategies pursued by system builders, here understood as key actors (individuals or institutions) who play a role in building functioning niches by undertaking specific activities that contribute to the strengthening of innovation systems around those technologies (Byrne et al., 2014; Ockwell and Byrne, 2015). By drawing on the literature on institutional entrepreneurship (DiMaggio, 1988), especially the concept of 'institutional work' (Lawrence and Suddaby, 2006), the study explores how and through what forms of institutional work actors seek to influence the system in which they are embedded. The concept of institutional work provides an analytical tool with which to explore "the purposive action of individuals and organizations aimed at creating, maintaining and disrupting institutions" (Lawrence & Suddaby 2006: 215). It highlights the effortful and skilful practices of interested actors and is therefore useful in exploring how actors, through practice, institutionalise the niche.

In Kenya, the private mini-grid niche consists of a small number of private firms that are experimenting with a new socio-technical configuration characterised by high-tech, ICT-based technologies, demonstrations of commercial viability, including cost-recovery tariffs, in-house technological development, private ownership and strong international partnerships and networks. This niche is emerging within an incumbent rural electrification regime which historically has been dominated by national-led grid extensions. The niche is in its formative phase, where it is characterised by its instability and fragility (Geels, 2005) and its lack of a proper institutional set-up (Kebede et al., 2014). According to the MLP, a niche's viability is influenced by internal niche processes related to the shaping and alignment of expectations, learning and network-building (Schot and Geels, 2008). In addition to these internal niche processes, this study highlights the defining characteristic of niches as being weakly institutionalised spaces where practices, norms, values and routines are competing for legitimacy and where they are not (yet) being mutually constructed by actors in the system (Fuenfschilling and Truffer, 2014). Thus the viability of a niche is contingent on the increased institutionalisation of cognitive, normative and regulative structures and activities at the niche and regime levels in support of the niche.

In section 4, the regime will be accounted for in terms of both historical stability and current de-stabilising factors. Based on the ontology of institutionalism, tensions, conflicts and struggles within the regime are given prominence as a way to account for the semi-coherence of the regime. Conflicts and tensions can help expose the instabilities of a regime in which old ways of doing things are being challenged by new actors in the space, thus pointing to areas where institutionalisation is happening and being negotiated and where change is in the making (Fuenfschilling and Truffer, 2014).

In this study, institutional work describes the manner in which private mini-grid developers work to influence their institutional contexts through strategies such as lobbying for regulatory change. As a new organisational model in Kenya, the fully private mini-grid model represents a range of novel ways of doing things (e.g. in the form of charging cost-recovery tariffs) and hence a range of weakly institutionalised practices and norms. Institutional work aimed at *creating new institutions* (Lawrence & Suddaby 2006) in the sense of winning backing for new norms, practices and rules is therefore of particular interest in order to understand how niche-level actors are working to influence existing institutional settings at the regime level. Lawrence & Suddaby (2006) compiled a review of this type of institutional work which includes nine forms of work presented in Table 1. Three are related to the regulatory pillar of institutions (Scott, 1995), namely *advocacy*, *defining* and *vesting*, three to the normative pillar, namely c*onstructing identities*, *changing normative associations* and *constructing normative networks*, and three to the cognitive-cultural pillar of institutions, namely *mimicry, theorising* and *educating* (Lawrence and Suddaby, 2006; Perkmann and Spicer, 2008). The analysis identified four ways in which niche actors sought to influence the regime level directly, namely through advocacy, defining, mimicry and changing normative associations.

Table 1. Institutional work aimed at creating institutions

Forms of institutional work	Definition
Advocacy	The mobilization of political and regulatory support through direct and deliberate techniques of social suasion
Defining	The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field
Vesting	The creation of rule structures that confer property rights
Constructing identities	Defining the relationship between an actor and the field in which that actor operates
Changing normative associations	Re-making the connections between sets of practices and the moral and cultural foundations for those practices
Constructing normative networks	Construction of inter-organizational connections through which practices become normatively sanctioned and which form the relevant peer group with respect to compliance, monitoring and evaluation
Mimicry	Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption
Theorizing	The development and specification of abstract categories and the elaboration of chains of cause and effect
Educating	The educating of actors in skills and knowledge necessary to support the new institution

Source: Lawrence & Suddaby (2006)

3. Methods

The study is based on qualitative data, drawn mainly from 24 in-depth interviews. Data was gathered during a period of two months from July to September 2015. Twelve interviews were conducted with staff from four mini-grid firms, four with key informants with knowledge about the firms and the sector in general, and eight with regime actors, including representatives of the Energy Regulatory Commission (ERC), Kenya Power (KPLC), the Rural Electrification Authority (REA) and the Ministry of Energy and Petroleum (MoEP). According to agreement with case firms, they have been anonymised and references to interviews are numbered according to internal list of interviewees.

Case selection was based on definition and context (Miles & Huberman, 1994), with the four firms selected due to their characteristics of being well-established private mini-grid developers operating in Kenya. Interviews lasted for between thirty minutes and two hours and were recorded and transcribed. Additional data include observations at mini-grid sites and interviews with customers and their non-connected neighbours during four site visits documented through field notes. Lastly, the study draws upon secondary data in the form of reports, popular media articles and firms' internet websites. Transcripts, notes and documents were subjected to a qualitative thematic analysis (Braun and Clarke, 2006). Data were coded for emerging patterns and themes in three analytical steps. First, the unique patterns of each firm and differences and similarities between firms were analysed by combining in-firm analysis with a search for cross-firm patterns (Eisenhardt, 1989). Secondly, 'issues' regarding private mini-grid development which have not yet been settled within the incumbent regime of grid extension were identified in order to expose instabilities in the regime. Finally, pre-established codes corresponding to the nine forms of institutional work listed in Table 1 were applied to the data to analyse how firms and firm-actors were conducting institutional work.

4. The rural electrification regime in Kenya

This section describes the Kenyan rural electrification regime, followed by an elaboration of the areas of conflict and tension within the regime.

Since the establishment of the rural electrification programme in 1973, rural electrification in Kenya has been guided by general priority given to the industrial and productive sectors (Byrne, 2009). The cost of grid expansion to rural areas has been considered prohibitively high, and demand for energy in rural areas has been considered too low to be financially viable (Lee et al., 2016). Rural electrification has been driven by public funding that is highly reliant on foreign aid – especially from USAID, the US development agency. Despite a reorientation towards targeting the poor, particularly the rural poor, more effectively through its 'New Directions' policy in the 1970s (Byrne, 2009), rural electrification rates remained low in the following decades, still below four percent by 2003 (AEI, 2012).

With the de-regulation and unbundling of the energy sector in the 1990s, in which a framework was set out for opening up the sector to the private sector, and the further restructuring in 2006, with the establishment of a Rural Electrification Authority (REA), the government stated its intention to prioritise rural electrification. However, REA's mandate was limited to the electrification of public facilities like trading centres, secondary schools and health centres, which left surrounding households unconnected. Thus, although REA's work has led to an increase in electrification by raising the connectivity rates of public facilities from 25% in 2008 to about 68% in 2016 (REA, 2016), overall rural connectivity rates remain low. While national electricity rates rose from 9% in 2003 to 20% in 2013, rural electrification rates remained low at 7% in 2013 (IEA). Likewise, the stock-listing of KPLC in 2006 further solidified its role as a company accountable to its investors, leading to a continued and increased focus on urban industrial customers (Kapika and Eberhard, 2013).

4.1 Instabilities in the regime

Around 2011 windows of opportunity start materialising. A de-alignment (Geels, 2005) of the regime can be identified in the following years, supporting the emergence of a private mini-grid niche. The following landscape forces promoting this de-alignment have been identified: i) UN declaring the year 2012 the 'international year of sustainable energy for all' and the following push for a global agenda to end energy poverty by 2030 led by the SE4ALL initiative, with mini-grids highlighted as an important solution; ii) increased ICT penetration with 72% of the population living outside Nairobi below the poverty line using mobile banking in 2011 compared to less than 20% in 2008 (Suri and Jack, 2012); iii) the general fall in solar PV prices and the increase in the quality of renewable energy technologies leading to solar PV module prices falling by around 80% between 2009 and 2015 (IRENA, 2016); and iv) an increasing focus, driven by climate change, on green and fossil-free investments from the private sector (Climate Change Support Team, 2015; World Economic Forum, 2013).

Following de-regulation and the entry of new private mini-grid developers into the market, the de facto monopoly of KPLC was broken in 2015 when two mini-grid firms were granted licences by ERC to distribute and sell power directly to customers. KPLC's main focus on industrial users and grid extension persists. However, their recently announced flagship Last Mile Connectivity project, which is supported by the African Development Bank and the World Bank, is in essence a push towards increasing connectivity rates, also among low-consumption households, by offering highly subsidised connection fees to people living within 600 meters of existing transformer stations. This project is mandated to raise national connectivity rates to 70% by 2017 (KPLC, 2015). REA continues to focus on market centres, schools and health clinics; however their main method of extending power lines to rural areas has recently been diversified to include village-sized mini-grids to electrify rural areas and the second phase of the rural electrification programme also includes connecting households. Lastly, donors and development partners like the UK Department for International Development (DfID), the International Finance Corporation (IFC), the German Development Bank (KfW), the United States Agency for International Development (USAID) and the UN Environmental Programme (UNEP), have entered the mini-grid space with a range of initiatives supporting both REA and the private sector in disseminating mini-grids.

There are conflicting views among regime actors (regulators, policy-makers, rural electrification authorities and the national utility) whether mini-grid developers are regarded in a positive light as contributors to the goal of universal access, or as unwelcome actors that constitute a challenge to the regime. As one mini-grid developer expressed it, there is a great push, at a political level, towards the goal of universal access, and therefore *"anything that works towards that [goal] has got political support"*[i]. Also, there is an appreciation of the need for private-sector financing to achieve the goal of universal access. As an independent regulator, ERC views the entry of new actors into the market as *"a win-win development for Kenya that will allow more people to access electricity and make the industry more competitive"* (Waruru, 2015). However, although ERC is an independent authority in regulating the market, it is dependent on clear policy frameworks from the Ministry (MoEP) in order to make cases that create precedents regarding regulatory issues. And, however positive it may be regarding the overall idea of bringing private players into the sector, the MoEP is reluctant to come to any hasty conclusions in formulating policy regarding mini-grids. KPLC, as a parastatal company relying traditionally on its monopoly, shows little interest in supporting new players entering the field. In interviews we uncovered resistance to change based on i) the normative assumption that grid power is superior to decentralised options, ii) practises of costly investments in repairing and upgrading the existing network, and iii) the inherent inertia (based on practices, norms and rules) of a parastatal company with a staff of seven thousand. KPLC sees its traditional position together with REA as an established and non-challengeable way of delivering cheap (per kWh) power through grid extension.

In addition to the overall political tensions within the regime described above, the following legal and economic issues have been identified with regard to the co-existence of regime and niche: i) licencing, ii) grid-integration, iii) tariffs, iv) connection fees, v) connecting all vs. connecting some and vi) subsidies which will be described below.

License

Since the unbundling of the power sector, KPLC's monopoly has been maintained through practice and the absence of regulation because of it being the only player in the market. However, the entry of new players into the market in 2015 has exposed a lack of clarity in the current legal framework regarding how multiple players are to co-exist in the market. In reminiscence of its position as a distribution and retail monopoly, KPLC holds a licence to distribute power to the whole of Kenya. Although a mini-grid developer should acquire a licence for a restricted area, it will not be granted exclusive rights to that area. KPLC still retains the right to construct facilities within the same area, regardless of any licences that may be given to other utilities.

Grid-integration

Furthermore, the entry of new players has exposed a lack of clarity on economic and legal issues with regard to a situation in which the national grid is extended to an area already served by a mini-grid. Currently there is no standardised way of dealing with this scenario. A feed-in tariff (FIT) policy for solar PV has been in place since 2010 (MoEP, 2012). However, the policy caters for MW-sized projects, with a FIT of 0.12 US $/ kWh, which is not attractive to developers of village-sized mini-grids.

Tariffs

The universal tariff of approximately 20 US cents per kWh (ERC, 2013) for domestic users represents a highly institutionalised norm and practice in the current regime, in which price per kWh is viewed as a measure of equity. The saying, *"we are all Kenyans"* is used by regime actors to illustrate the point that rural and urban consumers should pay the same for electricity[ii]. The tariffs currently charged by private mini-grid operators of 80 US cents to 5 US dollars per kWh form a stark contrast to the universal tariff. This makes it a difficult balancing act, from a political point of view, to include private actors while maintaining an equitable tariff system. The tariffs charged by niche actors are currently being accepted by the ERC due to the pilot status of the projects. However, a lack of clarity over policy means that nobody, so far, has received approval of their tariffs through the ERC.

Connection fees

Connection fees, as opposed to tariffs, are not regulated by the ERC. KPLC has traditionally followed a practice of charging connection fees that reflect the actual costs of connection. Prior to Maj 2015, when connection fees were reduced to 15,000 KES (173 USD) [1] under the Last Mile Programme (Mulwa, 2015), the average connection fee in Kenya was 35,000 KES (404 USD), with connection fees in rural areas ranging from between

[1] Conversion rate as of 1 May 2015: 100 KES =1.16 USD

17,400 KES (201 USD) to 46,400 KES (536 USD) (Njuguna, 2012). These fees have been prohibitively high for many low-income households to become connected the national grid.

Connecting all vs. connecting some
The issue of accessibility versus affordability is a well-documented problem of KPLC's approach (Lee et al., 2016), meaning that large populations are living in close proximity to the national grid lines without having the financial means to become connected. KPLC and REA follow a model in which only those who can afford the high connection fees within an electrified town or village are connected. The new mini-grid models with connection fees of ten dollars are introducing alternative practises into the system, including models that actively seek to connect everyone within a specific targeted area.

Subsidies
A last economic aspect representing a conflict within the regime with regard to co-existence with the niche is the issue of subsidies. Rural electrification, whether through KPLC programmes or through REA programmes that are handed over to KPLC for operation and management after completion, are effectively subsidised by the government and international donors. Thus the claim that 'we are all Kenyans' is used by niche actors to argue that, in order to deliver electricity at a universal tariff, they should have the same access to government subsidies as KPLC.[2]

5. The Kenyan mini-grid niche

This section provides an overview of the mini-grid niche in Kenya and describes how the four firms that represent the private mini-grid niche in this study conduct system building.

The private mini-grid niche emerged in Kenya in around 2011, when the first private mini-grid firm was established, followed by three other firms in the following years. The four firms resemble each other in experimenting with solar-powered, village-sized mini-grids with battery storage for 24/7 service in rural parts of Kenya. Three of the firms are conventional start-ups, while the fourth was started by an international development corporation with the aim of piloting a for-profit business model. The firms have taken different development paths and are experimenting with different business models, system sizes, types of partnerships, types of research and development, types of targeted communities etc. Their mini-grids are between 1.4 and 50 kWp in size, with the three conventional start-ups experimenting with tier 2-power[3] at levels between 50 and 90 watt per household, and the development corporation firm experimenting with higher tiers.

[2] In India, the state government of Uttar Pradesh launched in 2016 a mini-grid policy in which the government provides a 30% CAPEX subsidy for projects based on a ten-year 'build own operate and manage contract' with restrictions on tariffs of a monthly charge to customers of 1.8 USD (up to 100-watt load for a minimum 8 hours per day). 120 INR/month. (Government of Uttar Pradesh, 2016) Exchange rate as of 29 September 2016: 100INR=1.5USD.

[3] Tier 0: no capacity, tier 1: very low capacity (minimum daily supply capacity: 5 watts, 20 watt-hours), tier 2: low capacity (70 watts, 275 watt-hours), tier 3: medium capacity (200 watts, 1kWh), tier 4: high capacity (800 watts, 3.4 kWh), tier 5: high capacity (2000 watts, 8.2kWh) (IEA and World Bank, 2015).

The private mini-grid niche differs from what could be termed a donor mini-grid niche in which socio-technical configurations are characterised by intermediate or appropriate technologies, donor-financing, demonstration of service delivery and affordability, in-house capacity in achieving rural development and poverty reduction, single project approaches, communal ownership forms, and a focus on local partnerships. There is little if any competition between the private and donor niches. The private mini-grid niche is to a greater extent competing with what could be termed a solar home-system (SHS) niche. The SHS niche somewhat resembles the private mini-grid niche by being driven by socially motivated entrepreneurs, who are developing business models based on state-of-the-art technology to serve an under-served market while pursuing a profit. Although interesting, these niches will not be considered here. The key characteristics of the four firms selected for this study are listed in Table 2 below.

Table 2. Key Characteristics of four Kenyan private mini-grid firms

	Ownership structure	Key focus	Business model characteristics	Up-scaling strategy
Alpha Beta	Private	Specialising as a contractor and supplier for other firms	Revenue-driven model Low connection fee. Connecting only households consuming the greatest amounts of energy. Tariff: 1.8-5 UDS/kWh CapEx payback time: 7-10 years	One project at a time, depending on inflow of funding
Gamma	Private	Project and business development (vertically integrated)	Equity-driven model Low connection fee Connecting as many as possible within an area Tariff: 3-5 USD /kWh CapEx payback time: 15 years	Roll-out of 100 sites in the pipeline
Delta	In trust	Generating knowledge about the private-sector model	Donor-driven model Low connection fee Connecting those who are interested Tariff: 70-100 KES (0.8-1.2 USD)/kWh CapEx payback time: 9 years	No intention to upscale

5.1 Alpha and Beta

Alpha and Beta were both started by expatriate engineers in 2011 and 2012 respectively. Alpha started its business focusing on wind power and the local manufacture of small turbines (200W to 1 kW) in a factory in Nairobi. In 2013 it changed its focus to develop solar PV mini-grids and has established a solar PV mini-grid production facility in Nairobi employing approximately twenty staff. Alpha currently owns twelve mini-grids and has installed more than eighteen in Kenya and Tanzania for others (including Beta below). Beta was started in 2012 with a core business to develop mini-grids from initiation to completion. As part of its experimentation, it developed a monitoring and metering system because of the lack of such a system in the market. This research and development process took approximately two years and included experimentation with its own mini-grids. This technology has since become Beta’s core business. Currently, Beta owns two mini-grids and supplies technology through its monitoring and metering system to around thirty mini-grids (including those installed by Alpha). The implementation approach that characterises both firms is to supply tier 2 power (approximately 90 watt per user and less than 250 watt hours per day) to the most highly energy-consuming segment of rural market towns. Their criteria for choosing which households to connect include a minimum threshold of energy consumption. Their mini-grids are between 1.4 and 6 kWp in size, with a tariff of 1.8-5 US per kWh depending on site and calculated to be 20-50% lower than users' existing spending on alternative fuels. Although, at the outset, the aim of the two firms was to attract funding for their own mini-grid developments, the strategy has since slightly changed for both firms.

Acting as contractors, suppliers and service-providers for clients who have access to capital, rather than raising their own capital, has secured them a revenue stream which in turn has allowed them to expand their business. This business strategy, which is to some extent conditioned by the barrier to scale up funding for their own mini-grid portfolios, has led them to pursue a role as facilitators for the mini-grid sector at large. As highlighted by a representative of Beta, they are interested in opening up the mini-grid sector as widely as possible and in shedding light on aspects of mini-grid development which outside investors and other interested developers know little about[iii]. They see their own success as dependent on attracting developers and investors into this space while at the same time remaining the main technology provider. Both Beta and Alpha thus see themselves as firms that can enable the sector to grow, can create an impact and can contribute to expanding the mini-grid niche by providing critical tools for others in the market.

Practised business model

Alpha and Beta are deliberately avoiding the time-consuming and bureaucratic process of obtaining licences and negotiating tariffs with ERC etc. Instead they have established a verbal agreement with ERC that they can run their projects as pilot projects and thereby avoid these bureaucratic processes. Rather than spending time on negotiating with regime actors, they focus their time on improving operations and services to put themselves in a position to be a first choice for potential investors.

Alpha and Beta have developed what Beta refers to as a "*symbiotic partnership"* in which Beta is using Alpha as a contractor in projects led by Beta, and Alpha is using Beta as supplier in projects led by Alpha[iv]. They have thus developed core businesses that supplement each other and can collaborate in bringing funding into the sector. They also use each other's skills, and exchange data and learning across the firms. This close partnership is reinforced by personal friendships across the two firms. Alpha highlighted how, if they experience problems during testing of their mini-grids, they can just pick up the phone and obtain instant answers or guidance on how to resolve the problem from staff at Beta[v]. Their opportunistic approach to network- and partnership building, where they view quantity and diversity of partners as a strength, can help grow the niche both locally in Kenya and internationally. The larger a client base they can establish, the better business they can generate. They have each developed a broad and to some extent interlinked network of partnerships and client relationships, including universities, NGOs, donors, angel investors and corporate investors, as well as regime actors.

According to Alpha, strong international connections, primarily with countries of its founders' origin, are crucial in building these strategic partnerships. Partnerships are built and maintained by the firms’ directors, who travel abroad regularly and for long periods of time to raise funding and awareness and establish new partnerships.

As part of their strategy to nurture a broad collaborating network of actors within Kenya and from abroad, they are also pursuing working relationships with regime actors. Alpha and Beta have concrete plans to enter into a collaborative relationship with KPLC, Alpha as a contractor and Beta as a supplier of technology. In their efforts to stay on good terms with KPLC, the firms have chosen a cautious approach, operating in remote locations far from existing grid lines. Although having eight hours of travel time to sites makes their operations more expensive, this strategy was adopted to mitigate risks in regards to KPLC by refraining from approaching sites of potential conflict with KPLC.

Beta, in particular, is focusing on generating data and knowledge to support its business. Beta has two strategies: i) doing research to increase general knowledge about the private mini-grid model in the network; and ii) developing a business asset consisting of a world-class database. Through university and research grant funding and angel investor funding for research activities, Beta generates knowledge and data on the private mini-grid model. In Beta's view, commercial investors will not invest in these experimental projects unless someone has documented the business model and established credible and robust evidence for investors to base decisions on. This goes hand in hand with their aim to open up the sector to as many actors as possible. Beta is, for example, working on a research paper with an angel investor based on data collected from their installed mini-grids with the aim of generating key success indicators for mini-grids which they can use in their work advising new investors in the field.

Through their metering and monitoring product, Beta is generating data from its pilot projects, which are analysed in order for the results to be shared with or sold to other interested developers and investors. Beta is working to build up a full range of data representing different types of business cases so as to be able to cater for future potential investors with varying objectives ranging from social impact to purely commercial objectives. This database has already become an asset for Beta, as it is being approached spontaneously by investors who are interested in developing mini-grids but who lack experience of and specific knowledge about the market. This approach represents an ad hoc business development strategy where each new project is unique and where a business is built up from project to project based on the practical requirements of investors.

5.2 Gamma

Gamma was started in 2011. Since then it has been successful in attracting commercial capital through various funding rounds, including seed, venture and equity capital. Its access to large-scale funding has allowed it to set a long-term vision based on a three-phase scaling-up strategy. Phase one included experimentation with and the testing of its model in four pilot sites of varying sizes (1.4, 10, 20 and 50 kWp). Phase two, which is currently being implemented, includes experimenting with the roll out of a standardised yet locally adapted mini-grid to a hundred sites in the country. This activity will lay the basis for phase three, which is a further expansion of its activities both in the region and globally. Access to large-scale financing has further allowed it to attract senior staff with valuable knowledge about the Kenyan energy sector. In addition, Gamma's business model differs from that of Alpha, Beta and Delta by being vertically integrated with integrated R&D functions involving software and hardware solutions, financing, project development, and operations and management. Like Beta, Gamma has developed a proprietary metering and monitoring solution which is at the core of its mini-grid system.

Practised business model

Gamma's model is to connect as many households as possible within its targeted operating areas. Its connection fee of 2500 KES (29 USD) includes a start-up package with light bulbs. There is an extra cost of 5000 KES (58 USD) for wiring, which is given as a loan repayable in daily instalments of 70 KES (0.8 USD) over a period of two years. Gamma's model is designed to make connections available and affordable to as many consumers as possible and thus to saturate the areas in which it operates. This includes, for example, leaving ten percent of connections vacant in their systems for potential future customers and cross-subsidising between consumers in the system. Gamma is constructing mini-grids to be grid-ready, thus being able to accommodate large loads and to meet the standards of the national grid. This in turn means that Gamma is future-proofing its systems by over-dimensioning from the outset. Gamma has also established a buffer zone of 600 meters from existing KPLC infrastructure as part of its selection criteria for new sites.

With its mission to build up a strong market position through a vertically intergraded approach based on turnkey mini-grid projects, Gamma has kept a closed and protective approach towards other actors in the niche. It is not reliant on other actors in the niche but instead is building networks based on strategic ties to overseas investors and business partners such as suppliers of branded technologies and investors. Through previous start-ups, the firm’s founders have acquired links to finance and knowledge networks and are driven by previous experience within the telecommunications market and with mobile charging solutions. As part of its approach to building up a strong market presence in Kenya, Gamma has made a number of strategic local recruitments. Thus it has recruited an ex-KPLC and ex-REA director to head the East Africa division with a total of 25 years' experience within the two organisations, as well as an operations manager with 15 years' experience of the telecom sector. The operations manager, who is in charge of Gamma’s hundred-site roll out, was headhunted directly from the telecom construction sector and has a long professional background in telecom site construction. Furthermore, Gamma has managed to bring on board an Oscar-winning actor and distinguished climate change advocate as a special advisor to the firm.

In order for Gamma to move from experimenting with four sites to developing a portfolio of one hundred sites, it is dependent of the support of regime actors, with whom it has initiated bilateral and multilateral meetings. As a platform for making its viewpoints heard, these meetings take the form of 'discussion forums' to which representatives from ERC, MoEP, REA and KPLC are invited. According to Gamma, the objective at a general level is to *"figure out how this will work"* and to agree on a direction for mini-grid development[vi]. These discussions are unprecedented, and agreements will hence play a part in setting precedents for the rest of the niche. In these talks, Gamma is addressing specific issues arising from its experiments, and the talks are guided in particular by two themes: legal issues, including licencing and rights to operate in areas of shared interest between Gamma and KPLC, and economic issues, including tariff setting and broader negotiations on the business prospectus.

Due to uncertainty over the frameworks for how new entrants in the distribution market should be included under existing policies, Gamma is seeking to find concrete solutions relating to its operations for how to coexist with KPLC. Gamma is therefore seeking to lower the level of uncertainty by interacting with, negotiating with and agreeing upon terms directly with KPLC. *"[...] with KPLC specifically we want to lay framework of what happens when we meet. Do you buy us out? Do we buy power from you and continue powering the village? You know, there are so many scenarios, so we want to understand what these scenarios are and actually like to have some agreed options"*[vii]

Tariff negotiations and broader negotiations on the overall business prospectus, and more specifically the issue of returns on investment, are important for Gamma if its tariff is to be approved. Given that tariffs are a contested topic, and with the 'private mini-grid model(s)' not being well understood among the different regime actors, Gamma makes an effort to present its business prospectus and to explain its proposed business model to ERC and MoEP to convince them of the appropriateness of the assumptions involved, including regarding tariffs and returns on investment. This is done concretely by putting forward the feasibility studies underpinning its business model for review and scrutiny by legal and economic experts at the ERC. It is a committee of the ERC that is ultimately responsible for approval of the tariff.

Central to the way in which Gamma has gained access to regime actors has been its recruitment of its East Africa director. This has helped Gamma directly in its negotiations with ERC, KPLC and MoEP, especially in the matter of obtaining a licence. The director has a long working relationship with actors in MoEP, ERC, REA and KPLC and has, as an ex-director of the latter two organisations, direct access to the energy minister. Insights into *"what works politically and what doesn't work politically"* as well as the credibility he has built up as a director of the two organisations, has helped Gamma address political concerns and issues with regard to establishing and growing the firm[viii]. It has also helped it reduce resistance to the firm from KPLC, which did not object to its application, as KPLC was included in the licence process from the beginning.

Gamma is active in marketing the firm through the Kenyan media and engages in a mediated dialogue with regime actors by expressing its views on specific policy issues through the media. This is done by, for example, expressing the view that, just as Kenya Power has access to funds to assist with the costs of lighting up rural areas, so should smaller utilities also be able to tap into concessional loans, government guarantees and other financial support.

5.3 Delta

Delta was started in 2014 as a 'special purpose vehicle' by the German federal development corporation (hereafter "the corporation") as a private company in trust. The Delta project is a single experiment, which there is no intention to scale up. The mini-grid is a 50 kW system supplying tier 2-5 power to residents of a remote market town. As of August 2015, twenty people had been connected, with more to follow. The firm and its operations are fully funded by donor finance through the German government. However, the ultimate goal of the Delta project is to imitate a private business model in order to generate data and insights about this model and to feed this learning into national advisory processes and policy-making.

As Delta is financed by donor money and not by private finance, an agreement has been drawn up providing that the mini-grid will be handed over to REA at the end of the project phase. This arrangement also means that Delta is *simulating* a private model rather than *being* a private model. This simulation includes approximation of assumptions and figures underpinning its business model. This model simulates an approach based on 20% equity from the mini-grid developer and 80% loan, the loan being conditioned by a 10% interest rate, which, according to Delta, is "*a little bit low"* as Kenyan commercial banks are lending at a higher rate [ix]. Furthermore, based on its own feasibility study, Delta has decided on a tariff of a maximum 100 KES (1.2 USD) and a breakeven point of nine years, though excluding the cost network infrastructure (because the system will be handed over to REA), and with a situation of negative net present value. This exemplifies how, although attempting to simulate a private model, actual conditions for Delta may vary from those of 'real' private actors.

Practised business model

Although it is possible to operate mini-grids at a pilot stage without having a licence or permit from the ERC, as done by Alpha and Beta, Delta initiated the cumbersome licencing process as part of their aim to generate knowledge about the barriers to private sector-led mini-grid development. During the licencing process, KPLC made an objection to the application, claiming that the proposed mini-grid site was in conflict with its own expansion plans into the area. However, KPLC withdrew the objection when it was informed about the arrangements for the project involving assets being handed over to REA after project completion and the system to be operated and managed by KPLC henceforward. Based on its experience with the Delta mini-grid, the corporation has published a guidebook on the licencing process (GIZ, 2015), as well as one on the site selection process and a tool for calculating input into a feasibility study. It has also made publicly available various project documents like customer contracts, complaint forms etc.

The corporation highlights how the policy framework and environment for mini-grid development is not very conducive to private-sector involvement, and it sees itself as instrumental in improving the policy framework for private-sector mini-grids and taking on the role of guiding regime actors in making decisions. As a long-term donor agency in Kenya, the corporation has already established links with the various regime actors. It has also drawn up various draft policy documents based on the data generated in the Delta project together with the MoEP and the Kenya Private Sector Alliance (KEPSA) as input into policy formulation processes. These include concrete suggestions in the form of concept notes for how a cross-subsidy scheme and a new grid code could be designed. The corporation is arguing for using the rural electrification fund for cross-subsidising private-sector mini-grids. The rural electrification fund, which is financed through a five percent levy on the monthly electricity bill, is included in the proposed energy bill, which has been sent to the Senate for review (Shiundu, 2016). The corporation is accordingly suggesting tapping it to subsidise the private sector. In addition to working directly with MoEP, the corporation is cooperating with associations like KEPSA, who are lobbying on behalf of Delta and the rest of the private mini-grid sector.

In the town where Delta operates, it has outsourced all customer relations work to a German NGO, which has set up complaints procedures and has encouraged local villagers to form a committee in charge of communication with Delta/the corporation about any issues that arise.

6. Processes of system building

Based on the presentation above, this section will discuss how the expansion of the niche is supported by traditional niche processes, as well as show how the existing regime is being challenged through institutional work being carried out by niche actors.

6.1 Internal niche processes

Alignment of expectations

SE4ALL's commitment to achieve universal access by 2030 and the even more ambitious goal of the Kenyan government to reach universal access by 2020 set out a global vision for increased rural energy access through alternative measures like private mini-grids. However, when it comes to attracting finance to the niche, expectations seem to be shared only among particular types of investors. The firms have managed to attract finance for their experimental projects from particular types of investors. In addition to their own investments and to some extent grant funds, investors include angel investors and large well-established companies within the energy field, including a European electrical appliances manufacturer, a European utility and an American utility scale solar power company. Commercial loans from conventional banks, on the other hand, have not (yet) become part of the firms' financing portfolios. This indicates that expectations are shared among a group of like-minded investors with a background in the energy sector who are seeking to diversify their portfolios to include investments with a social impact. However, positive expectations of the viability and impact of the private mini-grid model are still to be taken up and be shared among more conventional financing actors.

Among the firms there is a high degree of alignment of visions and beliefs. The firms are driven by a social mission to deliver electricity to unconnected populations, and they view the economic viability of their businesses as the means to achieve that end. In terms of technological solutions as well, the firms are all relying on highly advanced technological components and systems, which they view as crucial for their success. However, in terms of strategies, agendas and interests, the alignment of expectations between the firms is less clear. Gamma's strategy of connecting everyone, as contrasted with Alpha and Beta's strategy to connect only the most highly energy-consuming households in a village, provide an example where further learning within and across individual projects can help articulate and specify expectations further, as the outcomes and consequences of the varying strategies are still poorly understood. Variations between firms are discussed more in detail below in Section 6.3.

Networks and learning

Alpha, Beta and Gamma are all embedded in networks stretching back primarily to the USA and Europe. This is highlighted as one of the reasons for their success in attracting funding to the niche. While Alpha and Beta are relying on a broad range of partners and collaboration, characterised by ad hoc project-to-project interaction, Gamma is developing its technology and business model in collaboration with one 'strategic investor from the solar industry'. Its strategy in teaming up with a large solar utility player is based on the active participation of the partner in the innovation process. Furthermore, Gamma has gained access to specific expertise and expanded its understanding of cost-reduction strategies, logistics and financial strategies.

For all four firms, the viability of their business models is dependent on a careful understanding of user patterns, user preferences, user affordability, data generation and insights into how to optimise their models according to the identified patterns. By working with universities and research-oriented investors, Beta is supporting the codification and diffusion of this learning. Alpha and Beta are working to generate knowledge about the 'private mini-grid model', as they see this as a way to open up the sector more widely, bring in more investors and increase their network of clients. By collecting a whole range of data based on different implementation models with varying degrees of commercial viability, they are building up a large database to cater for any type of potential collaborative investor in the future. For Beta and Alpha, the codification and dissemination of knowledge acquired is part of a strategy to increase its impact in the niche. For Delta, the codification and dissemination of knowledge acquired is part of its mandate and raison d'être. Gamma, on the other hand, conditioned by its vertically integrated approach, is taking a closed approach where learning is not shared across the niche.

In addition to these traditional niche processes, system-building is taking place as a result of niche actors' active involvement in working towards the regime level to create new practices, rules and norms in support of the niche. This will be discussed below.

6.2 System building through institutional work

This section will discuss the ways in which the existing regime is being challenged through processes of institutional work carried out by niche actors. As outlined in the conceptual framework, institutional work takes various forms, which will be used to structure this discussion. The following three subsections discuss how the regime is being challenged through i) regulatory forms of work in the sense of advocacy and defining; ii) cognitive forms of work in the sense of mimicking; and iii) normative forms of work in the sense of changing normative associations.

6.2.1 Regulatory work

Advocacy, understood as "the mobilization of political and regulatory support through direct and deliberate techniques of social suasion" (Lawrence and Suddaby, 2006), takes the form of bilateral meetings in which niche actors negotiate various issues, taking their point of departure in their specific business cases. Through the meetings they have initiated with MoEP, KPLC and ERC, and through collaboration with the advocacy organisation KEPSA, Gamma and Delta are campaigning for political and regulatory support through representation of their interests and direct and deliberate social persuasion.

Part of this work also entails *defining*, understood as "the construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field" (Lawrence and Suddaby, 2006). Niche actors, for example, need to convince ERC and MoEP of the appropriateness of their model in order to have their tariffs approved by ERC. This process includes revealing and explaining elements of their economic models, such as returns on investment and tariff levels, as well as answering questions and explaining the rationales underpinning the model. These negotiations thus become part of a process to formalise new rule systems with regard to the niche. Similarly, by being involved in developing specific concepts of cross-subsidisation and grid-codes for mini-grids together with the Ministry of Energy, Delta/the German development corporation is engaging in *defining* work to establish the parameters of future institutional structures and practices.

Through the establishment of the special purpose vehicle of Delta, the corporation has acquired a new legitimacy to speak on behalf of private-sector mini-grid developers and to use its access to policy-makers to advocate the case for mini-grids. In its efforts to formalise the underpinnings of the private mini-grid model, it has also produced material to explain the advantages of its business model to regime actors. The corporation, in particular, creates templates and formal documents representing their model, thus targeting and seeking to influence both the legal and economic instabilities in the regime by suggesting specific solutions on issues of licencing, grid-integration, tariffs and subsidies.

Gamma and Delta, through advocacy towards regime actors are acting as front-runners in setting precedents for both themselves and other actors in the niche. In particular, their success in obtaining a licence has been a form of persuasion through practice, and they have now paved the way for later applicants to follow.

Gamma seeks to promote its agenda towards the regime not only through bilateral or multilateral meetings with regime actors, but also by reaching out to a broader set of actors through the media to create pressure on the regime and to gain support for its work. By inviting regime actors to engage in initial discussions about its work and business model, and by engaging in direct negotiations with regime actors, Gamma is building what Markard et al. (2016) refers to as advocacy coalitions across the niche and regime level to enhance the chances of change materialising. Furthermore, by linking up with an established 'climate hero', Gamma is seeking to increase its legitimacy internationally, while by recruiting an ex-KPLC/REA director with already established legitimacy in the national energy sector, it is acquiring instant access to the assets this person represents in the form of access to policy-makers, political know-how, in-depth knowledge of the sector and established relationships with regime actors. Gamma's inclusive and collaborative approach towards regime actors has reduced resistance from the regime to its experimentation and upscaling efforts. KPLC, for example, did not object to the application process for the permit as it did with Delta. Although Gamma operates in close proximity to KPLC and thus establishes itself as a competitor, its inclusive strategies support a narrative about niche actors as contributors to the overall goal of universal access rather than as competitors to the existing regime.

6.2.2 Cognitive work

An important but less visible part of niche actors' institutional work is conducted in terms of mimicking, understood as "associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption" (Lawrence and Suddaby, 2006). In this case, mimicking is closely linked to applying existing technologies and practices from the telecom sector to the mini-grid niche.

The mini-grid firms have adopted existing practices and technologies from the telecom sector in order to reduce investment costs and operational costs. By employing an operations manager from the telecoms industry, as well as by adopting and imitating large-scale implementation methods through the translation and transfer of knowledge, ideas and experience from the telecoms construction sector, Gamma has reduced its investment costs. Secondly, it has reduced operation and management costs by introducing mobile-phone technology for the real-time operation, management and surveillance of the systems. In addition it has ensured future integration with the main grid by using certified components and the same grid-code construction standards as those used by KPLC.

Besides the technological benefits of including existing technological components in the new private-sector mini-grid technology, our analysis shows that there is a less visible, but important element of institutional work embedded in this technology choice, in terms of mimicking.

Mimicking the use of the popular mobile paying systems for payments in mini-grids is a way of gaining popular acceptance for the system and thus easing adoption. Using mobile telephone technology for communication with and control over the system, are seen as 'modern' and acceptable practices. Similarly the use of grid-standard components is conveying the message that mini-grid operators' approaches to delivering electricity are not dissimilar to those associated with the national grid. These firms are thus creating links between new practices related to mini-grids and already established practices related to extension of the national grid. In this way they are reducing rather than emphasising the gaps between the regime and the mini-grid niche which can help lower the potential barriers to future integration into the national grid.

6.2.3 Normative work

Niche actors conduct normative institutional work in terms of changing normative associations, understood as "Re-making the connections between sets of practices and the moral and cultural foundations for those practices" (Lawrence and Suddaby, 2006). With respect to tariffs in particular, niche actors have had a strong interest in changing normative associations, in this case to discursively change the way the price of electricity is defined and perceived within the regime. This is due to the fact that niche firms charge four to twenty times more than the national universal tariff for electricity. Rather than supporting the conventional view of the price of electricity as a price per unit (KES/kWh), niche actors are instead working to create a narrative of a holistic pricing model. Through this holistic pricing model, they convey the idea that the private mini-grid model provides better service than what is already available (kerosene, diesel and expensive phone charging), at a lower price than what people are currently paying for these inferior services. In addition, by charging low connection fees and low wiring costs, they provide, from a holistic cost point of view, cheaper power than what is available from KPLC over a period of many years.

This holistic pricing model represents an idea which associates the mini-grid model with the practice of helping individual households pay less for a better service. However, the displacement argument is in conflict with the political view that it is unjustifiable to defend a situation in which the rural poor are paying significantly more per kilowatt hour than their urban neighbours. However, by arguing for a holistic pricing model, niche actors are questioning the normative associations underlying the uniform tariff and seeking to reformulate the normative associations related to their models.

Gamma has applied a second approach to changing normative associations by connecting as many people as possible within its target areas. This has acted to create a positive narrative about its model both in the targeted community and among external actors, including regime actors, investors and donors. By applying this strategy, Gamma not only improves its own business model in terms of i) potential growth in the future, ii) keeping the costs per connection down and iii) the possibility to make high-consumption customers subsidise low-consumption ones, it also argues that it is the morally right thing to do and in this way is creating normative connections between its sets of practices, including the moral and cultural foundations of these practices and its mini-grid model. Gamma's model of saturating targeted areas is challenging the conventional ways of doing business represented by REA and KPLC, where the majority of people cannot afford to connect, in regards to achieving just and equal access. Gamma's model is also contrasted by other private mini-grid models, where only the 10-20 % most energy consuming households in a community are connected. Through this strategy, Gamma is associating its model with norms of human welfare and affordability, rather than traditional associations of the private sector, such as turning a profit, and is thus targeting the world views of both regime actors and the general public.

6.3 Reflections on variations between firms

Scholars have highlighted how institutional work requires resources and skills that are available to some actors and not to others (Lawrence and Suddaby, 2006; Perkmann and Spicer, 2008). This section will reflect on how the various system building strategies discussed above are related to the firms' various skills, resources, business models and mandates.

Alpha and Beta are refraining from institutional work targeted directly at the regime. Instead, their system building strategies are primarily focused on creating room for manoeuvre and on strengthening their positions within the niche by creating networks and facilitating learning. They are carefully prioritising their time and resources needed to develop client relationships and improve their businesses over the time-consuming and bureaucratic processes of obtaining licences and tariff negotiations directly targeted at the regime. This strategy seems to be conditioned by their revenue-driven business model, which has led them to pursue a role as facilitators for the mini-grid sector at large. This business model is to some extent conditioned by the barrier to scaling up funding for their own mini-grid portfolios and hence an expression of a lack of access to monetary resources.

Furthermore, their specialisation as a sub-contractor and a supplier respectively and their aim of becoming a sub-contractor/supplier for KPLC has led them to construct mini-grids far away from existing KPLC infrastructure, thus pursuing a non-confrontational approach towards regime actors as a way to mitigate the risks to their business.

Delta, on the other hand, although established as a private firm with a CEO from the private sector, is firmly embedded within a 'donor discourse' with a business model reflecting the skills and resources of the development corporation. Its mandate is to act as a facilitator of the policy process and as a result, it needs to establish and define a balance between investor considerations, government considerations and customer considerations. In this work it relies on its already established credibility as a well-established development corporation on the political scene in order to gain influence at the political level.

Gamma, with its access to finance and its claimed ability to scale up its operations, is in a position where it is forced to engage with regime actors. As a strategy to increase its chances of success, it has taken a very direct approach towards regime actors by relying on a broad set of skills and resources. Its access to finance has made it possible to attract highly skilled staff, which in turn supports it efforts to influence the regime through a combination of regulatory, cognitive and normative institutional work. As Gamma has decided to build its mini-grids in close proximity to existing KPLC infrastructure, political skills are leveraged to push for negotiations with MoEP and KPLC on issues like licencing and future grid integration. Technical skills are leveraged to create a shared understanding between regime and niche actors through, for example, mimicking standards and large-scale implementation models. Lastly, cultural skills are leveraged to create a normative and moral narrative about the private mini-grid model.

7. Conclusion

This paper has offered an empirical account of how a group of privately owned start-up firms has challenged the conventional way of carrying out rural electrification in Kenya. While little happened on the ground at the beginning of the millennium, or even after the establishment of the Rural Electrification Authority in 2006, the emergence of this small group of private firms, together with donor-supported initiatives, has in a relatively short time changed the thinking, planning and regulation of 'doing' rural electrification in Kenya. That said, the development trajectory for the niche is still uncertain, and it is still too early to judge whether the current hype of private-sector mini-grids will lead to a fundamentally different way of carrying out rural electrification in Kenya.

In this regard, the paper has pointed to a number of emerging questions with respect to the long-term sustainability of these business models. Will private mini-grid developers have access to same level of subsidies as the mini-grids implemented by REA, and if not, will they be able to attract sufficient external capital and survive? Will private business operators be able to make a profit out of the popular 'connect all' strategy, when publicly driven electrification schemes have not found it profitable to connect the poorest segments of the population? And how will private businesses be able to balance the dual objective of earning a profit and providing affordable electricity to the poor?

Drawing on the multilevel perspective, these questions are relevant to understanding whether the niche will be able to upscale and become a sustainable, complimentary rural electrification approach in the long term and ask for further research, now and along the future path of development. At this point, however, with a relatively stable regime combined with relatively strong and broad social networks and niche actors able to learn effectively from experiments, the private mini-grid niche seems to represent what Raven (2006) refers to as a promising technology. Given the increasing institutionalisation of niche rules, practices and norms (niche stability), combined with a relatively stable regime, the niche should be able to grow, though rapid expansion may be prevented by regime stability. Regime-stabilising factors, like donor-supported mini-grids established by REA and handed over to KPLC, donor-supported grid extension programs, existing investment in current grid-infrastructure and government-backed guaranties for KPLC initiatives, may in this regard limit opportunities for further niche upscaling. Under such a scenario, niche actors will compete directly with the regime actors for market share (Raven 2006). Alternatively, if regime stability decreases and the niche become increasingly stable, the niche can end up as a problem solver, with regime actors proactively supporting the niche, thus leading to its rapid expansion.

In this regard, institutional work by niche actors targeting the regime may prove crucial in creating the conditions for change. By drawing on the concept of institutional work, this paper has provided insights into the processes at work during the first important stages of private mini-grid development, and it has shown how niche actors are focusing on a dual strategy of expanding the niche though niche-internal processes while at the same time trying to reform and challenge the existing regime's conditions.

The paper has also shown how actors within the niche are targeting openings in the form of tensions and conflicts within the existing regime to encourage and push for the creation of niche-supporting institutions in the sense of rules, norms, values and belief systems. Niche actors focus primarily on rule-based institutional work, such as advocacy and defining, which is targeted at policy-makers to improve the legal and economic frameworks for niche development. This is fully in line with the general focus of development actors and policy advisers on the role of an enabling framework that stresses the legal and economic aspects (UNDP, 2011; UNEP, 2015; Williams et al., 2015).

Less visibly however, niche actors also engage in cognitive institutional work in the sense of mimicking, with the objective of internalising the assumptions underpinning the private mini-grid model and thus constructing a shared world view between niche and regime actors. Interestingly, niche actors also produce a substantial amount of normative work, for example, by trying to discursively change the way the price of electricity is defined and perceived both among consumers and within the regime. This work of the niche actor has been deemed necessary in order to create links between the private model and 'positive' normative associations like equity and social justice, which are normally associated with public sector engagement.

The analysis further shows that not all actors in the niche engage to the same extend in these purposive practices targeted at creating change in the regime. These empirical insights contribute to the discussion of why some actors engage in institutional work while others do not (Ritvala and Kleymann, 2012), as well as to debates over the roles of skills and resources when actors perform institutional work (Lawrence and Suddaby, 2006; Perkmann and Spicer, 2008). While some actors are mostly engaged in niche-*internal* processes, other actors are equally engaged in niche-*external* processes, conducting institutional work targeted directly at the regime level. This indicates that different business strategies and different skill-sets within these firms are determining the way in which firms and individuals engage in system building. Their attempts can be viewed as a collective effort in which actors embedded in differing world views, drawing on different business models and having different mandates are relying on different skills and resources and who are thus engaging in different types of system building. These findings concur with those of (Greenwood and Suddaby, 2006), according to whom institutionalisation processes are rarely if ever achieved by a lone institutional entrepreneur or a hero entrepreneur, as suggested by Hellsmark and Jacobsson (2009).

By emphasising the practised work of system builders, the study contributes empirical insights into the role of actors in processes of how niches contribute to changes in the behaviour, practices and routines of existing regime actors (Schot and Geels, 2008) and thus to the ongoing effort to conceptualise agency within the framework of transitions theory (Fuenfschilling and Truffer, 2016; Jolly and Raven, 2015). The paper also provides new insights into how niche actors complement and combine niche-internal and niche-external processes in driving the expansion and scaling up of new niches to provide a more comprehensive understanding of niche development patterns (Raven et al., 2016).

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[i] Staff interview # 5
[ii] Key informant # 3, # 5
[iii] Staff interview # 2
[iv] Staff interview # 2
[v] Staff interview # 4
[vi] Staff interview # 5
[vii] Staff interview # 5
[viii] Staff interview # 5
[ix] Staff interview # 7

Article 4

Competing logics in rural electrification: The case of private mini-grid development in Kenya

Mathilde Brix Pedersen[1], Walter Wehrmeyer[2] and Ivan Nygaard[1]

[1] UNEP DTU Partnership, DTU Management Engineering, UN City, Marmorvej 51, 2100 Copenhagen, Denmark
[2] Centre for Environment and Sustainability, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, UK

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Abstract

Private mini-grid developers, which deliver power to rural communities in developing countries through for-profit business models, represent an alternative organisational model compared to traditional state-led, donor-led or community-driven models of rural electrification. This paper seeks to broaden our understanding of this particular model, which is usually referred to generically as a private model. By using insights into organisational hybridity as a defining characteristic of organisations that have a dual mission of social and economic aims and applying the analytical concept of institutional logics, this paper explores the complexities of the private model to rural electrification. By studying the practices of four different firms, as well as the effects of these practices in the targeted areas, the paper seeks to uncover ways in which firms through their activities and sense-making draw upon the two logics of economic viability and social welfare in their work. The paper finds that, although these private firms primarily rely on the logic of economic viability in their self-representations, when analysing their practices on the ground their business models are shown to vary in terms of how they enact logics. The paper illustrates this variation by presenting these firms as two distinct hybrid forms, one enacting primarily the logic of economic viability, the other blending the two logics and thus apparently deriving synergies from integrating the two. These hybrid strategies are discussed with regard to firms' resource dependency, their rootedness in the commercial and/or social sectors and legitimacy.

Key Words: institutional logics, hybridity, rural electrification, private model, mini-grids, Kenya

1 Introduction

Private firms are emerging globally that deliver electricity to poor rural households through for-profit business models (Schnitzer et al. 2014). Although electricity provision is traditionally seen as a basic public service delivered by the state, the current situation in many developing countries suggests that the utility lead model, with national grid extension as its primary form of electrification, will not succeed in delivering universal access in the near future (OECD/IEA 2010). The 'private model', where private-sector funds are leveraged through economically viable projects to achieve scale (Schmidt et al. 2013), is stressed as crucial to meet the UN goal of Sustainable Energy Access for All by 2030 (OECD/IEA 2010; Bardouille & Muench 2014; SE4ALL 2012).

The current literature on rural electrification in the context of developing countries treats the private-sector model as a particular and homogenous organisational form (e.g. Palit & Chaurey 2013; Franz et al. 2014), yet little is known about how private energy-service providers operate in practice or whether different business models have different effects in targeted communities. However, treating the private model as a 'black box' does not reveal any insights into or explain the heterogeneity within what seems to be a similar organisational form. Private mini-grid firms that choose to pursue a social mission through commercial activities operate in a sphere of competing social and economic logics (Pache & Santos 2013). The fact that electricity is an important enabler of socio-economic development is well-established (UNDP 2011) and behind firms' functional goals to connect people to electricity lies a social goal of catalysing social impact by bringing "change to people's lives" (Earley 2015). This opens up a heuristic avenue for research into how mini-grid firms respond to competing social and economic logics as a way to improve our understanding of the complexities of the private mini-grid model.

Research into the combination of logics is primarily focused on processes *within* organisations or between organisational fields. This includes research on how organisations may become fragmented and lose coherence as a result of competing logics (Raynard & Greenwood 2014), as well as the ways in which they respond to, or manage, competing logics (Tracey et al. 2011; Pache & Santos 2013; Doherty et al. 2014) and reduce contingencies (Skelcher & Smith 2015). This paper is interested in the micro-processes of how competing logics are made manifest through practice. It will therefore explore the process of how mini-grid firms enact logics on the ground through their practices by focusing on the interactions between firms and their customers.

Following the introduction, Section 2 presents the analytical framework and outlines the available logics identified in this case study. Section 3 describes the methods underpinning the study. Section 4 uses two narratives drawing respectively on the logics of economic viability and social welfare to show how mini-grids and mini-grid firms are discursively constructed by themselves and their environments. Based on an analysis of the logics that underpin the four firms' practices and decisions regarding their customers, as well as the effects of these practices on communities, Section 5 presents two groups of hybrid organisations that are responding differently to the competing logics they are exposed to. Section 6 discusses the wider institutional embeddedness of these hybrid forms in the context of how they respond to hybridity. Section 7 concludes the paper.

2 Institutional logics in hybrid organisations

The inherent organisational complexities of balancing social and economic aims (Battilana & Dorado 2010; Pache & Santos 2010) opens up for the conceptualisation of mini-grid firms as hybrid organisations (Raynard & Greenwood 2014; Doherty et al. 2014; Skelcher & Smith 2015). Hybrids are carriers of multiple institutional logics understood as taken-for-granted social prescriptions that guide actors' behaviour (Friedland & Alford 1991; Suddaby & Greenwood 2005; Thornton et al. 2012). Hybrid organisations thus play in two or more 'games' at the same time and "engage with multiple audiences that prescribe different and, at times, conflicting demands" (Raynard & Greenwood 2014:1). Although mini-grid firms may not identify or in fact perceive themselves as social enterprises (Dacin et al. 2011; Dees 2012; Santos 2012), nor explicitly develop business models with a dual or triple bottom line (Schaltegger et al. 2015), they operate in a hybrid reality in which multiple logics are made available to them, a situation to which they must respond (Pache & Santos 2013).

Institutions are defined as "cognitive, normative and regulative structures and activities that provide stability and meaning to social behaviour" (Scott 1995: 33). The institutional logics perspective provides a framework with which to understand the institutional embeddedness of actors and organisations (Friedland & Alford 1991; Thornton et al. 2012). The plurality of institutional logics and their availability for utilisation by actors within organisations makes the institutional logics perspective of particular interest when studying firms that are operating within a presumably homogeneous organisational field (private mini-grid firms) while also having to respond to the demands of competing logics. Following the institutional logics perspective, individuals, their interests and motivations, and organisations are institutionally shaped by being anchored in cultural institutions of different institutional orders; their behaviour can therefore be explained by understanding the nature of this embeddedness. Institutional logics thus represent "frames of reference that condition actors' choices for sense making, the vocabulary they use to motivate action and their sense of self and identity" (Thornton et al. 2012: 2). Plural institutional logics are made available to actors and organisations, and their enactment reveals insights into how and why sense-making and decisions are made within organisations (Thornton et al. 2012; Thornton et al. 2002).

So rather than following a functional triptych definition of mini-grid models in which a 'hybrid model' is one that combines different functional aspects of the utility model, community model and private model (e.g. Franz et al. 2014; ARE 2011). Instead, it will use the concept of organisational hybridity to uncover variations within the 'private model' by exploring the dynamics between how firms rely on different logics and how this hybridity becomes manifest in their business practices on the ground.

Following Powell & Colyvas (2008) and McPherson & Sauder (2013), the focus here is on the micro-level manifestations of logics, seen as practice and action at the individual level. The study will contribute with an empirically based understanding of how mini-grid actors (firms and individuals) translate logics into action as they engage in everyday operational activities to achieve their goals. Viewing institutional logics as instantiated in and carried by individuals through their actions, tools and technologies (Powell & Colyvas 2008), and institutions as being reproduced through the everyday activities of individuals (ibid.), this study will therefore explore how different logics become manifest in daily activities and practices by interpreting the sense-making and decision-making of mini-grid actors.

With the aim of exploring the duality between the social and economic aims of commercial firms with a social mission, we have identified two ideal-type logics in our material, which we call the *economic viability logic* and the *social welfare logic*. The economic viability logic refers to the actions and practices of a firm that is seeking to optimise the economic viability and efficiency of its business model. The enacted logic of economic viability is thus directed towards the good of the firm and is a manifestation of the market logic (see Thornton 2012). In enacting this logic, the focus of the firm is its own self-interest, its activities and practices being tailored towards increasing organisational efficiency and profit. This logic directs attention away from the customer, their circumstances and the wider community, and instead focuses attention on the firm itself and how its actions measure up to standards of economic efficiency.

The logic of social welfare, by contrast, is oriented towards the interests of the targeted community. Here the firm is accountable to the community it serves. This logic is enacted through the firm's activities and practices being directed at supporting and optimising social and human welfare and development. The logic represents the firm's actions and practices in seeking to increase democratic participation, increase the firm's accountability towards the community and secure equal access. This logic is thus to some extent a manifestation of the state logic (Thornton et al. 2012), in which the cognitive attention of the firm's actors is directed towards the good of the community, democratic participation, the rights of citizens' and human rights.

3 Methods

The present case study consists of the four private mini-grid firms found to be operating in Kenya during fieldwork in 2015. All were founded by foreigners, three of them having founding origin in the business sector while one has founding origin in the social sector. All four firms deliver power to rural populations through technologically advanced solar-powered mini-grids, a service for which customers pay a tariff per used unit via their mobile phone. According to agreement with case firms they have been anonymised and references to interviews have been numbered in accordance with the authors' internal list of interviewees. Table 1 summarizes the key features of these four firms.

Table 1. Key features of the firms in the case study

	Year founded	Origin	# Sites[1]	System size	Connections	Tariff USD /kWh	Funding
Firm 1	2011	Commercial	12	1.4-6 kW	250	2-5	Client based, Venture
Firm 2	2012	Commercial	3	1.4-6 kW	60	1.8-4	Client based,
Firm 3	2011	Commercial	4	10-50 kW	300	3-5	Venture, Equity
Firm 4	2014	Special purpose vehicle of international federal development corporation	1	50 kW	250	0.7-1	Donor funded

The empirical data used in the study comprise in-depth, exploratory interviews with three groups of participants: i) twelve interviews were conducted with firm staff from four mini-grid firms; ii) twelve interviews were conducted with key informants with knowledge of the firms and the sector in general; and iii) sixty-one interviews were conducted with end-users and non-connected neighbours in four villages. Interviews with firm staff and key informants were conducted in English, recorded and transcribed, while interviews with customers and their non-connected neighbours were conducted using an interpreter and documented through hand-written notes. Data were collected over a two-month period in 2015. Further, the analysis draws on secondary sources like the grey literature, popular media reports and information from firms' websites.

The analysis consisted of three steps. The first step included an open and inductive coding exercise to explore how firms were constructed discursively. This included firms' representations of themselves, as well as how mini-grid development was represented by actors in the broader environment such as development practitioners, policy-makers and the public media. Furthermore, firms' practices were coded according to aspects of their business models and enacted logics. This first step led to the development of the two ideal-type logics. The second step included an analysis of how firms enact these two particular logics through their practices in their interactions with customers. The analysis focuses on relations between the firms' and their respective customers and is therefore organised according to the business-model aspects of customer segments, channels and customer relationships (Osterwalder & Pigneur 2010). The customer segments are the different groups of people or organisations that an enterprise aims to reach and serve. The channels describe how firms communicate with and reach their customer segments, raise awareness, help customers evaluate their products and provide post-purchase support. Customer relationships are those a firm establishes with its customers, including customer acquisition, retention and increasing sales. With respect to these business-model aspects, each firm's practices were coded according to the prevailing logic underpinning the action. The analysis is based on both reflexive and non-reflexive representations of the logics, taking into account both how firms talked about their practices and how the logics we have identified may become manifest unintentionally

[1] Not including those operated for others

through their practices. The third stage identified the effects of various practices in the served communities.

4 The hybrid representation of mini-grids and private mini-grid development

The question of mini-grid development is being debated and framed by a broad field of global actors, including development practitioners, bureaucrats, policy-makers, researchers, investors and the media, as well as by the mini-grid developers themselves through self-representations on websites and in the media. Narratives and representations of phenomena are selective use of language based on cognitive and normative frames constructed by those who use it. This section describes how mini-grid development is represented through two narratives drawing on the economic viability logic and the social welfare logic respectively. The narratives each consist of a broader global narrative about private mini-grid development, as well as of self-representations by the four firms. These mini-grid narratives are presented below.

Techno-economic narrative: *mini-grids as technical wonders and profitable business cases*

The techno-economic narrative is a manifestation of the commercial logic. It is based on arguments concerning the reasons or premises that have made mini-grids a realistic alternative compared to other forms of rural electrification, such as grid-extension, home-based systems or pico-lighting options. Technical advances in solar cell components and storage technologies have led to increased performance as well as reduced costs (ACORE 2015), while technical advances in the area of telecommunications have made it possible for firms to do remote monitoring, obtain real time data and manage payments effectively (Schnitzer et al. 2014; Franz et al. 2014). These advances have made such systems economically viable in ways unseen before, and solar powered mini-grids have proved to be more economically viable in many cases – specifically for off-grid areas with low-density populations – than diesel-powered alternatives (Moner-Girona et al. 2016; IED 2013; Szabó et al. 2011; Blum et al. 2015).

Private mini-grid firms are particularly embedded in this commercial logic and draw primarily upon a techno-economic narrative in their self-representations. Firms highlight proving viability as an organisational goal: *"I think we see the most important goal as proving financial viability."* [1] They also emphasise the importance of their highly advanced and novel technical solutions as one of the reasons turning their businesses into a success: *"Our core product, a microgrid management platform, combines a range of technologies (including smart metering, data analytics, mobile money, a web-based management app) and applies them to deliver solar electricity in a way that's never been done before."* [2] The solution is even highlighted as a way of leapfrogging the aging power models and infrastructure of the more developed world[3] by being smarter and more technologically advanced than conventional energy distribution systems: "*[the firm's] technology turns any solar installation into a utility service more advanced than you can find in most OECD cities.*" [4] The close link between technological innovation and economic viability in the case of private mini-grid developers is emphasized by the Ashden Award, which highlights how the underlying technology of a mini-grid firm *"stands to tip the balance in expanding access to electricity by making micro-grids an investable proposition."* [5]

Private mini-grid firms typically frame their demonstrations of a viable business case as a condition for attracting investors. A firm's ability to be profitable is dependent on its technological product, which in turn is crucial to attracting commercial finance and scaling up operations. One developer expressed the connection between technological innovation and economic viability in this way: *"[the firm's] technology and data-driven approach to microgrid development and operations will enable the formation of a new asset class. It will enable us to cost-effectively reach tens of millions of people in rural villages unserved by grids while offering strong risk-weighted returns to investors."* [6] (popular media news article). This technologically advanced solution is also highlighted as providing leverage for private investments: *"A key driver of these investments is no doubt the role of remotely controlled and monitored solar equipment, enabling flexible payment models and the collection of valuable electricity consumption data."* [7]

Rural development and social impact narrative: *mini-grids as a way to achieve universal access to electricity and to catalyse rural development*

The rural development and social impact narrative is a manifestation of a social welfare logic and uses arguments highlighting the positive outcomes of access to energy for productive use. These arguments stress the social benefits of mini-grids and of electricity from mini-grids as a *"life-changing alternative"* to diesel kerosene and charcoal.[8] Since mini-grids can provide sufficient electric power to support productive uses (SE4ALL 2012; UNDP 2011), they are highlighted as a more advanced solution compared to pico-lighting systems (SE4ALL 2012). The link between access to productive energy and rural development and poverty reduction, by offering opportunities to improve people's lives and alleviate poverty, has received considerable attention from international development actors and governments in the past few years (ARE 2011a; UNDP 2011; Practical Action 2014). As expressed by SE4ALL (2015): *"Without access to modern energy, it is not possible to achieve the Millennium Development Goals"*. These arguments are aspirational in nature and tend to highlight the potential impact of mini-grid implementation rather than actual evaluated impacts. This includes how access to productive energy is linked to benefits such as cleaner, safer homes, lives of greater dignity and less drudgery, better quality health and education, and the potential for better livelihoods though local income generation (Practical action 2014). Likewise, the potential of mini-grids to impact positively on whole communities through "village-wide" distribution networks (ARE 2011b) provides an argument that supports the narrative of mini-grids as a superior solution to individual solutions like pico-systems or SHS. Especially media reports from both the traditional media and online media specialising in energy issues emphasise the community aspect of mini-grids: *"[the firm] is harnessing the power of mobile to bring affordable electricity access to rural, off-grid communities"* [9] and *"[...] grassroots sustainable energy provided to off-grid communities, often forgotten about by big business, can create jobs, pay for education and transform lives."* [10] Through self-representation, private mini-grid developers draw upon this narrative as a way to legitimise their area of business to both external stakeholders and internally. Here they draw upon arguments involving notions of morality and justice by highlighting how their firms are *"providing access to those who need it most,"* [11] securing *"better lives for the most vulnerable people,"* [12] and *"transforming people's lives."* [13] Customer stories are presented on firms' websites to communicate the ways in which their businesses are improving people's lives by highlighting how *"[c]ustomers are now able to light their homes longer to work or to study"* and how they *"benefit from increased access to information, entertainment, and connection via radio, television, stereo, and satellite dish."*[14] Although mini-grid firms are primarily seeking to demonstrate economic viability, their businesses are also built on a sense of purpose that they are doing business for a good cause: *"for us at [the firm] the sense of purpose runs particularly strongly [...] We watch in real time from [...] HQ as these people tune in for the Sunday afternoon Premier League match or switch on their irrigation pumps. In terms of positive career affirmation, it doesn't get much better than that."*[15] Thus firms view themselves as providers of solutions to achieve these development impacts through 'good business': *"[the firm owner] believes the way that you improve the lives of people [...] is not through charity, but with good business [...] We're of the camp that believes that if people value something then they will pay for it [...] We think the way to really achieve development results is to treat people like adults and design a great product that they love, that works for them and gets them on board with a business."* [16]

This section has shown how the broader narratives about mini-grids are embedded in both the economic viability logic and the social welfare logic, while mini-grid firms' own self-representations are primarily embedded in the economic viability logic.

5 Logics in action: prioritising between or combining logics

From the broader narratives about private mini-grid development and firms' self-representations, we now turn to the micro-level processes of hybridity by zooming in on firms' actual practices and actions on the ground. Based on an analysis of the logics that underpin the four firms' practices and decisions, we show how in practice firms enact different logics and thus how they respond to the competing logics to which they are exposed. While the four firms act differently, the patterns of practices emerging from the analysis can be condensed into two main groups of hybrids following similar patterns. The first group including case firms 1 and 2 relies primarily on the logic of economic viability, which is prioritised above the logic of social welfare in their work, while the second group including case firms 3 and 4 combines and blends the two logics.

5.1 One dominant logic guiding the work of the firm

This section illustrates a pattern of competing logics where firms predominantly enact the logic of economic viability in their work. Site selection and customer acquisition are, for this group of firms, based on criteria of remoteness from existing infrastructure, economic activity in the area and demonstrable demand for power by individual households. Within selected rural market towns, they connect mainly small businesses (shops, restaurants etc.) or in some cases households that have a demonstrable demand for electricity, usually through their involvement in some kind of trade or business.[17] Although there is no set minimum threshold for connecting a household, only households with a *"decent load"* will be connected.[18] New customers need to demonstrate what is regarded a viable level of demand from the firm's viewpoint, and a desire by people to connect based on recommendations from already connected neighbours is not a convincing argument on its own.

This practice of selecting which villages to electrify and which not is thus based on the criterion of economic viability. The practice of connecting households that demonstrate a decent demand for power reflects the firm's interest in acquiring customers who have an actual demand for power. It is based on the consideration that those who are already consuming power will constitute a viable customer group capable of generating immediate revenue for the firm and increasing their demand for electricity over time to improve or grow their businesses, which will in turn further improve the viability of the site.

Managing the expectations of community members and community leaders becomes highly important when following this practice due to the fact that not everybody in the village will be connected. According to case firm 2, their staff state clearly up front that the precondition for being connected is to demonstrate a minimum use of power. As part of the strategy of managing expectations, the firm's staff communicate clearly to customers, as well as to other stakeholders such as village leaders and local government, the firm's goal of being economically viable in order to foster understanding and acceptance of their aims and hence of their strategy of connecting only parts of the village: *"So far we've done a good job of like managing expectations so we never say everyone is going to get power [...]I think people generally understand that, like, if you want to get connected you need to demonstrate that you can use power."* [19] This prioritisation of the logic of economic viability over that of social welfare in terms of who to connect is further illustrated by one firm's decision to remove a mini-grid from a site because the site was not generating high enough revenues. Following a heated struggle with angry community members, some of whom had already bought appliances like fridges, the firm approached the county government and village leaders to obtain their agreement with the decision to pull out. The latter ended up supporting the removal, despite protests from the locals.

In order to communicate and reach its customers, this group of firms uses a one-to-one individualised communication strategy. Head-office field staff visit the sites and go from door-to-door in an effort to sign up potential customers. This approach is used both in the initial site identification process to assess the viability of a potential site and in the ongoing communications with connected customers. The field team engages directly with individual households to interview potential customers about their current energy use and demand and to explore the interest in and support for the idea of becoming connected to the mini-grid system, as well as to provide information, training and an after-sales service. By using an individual communications approach, the firm can retain control over which households in the community to approach and thus ensure that only the most energy-consuming households are informed of and offered an opportunity to be connected (economic viability logic).

While connections are carried out initially by professionally trained electricians, one firm highlights how it allows people to do their own connections: *"We have actually had some people who [...], like, from their own initiative connect their neighbours from their houses and they just split the bill, like: we think that's great, you know; we are generating the power, so we want it to get used"* [20]. This practice reflects an economic viability logic in which the opportunity for the firm to increase its revenue is given a higher priority than making sure that all connections are done correctly, safely and according to the right specifications (social welfare logic).

With regard to after-sales service and customer relationships, two practices are observed. One is to use a site agent to act as an intermediary between the firm and its customers. A site agent is a person living in the village in which the firm is operating and who is paid to be the point of contact for the firm. The site agent thus acts as a link between the firm and its customers but is not a firm employee. The site agent is also responsible for some of the systems operational and maintenance tasks. Customers do not have direct access to the firm but receive text messages directly from it if there are technical problems with the system. The second practice is use a direct customer phone line from the connected customers to the main office. This approach offers a highly personalised form of assistance whereby each customer has direct access to the firm. This one-to-one communication between connected customers and the firm enables the latter to provide personalised and on-demand assistance. Both approaches, however, also represent a way for the firm to control the flow of information in the community by excluding that part of it that is not connected from having access to information about the system, the prospects of being connecting in the future etc. Using a site agent is therefore a way not only of streamlining the firm's operations, but also of controlling the flow of information by using one-way communications and establishing an arms-length principle with their customers to minimise resource-consuming interactions with them (economic viability logic). Likewise, by introducing a customer care phone, the firm has established a direct connection between its customers and the head office in which all connected customers are able to contact a dedicated member of staff at the firm whenever they experience a problem or have a question. However, those in the village who are not connected do not have access to the firm.

5.1.1 Effects of practices driven by one dominant logic

In communities where enactment of the economic viability logic predominates in firms' practices, we observed three effects: i) information asymmetry; ii) competition with community and information capture by gatekeepers; and iii) entry barriers and lock-in effects.

In communities where an individual approach to communication is used exclusively and only some of the community is connected, low levels of information are available in the wider community, and there is an information asymmetry between those who are connected and those who are not.[21] Internal competition in the community and information capture by gatekeepers is a second effect that is closely linked to the low levels of information available and the information asymmetry in the community. While access to electricity may increase income opportunities for those connected to the mini-grid, in some cases, such as mobile-phone charging, connecting more people leads to a decrease in existing business. With more households being connected to electricity, people become capable of charging their own phones as well as starting their own phone-charging businesses, increasing the degree of competition in the community.[22] It was observed that this competition created resistance on the part of the connected households to new households becoming connected, as households with a productive business (e.g. hairdresser, phone-charger, bar) had a clear competitive advantage compared to households who were not connected and who relied on individual generators for power.

This issue of competition between connected and non-connected households led to another observed conflict of interest on the part of one site agent in acting as a representative of the firm on the one hand and protecting his own personal interests on the other. As a businessman already relying on generator sets, the site agent's connection to cheaper mini-grid power had enabled him to increase his income from his business of charging mobile phones. In his position as a firm's site agent, on the other hand, he had given the task of exploring and collecting the names and phone numbers of those who were interested in becoming connected. This information would be used by the firm to determine whether an expansion of the system would be viable. However, although according to the firm a fair number of people (10-15) had expressed an interest in becoming connected at the time of the study, the site agent explained that he had *"been too busy to collect names and numbers of people who was interested and to report back to the [the firm]"*.[23] This shows the risk of potential information capture in situations where communications between the firm and community members are mediated by people with vested interests.

Furthermore, the approach of connecting only some of a community created an observed entry barrier for non-connected households that it was not deemed viable to connect when the system was initially introduced. Although a household may become eligible for connection over time, it may not be viable or feasible for the firm to connect it. As highlighted by a villager who was living in a rented house at the time of registration and later built her own house in which she ran a small business (a bar), she could not on her own demand to become connected, even though she could demonstrate her ability to pay.[24] This suggests that exhibiting a "decent load" and a willingness to pay is not enough to become connected to an already operational system. Connection will happen only at the firms' discretion, and in order for it to be viable for it to make the necessary reconfigurations to the system, up-scale the capacity and take the other measures required to connect new households, a certain minimum number of interested households is needed. While solar-powered mini-grids are emphasised for their positive characteristics of being modular (Yadoo & Cruickshank 2012; IRENA 2016) and thus easy to scale according to need and additional loads, this modularity is conditioned by the existing configuration of the system, as well as, possibly, by new investments in the form of, for example, additional solar-panels, battery storage etc. Furthermore, due to the unpredictable nature of future increases in demand, it is not possible for the firm to give any indications of a timeline for making new connections, leaving those who are interested in being connected in an a situation of uncertainty.[25] Lastly, there is the risk of a potential lock-in: as these firms operate in areas far from existing infrastructure, it is unlikely that the national utility, KPLC, will extend the national grid into these areas in the near future. Furthermore there is a risk that these areas may even be bypassed by KPLC and other competing private operators in the future due to the fact that a mini-grid developer is already operating there. This presents a possible dilemma that certain parts of communities are unable to acquire access to power even though the community is already served by a mini-grid developer.

5.2 Firms combine the two logics in their work

This group of firms follows practices of site selection and customer acquisition based on population density and proximity to existing infrastructure, as well as a goal of connecting as close to 100% of the households within the chosen area as possible. This 'connect all' strategy is made sense of by a firm's representative in three ways, drawing on a combination of the two logics of economic viability and social welfare. One argument is based on keeping the costs of new connections low. The more sites built in a single area, the lower the contracting, operational and management costs (economic viability logic). A second argument is based on the firm's aim of building good relationships with the communities they serve and stresses the need to gain the acceptance of the whole community. By prioritising to connect everybody within a community, despite unviable demand from low-consuming customers, the firm gains acceptance in the community and builds its legitimacy in the areas where it works. This argument is rooted in a belief that the economic success of the firm *depends* on social welfare, prompting use of the two logics to create synergies between the two goals. One practice that was observed to ensure high connection rates within an area is to leave two vacant connections for each new sub-hub the firm installs.[26] To mitigate the negative economic impact of low-consuming customers, the firm has set up a payment scheme in which high-consuming customers are effectively cross-subsidising low-consuming customers. A collective buy-in from community members is highlighted as important in order both to gain access to exploit the cheapest options (e.g. wiring across landowners' land) and to make sure that no one is left out. *"They have to have a realistic chance of getting access to this, otherwise then you don't get complete ownership of the micro-grid by the village, and then you will have elements in the village that will oppose why they were left out, so that's key."*[27] Thirdly, by actively pursuing saturation in the areas in which it operates, the firm avoids a situation in which a large unconnected group will be left without the opportunity to connect in the future. Here the social welfare logic is nicely aligned with the economic viability logic of having access to a larger customer base in the future from which to draw valuable data and to whom to sell additional energy-consuming products or services to increase the firm's revenues.

To communicate with and reach its customers, this type of firm uses primarily 'Barazas' or open-air meetings as a platform to engage as many in the community as possible at one time. This strategy is combined with door-to-door visits to solve individual problems, as well as to reach all connected households for training purposes.[28] Open-air meetings are used during all phases of project development, from the initiation phase to provide information about the firm, phone numbers, tariff and connection fees, how to pay the bill, business numbers, connection procedures etc., to the operational phase for training purposes and for the ongoing exchange of information between customers and the firm. By applying a collective communication approach, the firm efficiently reaches its customers by spreading information to more people at once, as well as minimizing the risk of misinformation being spread (economic viability logic). At the same time, the firm supports public participation by the whole community by providing people with an opportunity to speak out and ask questions, as well as promoting the open and inclusive diffusion of information throughout the served community (social welfare logic). The two logics are thus congruent and provide synergies in supporting the overall aim of connecting as many customers as possible. Communal decision-making is therefore used as a tool to arrive at collectively agreed decisions between the firm and community members. In a move to organise households into clusters to form a single substation, one firm involved the interested households by assigning them the task of forming the groups themselves. In this way the firm transferred ownership of the process to the community, as well as the responsibility for creating a commonly accepted solution. Communal meetings were also used as a participatory exercise to include community members in decision-making processes in order to increase ownership with regard to specific decisions and the project in general. Issues such as where to place the mini-grid system (panels and container for hardware) and the process of organising households into clusters for a connection sub-hub were facilitated through common meetings in the village. These communal approaches show how social welfare measures, including democratic participation and inclusive decision-making, are used to leverage the firm's efficiency and viability goals and thus how the two logics are enacted in combination. Furthermore, one firm implemented formal procedures to increase community members' influence over the project process itself. Practices such as establishing a project committee with balanced gender representation and setting up complaint procedures were made to foster accountability of the project on the part of community members and to increase consumer rights within it (social welfare logic).

One firm emphasises the importance of community members having their own individual connections: "*Each wants their own individual connections because they want to have control over their spending and they do not want to be cut off because somebody else did not pay their portion or anything like that. So we find it best if everyone has access and control over what you are going to consume and what you are going to pay.*"[29] This shows how the interests of the community are served and how the sense of control by customers individually constitutes the basis for the decision to connect and thus reflects the social welfare logic in the firm's sense-making over how customers should be connected.

Lastly, with regard to their ongoing engagement with customers, this group of firms has established local offices or hired local staff to act as site managers. One firm has employed staff local to the specific villages in which they operate, including site managers who are responsible for the everyday operations and management of the sites. It has also opened an office within a fifty-kilometre radius of their current sites, enabling them to have daily or weekly personal interactions with the communities they serve, depending on nature and urgency of the issues to be solved. By following this practice, the firm has in-house staff responsible and readily available in the area to fix problems. In contrast to the site agent, the site manager is a formal employee of the firm who gives customers easy access to the firm. As one customer expressed it: *"I called [the site manager] and he sent a technician the next morning. He fixed the problem."*[30] Another firm has set up an office in the actual market village in which the mini-grid has been installed. Here the firm integrates the need for customers to have easy and equal access to the firm (social welfare logic) with efficiency and quality concerns in having its own trained staff, who are trusted by the community, readily available in the area (economic viability logic).

5.2.1 Effects of practices driven by a blended logic

The following effects are observed in communities where the blended logic is enacted by firms: i) high levels of trust and goodwill of community members towards the firm; ii) information-sharing and diffusion in the community; and iii) an opportunity for community members to exert power towards the firm.

By following a strategy of connecting as many households as possible within an area, regardless of individual energy demand, and by creating a collective buy-in to the idea of establishing the mini-grid in the village, the firm has won itself a good reputation and general goodwill from the people in the community. Although 100% connectivity may be the goal, this is difficult for the firm to achieve due to issues of affordability on the part of some residents who cannot afford the connection fee, as well as areas in the community where the cluster of households is not big enough to start up a sub-hub. Negative views of a firm can arise from its failure to connect individual households that have already paid their connection fees but are not yet connected, e.g. due to a lack of space for new connections in the sub-hub or too few people in an area to start up a new sub-hub).[31] However, by including as many households as possible, the firm can manage to evade *"strong descending voices within the community"* [32] and establish a generally positive view of itself within the community.[33] This goodwill towards the firm is reflected in its acceptability and the willingness of landowners to cooperate, for example, when the firm needs to take wiring across their land. Also the use of local staff underpins the view that the firm is trustworthy as far as the community members are concerned. Interviewees highlighted how their personal link to a member of the firm's staff (*"he was my neighbour", "he is like a son to me", "he is my son"*) fostered a high degree of trust, both in the novel concept of establishing a mini-grid in the village, and in the firm itself.[34]

In villages where barazas are used to communicate with customers, there is a greater degree of information-sharing and diffusion in the wider community. Using communal meetings as a forum where people can ask questions and share their views has led to exchanges of ideas and information among community members.[35] People discuss the positive and negative aspects of the possibility of accessing power, which in turn gives the firm insights into the circumstances in which it is accepted or resisted within the community in general. One firm representative highlighted the experience of how bringing people together in big communal meetings fostered a higher degree of interaction and free discussion among them. People had a tendency to speak more freely in communal meetings compared to one-to-one discussions and gained "strength" (i.e. the courage to confront the firm with critical questions) from being in a larger group.[36]

This generally observed greater availability of information, however, is also conditioned by the nature of the served community. One firm operates in a relatively small community (approximately 300 households) with a high degree of ethnic homogeneity. In this community attendance at the regularly scheduled meetings was high, apparently fostering information-sharing among village residents.[37] Another firm was operating in a larger market village (approximately 700-800 households) which was ethnically diverse. Here barazas were complemented with door-to-door visits to increase access to connected households, as communal meetings were often not well attended.[38] This was due to the fact that most people in the market village owned a shop or had a business to attend to during the daytime.

This greater availability of information, combined with the opportunity for a large part of the community to get connected, also means that competition and information capture are not so evident in these communities. Instead, deploying easily accessible firm staff has fostered equal access to information in the community, as the site manager was often present.

Lastly, increased information dissemination and 'strength in numbers' seems to increase customers’ ability to exert power over the firm. In one case a group of customers who were experiencing problems with their connection managed to put pressure on the firm by organising a boycott of power usage. As the firm was automatically alerted to any irregularities in power usage etc. through its automatic remote monitoring system, it quickly became aware of the changed usage patterns in the village. In this way, customers exerted their power to get the firm to respond quickly by taking action to solve the problem [39].

6 Reflections on the two types of responses to competing logics

This section discusses the wider institutional embeddedness of these firms in relation to the ways in which they respond to hybridity.

The two firms representing the hybrid form in which the economic viability logic is dominant are both rooted in the business sector. Furthermore, they have developed a revenue-driven business model in which they sell mini-grid projects to clients who have access to capital. This strategy is to some extent conditioned by a barrier for these firms to scaling up funding for their own mini-grid portfolios. The revenue-driven model represents a short-term business strategy in which each mini-grid sold to a client represents an income which can fund new project development. Thus drawing on both the logic of social welfare and economic viability in the firm’s self-representations can be seen as a way to gain legitimacy from a broad spectrum of actors in the mini-grid field (investors, the public, governments, etc.), while prioritising the economic logic over the social welfare logic in its actual business activities can be seen as way for the firm to respond to pressures from investors to prove the economic viability of projects in the short term in order to secure resources (Bromley & Powell 2012; Minkoff 2002).

Of the two firms representing the blended hybrid type, one is rooted in the business sector, the other in the social sector. The firm with roots in the social sector is the only one to enact what could be said to be a 'pure' form of the social welfare logic (e.g. by implementing complaint procedures) in elements of its business model. This variation could be explained by the fact, highlighted by (Thornton & Ocasio 2008), that occupational groups and professions are powerful carriers of institutional logics and that professionals socialized into a given institutional logic would therefore carry this logic over into other fields. The firm, although set up as a separate entity in trust with a CEO recruited from the private sector, is still deeply embedded in social-sector institutions, which guides its decision-making. In terms of resources, this firm is fully financed by donor financing. While it was set up as a private model, it is simply *a simulation* of a private model rather than *being* one. Tariffs, for example, are fixed through negotiations with communities, rather than reflecting the costs of the project itself. Furthermore, the firm uses an artificially low interest rate in its feasibility studies and also disregards the cost of network structures in calculating its break-even point, as these infrastructures will be handed over to Rural Electrification Authority after the project is over. This shows how the blending of logics might be determined by the firm's rootedness in the social sector, as well as pressure from the environment, for example, in the form of the government of Kenya.

In the case of the blended hybrid firm with a business origin, the logic of social welfare is not a dominant part of its organisational identity. However, in practice the firm enacts this logic through its work, but only in combination with the commercial logic. By blending the two logics, the firm does not compromise on its goal of being an economically viable firm worth investing in. Rather, it combines the two in such a way that they are mutually reinforcing to gain synergies (e.g. to connect everyone, but also to implement a cross-subsidy scheme between high- and low-consuming customers). The synergy between the two logics thus seems to be a decisive factor in its strategy of blending. This firm has strong affiliations with tech-finance communities overseas and has had several successes in raising commercial finance in the form of venture and equity capital; it therefore does not need to conform to constraints on resources. Instead, through its access to large-scale funding, its few but significant strategic partnerships with large players in the sector and its affiliation with symbolically significant climate advocates, it has been able to pursue a long-term strategy by upscaling its business and making strategic recruitments based on long-term investments. So, despite its strong affiliation with the commercial sector, which might create the assumption that it mainly relies on the logic of economic viability, its access to human and financial resources and its long-term business outlook has allowed it to pursue an integrated business model in which the short-term goal of connecting everyone (social welfare logic) is fully compatible with its long-term goal of upscaling the business (economic viability logic). This finding of the symbiotic embodiment of multiple logics within a commercial and competitive hybrid recalls the work of Battilana & Dorado (2010), who identify similar results in the case of a micro-finance institution that blended 'banking' and 'development' logics in synergistic ways, thus allowing it to achieve its financial *and* social goals simultaneously. While Battilana & Dorado (2010) found that this blending strategy led the micro-finance institution to strike a sustainable balance between the logics of development and banking and thus avoid mission drift, it remains to be seen how these firms in the Kenyan mini-grid sector will perform in the long term.

7 Conclusion

By investigating global narratives, firms' self-representations and their practices on the ground, this paper has demonstrated that the competing logics of social welfare and economic viability are both available to mini-grid firms, and it has showed in particular how such firms respond to the competing demands of these logics through their practices. While mini-grid firms are discursively constructed primarily as part of a techno-economic narrative (logic of economic viability), at the same time they actively tap into the already established narrative of the link between access to energy from mini-grids and rural development (the logic of social welfare) as a supporting argument for why they are engaged in this type of business. When we turn to the micro-level of firms' practices, however, the study found that one group of firms enacts the economic viability logic as the primary logic guiding its decisions and practices, while the second group of firms combine these two logics in their work.

The first group of firms, although including the language of social welfare in their self-representations, maintain a strong logic of economic viability in their business models as practiced. In this way the formal idea of creating social impact is merely loosely coupled to concrete decisions and actions in day-to-day work activities (Meyer & Rowan 1977; Bromley & Powell 2012). The second group of firms enacts a blend of the two logics and seems actively to seek synergies between the two to reach its commercial goals. Our findings further show that private firms backed by large-scale financing may have better conditions for creating synergies between the two logics through blending due to their ability to make long-term investments, while firms with resource constraints are more prone to respond to the immediate demands of the economic viability logic. This finding is in line with Pratt's suggestion (1998) that high-plurality responses will be least appropriate when organizations are facing strict resource constraints.

While the study is based on a small sample, with only two firms representing each group, these four firms represent the full sample of mini-grid firms that were operating in Kenya at the time of our data collection and thus provide interesting empirical insights into the sector. The development trajectory for these firms is uncertain, however, and it is still too early to judge which of the hybrid forms will create economic sustainability for them in the long term. Nonetheless the presence of these two hybrid forms is significant in that it feeds into previous research on organisational responses to hybridity which have been shown to be driven by a need for organisations to maximise their legitimacy, increase their resources and to conform to external pressures from particular field-level actors (Meyer & Rowan 1977; Besharov & Smith 2014). While the study shows that under some conditions the competing logics of social welfare and economic viability may, rather than compete, be complimentary and create synergetic effects for the firm, the strategy of blending is not a choice that is available to all firms. Our findings show that, while cultural embeddedness in the social sector explains the strategy of blending to some extent, it does not explain why purely commercial firms choose to blend. The strategy of blending seems to be driven by sense-making within the firm that blending leads to synergies for the firm in the longer term, while those firms that pursue economic viability as their predominant logic favour the prescriptions of more powerful and more dominant logics in their business models (Ocasio & Radoynovska 2016). This opens up a path for research into the organisational drivers and specific circumstances that underpin the strategy of blending, as well as for a discussion of the policy designs that may support this particular firm strategy. While policy measures like subsidies and results-based-financing are available to governments and donors to support general private sector engagement, such measures could be further tailored towards supporting explicit social welfare goals in private sector business models.

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[23] Village interview #1
[24] Village interview #2
[25] Village interview #2, #9 and #21)
[26] Staff interview #12
[27] Staff interview #5
[28] Key informant interview #11
[29] Staff interview #5
[30] Village interview #49
[31] Village interview #53 and #56
[32] Staff interview #5
[33] Village interview #49, #58 and #59
[34] Village interview #49, #51 and #59
[35] Village interview #48, #51 and #58
[36] Key informant interview #11
[37] Staff interview #12 and village interview #48 and #51
[38] Key informant interview #11
[39] Village interview #48