Innovation case studies

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Case study of innovation system building: Off-grid solar PV in Kenya

Introduction

In developing countries – particularly low-income countries – it is often the case that relevant innovation systems do not exist to support the uptake of new sustainable energy technologies. Recognising the specific challenges that these technologies often present – e.g. pre- or early-commercial development stages, the public good nature of these technologies, and the urgency of the energy access policy challenge that seeks to rapidly scale up their use (see Ockwell and Mallett, 2012, Byrne et al., 2018) – a literature has emerged that seeks to apply lessons from the field of innovation studies to the context of low carbon development and the role that clean energy technologies might play, via international policy interventions, in underpinning sustainable development trajectories (e.g. Ockwell et al., 2008, Ockwell et al., 2010, Ockwell and Mallett, 2012, Sims Gallagher, 2013, 2014, Hansen and Ockwell, 2014, Watson et al., 2015).

More recently, a body of work has begun to emerge applying these ideas specifically to the issue of sustainable energy access (e.g. Hansen et al., 2015, Ockwell and Byrne, 2015, Ockwell and Byrne, 2017), although energy access is implicit in some of the former literature on low carbon development. And a further evolution of this more specific literature now includes the increasing application of socio-technical transition theories to developing-country contexts (e.g. Baker et al., 2014, Ahlborg and Sjöstedt, 2015, Rolffs et al., 2015, Byrne et al., 2018, Ockwell et al., 2018).

In this case study, we apply this more recent approach to examine how the Kenyan off-grid solar PV market was established. The story of the evolution of this market is often described as a private sector led development success, but, as the case study shows, this is a highly simplified interpretation (Ockwell et al., 2017a). Rather, the market was established through the painstaking piecemeal interventions of often donor-funded projects over a long period beginning in the mid-1980s. The accumulated impact of these efforts was to build a strengthening innovation system around off-grid solar PV in Kenya, efforts that Ockwell and Byrne (2017) describe as socio-technical innovation system building.

The case study proceeds with a brief discussion on socio-technical transitions theory as applied here, followed by an account of the methodology. We then present the case itself and finish with a discussion of its implications before concluding.

Socio-technical innovation system building

The socio-technical transitions literature theorises widespread transitions towards the use of new technologies as being in competition with stable existing socio-technical “regimes”, understood as rules shared by actors within functional domains (e.g. the shared knowledge base, belief systems, mission, strategic orientation, etc., within a particular society’s transport system) (Geels, 2004). In this way, technologies like off-grid solar PV can be understood as “niche” technologies, competing with more mainstream, often fossil-fuel-based technologies. In the case of sustainable energy technologies, for example, regimes would include the use of kerosene for lighting, fuel wood and

charcoal for cooking, batteries for charging phones, etc., and diesel generators. Whilst we could question the extent to which these fit with the kinds of regimes studied in the Euro-centric socio-technical transitions literature, the stability and vested interests that pervade these regimes of energy practice in developing countries should not be underestimated.

The socio-technical transitions literature also understands that technologies and innovation are intricately intertwined and co-evolving with social practices (Shove, 2010), and the literature highlights the path-dependencies of existing, widely used technologies (locked-in, as they are, to regimes of social practice and existing political economic interests). When considering how new technologies might increase energy access, it is necessary to consider the social practices that consumption of energy via these technologies facilitates (e.g. cooking or reading and working at night) and the existing technologies (e.g. wood stoves or kerosene lanterns) that currently support these social practices. Politics aside, without consideration of the social practices that energy technologies are intended to facilitate, there is a high risk that interventions will be overly managerial and ultimately fail to effect any kind of long term change (Shove, 2010). As Stirling (2015: 1) asserts, innovation is not just about technological invention, "… it involves change of many kinds: cultural, organisational and behavioural as well as technological". Indeed, Rolffs et al. (2015) demonstrate how attending to the social practices of poor women and men in paying for and consuming energy underpins the seemingly transformative success of contemporary mobile payment based finance models for solar PV that are currently attracting so much attention across sub-Saharan Africa.

Understanding the significance of paying attention to social practices when attempting to introduce new technologies is helped by the notions of 'fit' and 'stretch' (Hoogma, 2000, Raven, 2007). The idea here is that new technologies not only need to successfully harness technical principles so as to work in the technical sense, they also need to 'work' in a social sense. That is, they need to fit with people's existing social practices. Mobile payment-based finance models, for example, have repayment levels set at rates similar to normal day-to-day payments for kerosene. In other words, repayment terms fit with people's existing cashflow practices and so do not introduce new constraints. But, because these finance models enable people to get access to electricity, they also stretch practices. In this case, access to electricity facilitates access to practices that would otherwise be unattainable: e.g. the opportunity to study under a clean bright light compared with studying under the inferior and polluting light of a kerosene lamp. This stretching of practices is especially important for making a new technology attractive.

In this way, the socio-technical transitions literature offers us a theory of how change might occur in sustainable energy access. But to understand how new technologies in particular can be promoted, we need to focus on the part of the transitions field referred to as strategic niche management (SNM) (Kemp et al., 1998, Raven, 2005). This is concerned with how "niche" technologies – like new sustainable energy technologies – can be fostered to the extent that they can compete with socio-technical regimes.

This literature, based on extensive empirical analysis, has developed a number of core principles through which niche technologies might be strategically managed in order to influence socio-technical regimes. There is not space to introduce these principles in depth here (see Ockwell and Byrne, 2017 for a detailed introduction), but the core categories focus on the need for:

- Creating protective spaces
- Fostering experiments and learning
- Developing actor-networks
- Fostering shared visions
- Building institutions

Taken together as a systemic policy intervention, we can refer to them as socio-technical innovation system building (Ockwell and Byrne, 2017). This recognises the importance of focussing on social practice and the need to compete with socio-technical regimes, while extending this to recognise the fact that new sustainable energy technologies also require functioning innovation systems within which to foster adoption and further evolution. In many developing countries – lower income countries in particular – innovation systems around sustainable energy technologies tend to be fragmentary or weak (Byrne et al., 2012). They therefore need careful cultivation in order to create the conditions within which new markets for sustainable energy technologies can thrive.

Methodology

Our case study focusses on the off-grid solar PV market in Kenya, which enjoys widespread recognition as a huge success story (Ockwell and Byrne, 2017). We include in the case both the market for solar home systems (SHSs) and the emerging but rapidly growing market for solar portable lanterns (SPLs). Kenya has one of the world's leading markets for off-grid solar PV in general (REN21, 2019) and for SPLs in particular (GOGLA et al., 2019).

The received wisdom explaining the success of this market sees it is an example of private sector led development, and it is often further described as an unsubsidised market. This is repeated in both the grey literature and academic publications (e.g. Jacobson, 2007, Ondraczek, 2013, van der Plas and Hankins, 1998) and echoed amongst many donors and international observers, which is perhaps unsurprising given the resonance of this narrative with the dominant neoliberal development ideals (Selwyn, 2014). But, as the case demonstrates, this narrative is an oversimplification. Private sector actors have certainly played an important role in helping to grow the Kenyan off-grid PV market, but the public sector has been crucial, predominantly in the form of donor funding to enable the implementation of a range of projects over time that, in effect, have built a functioning innovation system around off-grid solar PV. The case, therefore, has implications for how to better promote the adoption and sustainability of energy access technologies, whether for electrification or for other energy services such as cooking.

One point of clarification is important here in relation to the declining price of solar PV. The cost of solar PV decreased by around 50 per cent, for example, over the five years to 2015 (Chattopadhyay et al., 2015). This will clearly have helped to increase sales of solar PV globally, including in Kenya. It is important to emphasise, however, that this declining price cannot, on its own, explain the *relative* success of the solar PV market in Kenya. If declining price were the key issue then market growth should have been witnessed everywhere in Africa. It has not been – not, at least, to the extent that it has been in Kenya. Even the same development interventions around solar PV, like the solar lighting efforts pioneered by Lighting Africa (under the International Finance Corporation – described in more detail below) met with different levels of success in Kenya (where

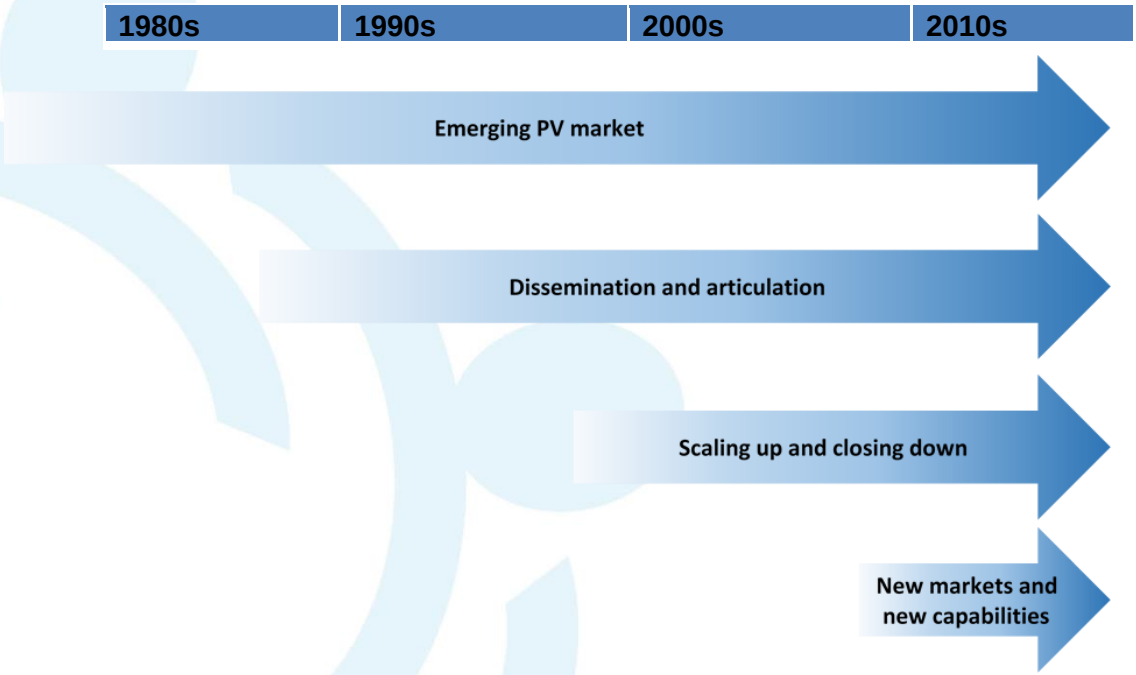
it was highly successful) and elsewhere, such as in its other pilot country, Ghana (where it is reported to be less successful). There are therefore important explanatory variables that need to be analysed and understood before any kind of transformative policy intervention might be designed based on learning from the Kenya PV success story.

The history summarised below is based on over 100 hours of recorded interview testimony collated during three phases of fieldwork in 2007-2008, 2012-2014 and in 2016, the results of a stakeholder workshop held in Nairobi in 2013, and extensive use of the peer-reviewed and grey literatures, including further work in 2019 focussed specifically on Lighting Africa. Working with our partners at the African Technology Policy Studies Network (ATPS) in Kenya, we modified Douthwaite and Ashby's (2005) "innovation histories method" (see Becker et al., 2013, Byrne et al., 2014) to focus on the analytic categories of the SNM literature outlined above. This facilitated semi-structured interviews that picked up on these analytic categories, providing (along with the stakeholder workshop) the data necessary to develop a detailed innovation history of the off-grid solar PV market in Kenya. Later research work was conducted with the African Centre for Technology Studies (ACTS), also based in Kenya. This history was then interrogated to understand how the market had emerged and the different factors that led to the successful market that exists today.

Summary history of the Kenyan off-grid solar PV market

Below we provide a brief summary of the emergence and development of the Kenyan off-grid solar PV market (and see Byrne et al., 2014, Ockwell and Byrne, 2017, Karjalainen et al., 2018, Ockwell et al., 2019 for more detil). As illustrated in **Figure 1**, this history can be summarised around four over-lapping phases. We summarise each of these phases in turn below, before discussing their relevance to a socio-technical innovation system building reading of this history and its implications for policy and practice.

Figure 1. The four phases of off-grid PV development in Kenya



Source: Authors

Emerging PV market: 1970s to 1980s
Contrary to the idea that the off-grid solar PV market in Kenya is a free market phenomenon, the market in fact has roots that stretch back to the 1970s. It is difficult to develop an accurate picture of exactly what applications were using solar PV in the early days, or who was funding their use, but it seems they were mostly focussed on telecommunications applications (Hankins and Bess, 1994, Duke et al., 2002). In the 1980s, more clearly documented examples can be identified, referring to PV applications for clinic and vaccine refrigeration (McNelis et al., 1988, Roberts and Ratajczak, 1989). These experiments with PV included funding from USAID and the World Health Organization Expanded Programme on Immunization and can be set against a context of wider development efforts in sub-Saharan Africa (beyond Kenya) that used solar PV for various applications, including rural clinics, vaccine refrigerators, school lighting and TV/VCR, water pumping, and outdoor lighting (Roberts and Ratajczak, 1989). At the same time, a number of operators set up offices in Nairobi with an eye on exploring the potential future market for solar PV in the country, but with no significant market having yet been established. These included, for example, Animatics, an agricultural equipment supplier in Kenya, BP Solar and Total Solar (Byrne, 2011).

The discovery of a household market for solar PV in Kenya seems to have happened in the early 1980s, largely through the efforts of two key individuals: Harold Burris and Mark Hankins, both of whom came to Kenya initially via the US Peace Corps (Acker and Kammen, 1996, Duke et al., 2002, Jacobson, 2004, Byrne, 2011). Burris, an engineer with a background in the nascent US solar industry, is credited with much early experimentation with PV systems, looking for configurations that might work in various Kenyan contexts, e.g. for powering sewing machines (his Kenyan wife was a seamstress) (SolarNet, 2001, Hankins, 2007, interview). When Burris later met Hankins, together they pioneered an installation of PV in the school where Hankins was volunteering (Byrne, 2011). This was based on a cost analysis that demonstrated to the school's board of governors that PV would be cheaper in the long run than using a diesel generator (which the board were considering buying) (Perlin, 1999), as well as a visit by the governors to Burris' home to see the system he had installed there. Subsequently, the head teacher and several other teachers bought PV systems for their homes (Hankins, 1993, Kimani and Hankins, 1993).

Soon after this initial installation, Hankins worked with Burris to develop a funding proposal to USAID (Hankins, 2007, interview). This allowed them to install systems in three more schools and, crucially, to train twelve Kenyans as solar technicians. It included the production of a training manual for solar technicians and training for the twelve chosen technicians in how to sell, install and maintain PV systems. At the end of this USAID-funded schools installation project, Burris and Hankins organized a networking event in Nairobi for the technicians to meet the PV and equipment suppliers who were based there. This resulted in several of the technicians being employed by the suppliers, whilst many of the others were employed by Burris in his own company (Byrne, 2011). After the successful school demonstration projects, all of which inspired teachers to buy PV systems for their homes, Burris began to market these 'solar home systems' in the area around the

schools, a relatively rich part of Kenya due to the production of cash crops. Within a few years, Burris and his technicians were busy installing SHSs and the PV suppliers in Nairobi began marketing in the same area once they heard about its growing success.

It should be emphasised that at this time there was no commercial market in Kenya for what are now known as “solar home systems” (SHSs). This early experimentation by Burris and Hankins drew heavily on technical experimentation by Burris, including experimenting with locally available components, like 12VDC lights that were being supplied to local buses. Burris also managed to persuade a local car battery manufacturer to produce batteries better suited to the charge and discharge conditions characteristic of SHSs (Hankins, 2001). With Hankins, this experimentation extended to attempts to understand user needs at different levels of application, from public buildings to individual households (Byrne, 2011).

Dissemination and articulation: late 1980s onwards
By the late 1980s, several companies were beginning to focus their activities on supplying components to this emerging household market (Byrne, 2011). This included the battery manufacturer Burris had persuaded to produce SHS-suitable batteries (Chloride Exide – now the largest supplier of solar modules in Kenya) (Ockwell and Byrne, 2017). Hankins, who had gone to the UK in the late 1980s for a master’s degree at Reading University, discovered there was a thriving SHS market when he returned to Kenya to do research for his dissertation. After gaining his master’s, he returned to Kenya and began to get more involved in solar training, and started his own company, Energy Alternatives Africa (EAA). Through this he started to win project funding to help experiment with ideas for further developing the SHS market.

Over the next decade or so, EAA became an important player in the Kenyan SHS market by implementing many projects with funding from various donors (Ockwell and Byrne, 2017). Some of the projects involved installing PV systems in community buildings, such as schools and hospitals, alongside training of local technicians. Others involved developing and testing various products or balance-of-system components, such as solar lanterns and battery charge regulators. Some projects helped build local manufacturing capabilities and capacity, such as for solar batteries. And some projects involved testing different financing mechanisms, such as micro-credit through local Savings and Credit Cooperatives.

There was also a much more concerted effort to survey and understand the potential market for solar PV in Kenya (Byrne, 2011). For example, Hankins managed to get funding for a more extensive study than the one he had conducted for his master’s dissertation, based on a detailed survey of 410 households that owned SHSs. This included questions on technology performance, how people were using SHSs and for what purposes, how supply chains were working, and so on. Hankins published the main findings in a paper in the peer-reviewed journal *Energy Policy*, co-authored with a key person from the World Bank (see van der Plas and Hankins, 1998). Many more surveys and market intelligence efforts followed, again often donor-funded and made available in the public realm (Byrne, 2011). As a result, a far more fine-grained understanding of the market in Kenya began to emerge, while the market itself continued to grow.

These efforts to understand the market from multiple perspectives – including those of users, and to articulate this information in publicly-available material – conform to the kinds of activities that

characterise a socio-technical innovation system building approach. Similarly, they included significant efforts to build networks of actors. Presentation of the market intelligence material, and the significant advocacy work that Hankins and colleagues were doing at the time, brought this nascent market to the attention of powerful international actors, including the World Bank and the new (at the time) Global Environment Facility (GEF). By the mid-1990s, when the GEF was beginning to look for projects to promote renewable energy technologies, the potential of scaling up the promising PV market in Kenya was attractive (Byrne, 2011). In 1998, the GEF and IFC began implementing the Photovoltaic Market Transformation Initiative (PVMTI), a project we discuss in the section below summarising the third phase of Kenya's PV market evolution.

The activities during the first two phases of the emergence of the solar PV market in Kenya clearly resemble the kinds of experimentation and learning that the niche management literature emphasises as critical to developing socio-technical niches that are able to compete with existing regimes. A niche for solar PV seems to have emerged at the household level, supported by efforts to align this with existing social practices and users' articulated needs. For example, Burris developed various forms for recording information about a householder's electricity needs and these were tailored to the kinds of homes that were characteristic of rural Kenya (Byrne, 2011). Potential users were able to see how this new – probably perceived as risky – technology might replace their reliance on existing technologies like diesel generators. This can be interpreted as an important site of learning. Hankins and Burris seem to have articulated a clear vision for how solar PV might meet local electricity needs. The marketing efforts supported broader enrolment in these visions. Furthermore, network building began, both through the demonstration projects in schools and the wider marketing efforts.

The training of local technicians also provided the beginnings of the institutionalization of practices around solar PV in Kenya – another key tenet of niche management. Indeed, the training manual Hankins developed for the USAID-funded schools project provided most of the material he would later use to write what became a textbook of PV system installation tailored to an African context. Importantly, the donor-funded nature of these activities (including the energy cost analyses comparing existing energy consumption in schools to future costs with PV) meant that all of this information was available in the public realm (Ockwell and Byrne, 2017). This meant that others could access and build on the information, in contrast to the kinds of private sector led market research and experimentation that is usually commercially protected and cannot therefore contribute to broader systemic developments in potential new markets.

It is also possible to see, even from this brief summary of events, how a nascent innovation system had begun to emerge around household applications of solar PV. This includes various component suppliers, technological capabilities around solar batteries and trained technicians, market research efforts, the beginnings of marketing models, and so on. As we will see below, these early activities began to provide the bedrock for what would become the burgeoning socio-technical innovation system that exists around solar PV in Kenya today.

An SHS niche can therefore be understood to have developed in Kenya, together with key aspects of a relevant innovation system, facilitated in large part by the strategic activities of certain key actors, particularly EAA. Over time, EAA worked with a wide variety of actors in the SHS niche in Kenya, and on a range of dimensions of the niche – some technical, some financial, and some

managerial. While doing so, Hankins wrote extensively about the various experiences, sometimes as a reporting requirement of the donors, and sometimes for his own publication record. The effect was to help build the actor-networks noted as important by niche management and the innovation systems literature; create many opportunities for learning in real-world settings, sharing this learning widely; build detailed market information, especially in articulating consumer preferences; and help to embed new socio-technical practices, not least through the solar training courses. Furthermore, Hankins, in particular, became an opinion leader in the solar field in Kenya, tirelessly promoting the technology locally and internationally.

Scaling up and closing down: late 1990s onwards
From the late 1990s onwards, the activities described above intensified as the PV market in Kenya continued to grow, and interest in scaling up this growth turned to action, but there were also efforts to close down around various perceived best practices. A range of different projects around solar also continued to be implemented, mostly donor-funded with technical foci: e.g. experimenting with different technologies and technical configurations in an effort to find what worked best in various Kenyan and other East African contexts. This included efforts in neighbouring Tanzania, where Hankins and EAA also began to play a leading role.
Following consultation with Kenyan PV actors to identify the "barriers" to scaling up the market, the IFC developed a proposal for transformation of what it described as a "true free market for PV products in Kenya" (IFC, 1998: 12) (and two other pilot countries). As mentioned above, in 1998, the IFC began implementation of this Photovoltaic Market Transformation Initiative (PVMTI) financed by the GEF.

PVMTI was essentially what can be characterised as a "hardware financing" intervention (Ockwell and Byrne, 2015). It framed the "barrier" to scaling up the market for PV in Kenya as the high cost of PV modules (Byrne, 2011). To overcome this barrier, the project would provide finance to suppliers so that they could buy modules in bulk, which should reduce the module price in the local market. It would also provide loans for consumers – through microfinance institutions (MFIs) – so they would be able to overcome the upfront costs of buying SHSs (Gunning, 2003). To support this supply and demand side intervention, PVMTI made a total of USD 5 million finance available to local actors. Negotiations on finance deals with local supply consortiums, MFIs and banks were, however, generally unsuccessful (Ngigi, 2008, interview). By the early 2000s, only around 170 SHSs had been financed as a result of the initiative (IFC, 2007), which is hardly a transformation in a market with annual module sales at the time in the region of 10,000-15,000. Consequently, a high degree of frustration developed amongst local PV actors (e.g. see various letters that appeared in the regional magazine SolarNet: Muchiri, 2001, de Bakker, 2001, Bresson, 2001). A range of factors contributed to the failure to broker finance deals for SHSs through the scheme. These include (Byrne, 2011):

1. Minimum deal-size being too large for the Kenyan market. Minimum investment was USD 0.5 million from a local actor, to be matched by PVMTI. No local suppliers were able to mobilise this level of investment on their own.
2. Misalignment between the IFC and local banking rules, making it impossible for either party to finalise deals.

3. Transaction costs being too high for mainstream banks, despite some interest in bundling deals for on-lending to MFIs. The deal flows ended up being too small compared with the costs of managing them.

In their frustration with PVMTI, Kenyan PV stakeholders began lobbying for the money to be diverted to support capacity building around PV in Kenya, as opposed to direct financing for technology uptake (van der Vleuten, 2008, interview). This was eventually agreed, and increased funding was channelled into developing a Kenyan PV training curriculum, introducing technical standards for the industry, and developing training courses for vendors and technicians together with printed manuals for these groups and their customers (Magambo, 2006, IFC, 2007, Nyaga, 2007, interview). These are all fundamental building blocks for developing functioning socio-technical innovation systems. Other kinds of PV finance experiments were tried during this time in Kenya, including efforts through MFIs (Byrne, 2011). These were largely unsuccessful, but generated important learning around whether or not microfinance might work; learning that was critical to the later development of the mobile payment based solar finance models (see Rolffs et al., 2015, and some brief discussion below).

Another important development, with significant relevance in terms of the institutionalisation pillar of socio-technical innovation system building, was the emergence in the early 2000s of focussed attention on the need for standards for PV equipment. Going back to at least the time of Hankins' master's dissertation (Hankins, 1990), issues of equipment quality had dogged the Kenyan market for years. Regular examples abounded of bad practices, badly designed SHSs and poor-quality components such as batteries, modules and lights. Eventually, by the late 1990s and early 2000s, the Kenyan Bureau of Standards was persuaded by actors in the PV industry that something needed to be done (Gisore, 2002). A committee of Kenyan PV actors was convened to advise on this and agreed on the introduction of PV standards (Loh, 2007, interview). But these standards were not widely adopted by technology suppliers and installers, leading to the eventual introduction of regulations (Mabonga, 2013, interview, Mboa, 2013, interview). These introduced strict, legally enforceable, rules around PV in Kenya and characterise a period of gradual closing down in the market around accepted norms of what represented good and bad practice (Ockwell and Byrne, 2017). There are claims that these regulations have led to significant improvements in the market, although we are not aware of any empirical research to support these claims.

As well as this institutionalisation process around standards and regulations, the advocacy work done by the PV industry actors involved also had significant networking benefits. The actors who convened to advise on standards-setting quickly realised that some kind of PV industry association would be of benefit in Kenya (Loh, 2007, interview). This led to the formation of the Kenya Renewable Energy Association (KEREA), which was still active at the time of writing.
Through the connections developed between KEREA, the Kenyan Bureau of Standards and other national energy policy actors during the standards and regulations setting processes, we can see the beginnings of advocacy efforts by the PV industry to influence energy policy in Kenya. The story of these policy advocacy efforts and their outcomes, and the treatment of solar PV by national policy in Kenya, is a messy one, too long to tell here (see Ockwell and Byrne, 2017, for more detail). Generally the relationship between PV market actors and the Kenyan government has been up and down (e.g. VAT was introduced on solar components, then reduced, then reintroduced) and could be described as lukewarm at best, with policy makers often hostile to the

industry (see Newell and Phillips, 2016, for a political economy perspective on this). In this sense, PV actors have struggled in their relationships with Kenyan energy policy makers, although the most recent iteration of energy policy indicates something of a thaw in these relations (Byrne et al., 2018).

New markets and new capabilities: late 2000s onwards

From the late 2000s onwards, another distinct phase of market development began. This took on the rhetoric of "the fortune at the Bottom of the Pyramid [BOP]" (Prahalad, 2004), understanding that SHSs were relatively expensive and therefore the preserve of the rural middle classes as opposed to the poorest people. Various actors began to develop ideas around how to introduce solar PV into the lives of the poorest women and men. There are three particular developments of note in this phase of the market's development, all of which speak loudly to the idea of socio-technical innovation system building. The first is the IFC's Lighting Africa programme, the second is the emergence of Kenya's first solar module assembly plant (see Ockwell and Byrne, 2017, for more on these two developments), and the third is the emergence of pay-as-you-go (PAYG) mobile payment models for solar (see Rolffs et al., 2015, for more on this). All three developments are summarised below.

Lighting Africa was launched in 2007 with the aim of catalysing the market for clean lighting at the BOP in Africa. At that time no solar products existed that targeted this part of the market. Earlier attempts had been made, but these failed (Byrne, 2011). Certain technical improvements in the early 2000s, like white LED lighting and improvements to batteries (largely the result of efforts within the mobile phone and laptop industries) meant that the design of smaller and cheaper lanterns was more feasible. The global lighting industry was not, however, engaging with these potential opportunities. Lighting Africa therefore set out to address this, with Kenya as one of its two pilot countries (Ghana was the other). It did so via a wide range of both technical and capability-building activities (see Ockwell et al., 2019, for a deeper analysis of the Lighting Africa Programme and its implications for modern energy cooking services).

The important thing about Lighting Africa's approach is that the suite of activities it pursued looks very much like the kinds of systemic interventions that characterise socio-technical innovation system building in practice. For example, the programme used competitions to award grants for technological innovations based on design criteria that reflected the social practices of people at the BOP, thereby raising the chances that the resulting solar lanterns would be adopted by poor women and men. This included, for example, the ability to reverse engineer and replace parts of lanterns and for them to enable additional services such as mobile phone charging.

Simultaneous to developing the technology-oriented competitions, Lighting Africa quickly began implementing a wider range of activities after its launch in 2007. By the time of its second-year progress report, these included: market research in several countries; product testing and the development of quality assurance methodologies; identification of financing needs throughout the value chain; knowledge-sharing and self-evaluation; and moves to identify policy constraints by researching the policy environments in several countries (WBG, 2009). For Kenya, by the end of 2008, there were already highly detailed qualitative and quantitative market assessments (IFC, 2008a, b). And much more research followed including on products available in Kenya, product-

testing, and a review of the policy environment and policy actors (see the Lighting Africa website[1] for these reports).

In 2009, Lighting Africa became much more active in Kenya in terms of interventions. Over the next few years – up to the official completion of its pilot phase in late 2013 – the programme engaged in an aggressive and roaming awareness-raising campaign, quality-assurance labelling of products, setting-up of a product-quality testing facility, training of technicians, capacity-building for business development and for finance institutions, lobbying of policy makers on regulations, and building of networks of actors to encourage the flow of information (Ockwell et al., 2019). Whilst it is difficult to determine the extent to which outcomes can be attributed directly to these efforts, the programme made a series of claims: e.g. by December 2014, Lighting Africa was claiming that over 14 million people across Africa had access to clean lighting and over 7 million solar lighting products had been sold across the continent (Lighting Africa, 2014). Castalia Strategic Advisors (2014), in assessing the Lighting Africa Programme at the time, estimated that only 29,000 lamps had been sold in Kenya in 2009 rising to 680,000 Lighting Africa certified lamps in 2013, which is suggestive of the Programme's success (and Castalia Strategic Advisors were themselves confident that the Programme's activities had indeed been important in establishing such explosive market growth). GOGLA[2] et al. (2019) estimate that global sales of quality-assured SPLs for 2018 were 5.5 million, 30 per cent of which were sold in East Africa. If non-quality-assured lamps are included, GOGLA et al. estimate the global market to be as much as three times this size.

Lighting Africa therefore looks very much like the kind of socio-technical innovation system building intervention articulated above. There are, nevertheless, several potential qualifications to the Lighting Africa success story. First, the Lighting Africa scheme focusses on one small-scale technology, and the social practices around lighting and mobile phone charging (and its implications for connectivity, see Jacobson, 2007). This has raised questions for some observers as to the extent to which lessons from Lighting Africa are relevant to larger scale energy technologies capable of underpinning economically productive energy uses – a particular concern of experienced commentators such as Barnett (2014). Second, it has been reported that the success of Lighting Africa in Kenya was not mirrored in Ghana (Urama, 2014). This raises a number of important questions warranting further research. Could the greater level of success in Kenya be due to the socio-technical innovation system that existed there as a result of the system building activities described in the history above – activities that are not mirrored in Ghana? Or is it, as the World Bank implies (World Bank, 2014), something related to the political economy of energy in Ghana, or the specific nature of the country's politics and decision making?

The next notable development around solar in Kenya in recent times is the establishment of the country's first ever solar module assembly plant, under the banner of Ubbink[3] in Naivasha. This suggests that, in line with much of the innovation studies literature (see Hansen and Ockwell, 2014, for a review of this literature), the market around solar PV in Kenya has developed to the extent of indigenising increasingly sophisticated PV technological capabilities. A visit to this assembly plant in 2013 demonstrated innovative levels of capabilities, with the company having

[1] http://www.lightingafrica.org/
[2] GOGLA is the Global Off-Grid Lighting Association https://www.gogla.org/
[3] Ubbink is now Fosera https://fosera.com/about/assembly-lines/kenya/

innovated in the production process to double production capacity within one year whilst simultaneously maintaining quality and gaining a reputation throughout East Africa for producing quality solar modules. According to their website, the company now employs about 100 people, and is producing about 70,000 modules per year. During the 2013 visit, we were told that all the employees at that time had been trained in the production process, implying further knock-on benefits for Kenya's technological capabilities around solar PV (Ockwell and Byrne, 2017).
The final contemporary development of note in Kenya is the emergence of PAYG mobile payment business models for financing off-grid PV in the country (see Rolffs et al., 2015). These payment models operate through the MPESA mobile payment mechanism (developed using donor-funding) (Onsongo and Schot, 2017) that has been a huge success in Kenya, meaning people in rural areas can use mobile payments as opposed to having to travel to take out and to store large quantities of cash. The transformative aspect of the mobile payment models for solar PV is that they have been developed on the basis of companies having spent years trying to understand how poor women and men pay for and consume energy. Through these payment mechanisms people can pay for SHSs and solar lanterns in ways that match how they would normally pay for kerosene. They therefore conform to the kind of best practice implied by the emphasis on social practice that a socio-technical innovation system building approach promotes. The significance of this is clearly illustrated by how fast these mobile enabled solar payments companies have expanded in recent years. Globally, according to REN21 (2019), more than 30 companies now use a PAYG business model for selling solar PV. Sales are concentrated in East Africa, with Kenya recording of USD 58 million dollars' worth of the market (GOGLA et al., 2019).

Conclusion

From the summary history presented above, we can draw a number of key lessons for informing future interventions that seek to expand access to sustainable energy technologies amongst poor women and men. Overall, the case study shows that explaining the success of the Kenyan solar PV market involves much more than describing private firms competing with each other in a free market as they seek to sell PV systems to consumers (as can also be seen in the Tanzanian case in Appendix 2). The private sector clearly played a role – particularly later in Kenya's solar PV history, where national capabilities developed to the extent that a burgeoning socio-technical innovation system can be identified, providing the conditions within which private sector led initiatives could thrive and help the market to grow. But this was only part of the story. The key forces that worked to create these enabling conditions were driven by long term systemic efforts by a range of key actors, often (and importantly) with donor-funding. Even though some of the key actors involved in this history, like Hankins, operated through private companies, the activities they undertook were much more broadly focussed on building the market, with strong normative commitments to the development benefits of these interventions.

Over the full sweep of Kenya's PV history, the accumulated activities key actors pursued represent what amounts to a broad and systemic set of interventions, all of which were developed from understanding the social practices of people in rural Kenya around paying for and consuming energy services. This was accompanied by experimentation, demonstration projects, network building and linking different actors across the nascent innovation system, the articulation of clear visions around how solar PV might contribute at the household level in Kenya, and multiple activities that served to codify and institutionalise best practice. Most of these activities took place over several decades, but the Lighting Africa intervention suggests that such socio-technical

innovation system building might be achieved over much shorter periods of time. However, as noted above, the Lighting Africa Programme was reportedly less successful in Ghana. Whether the differential success of the programme in Kenya and Ghana can be explained by the differences in the strength of the PV innovation systems in each country remains an open question, answerable only by further research. But it should be clear, in Kenya at least, that Lighting Africa was able to build upon a partially developed PV innovation system when it started operating in the country.

The case study findings, then, point to the importance of long term sustained investment in building a socio-technical innovation system around a specific energy service technology such as solar PV or, from the MECS Programme perspective, clean cooking technologies. If such an innovation system is to be both successful and relevant to the lives of poor women and men, it is essential that the specific interventions that drive the building process are informed directly from understandings of the lives of such groups, beginning with understanding their existing practices and then seeking to realise their desired practices. Achieving these outcomes will depend on the support of actors who can bear the long term risks of sustained investment, which means the public sector must play an active role but with the appropriate collaboration of private sector actors.

Case study of innovation system building: SHSs in Tanzania

Introduction

Interest in solar PV in Tanzania has a long history, beginning in the late 1970s and continuing through the 1980s and 1990s with various small projects and scattered attempts at wider dissemination (Byrne, 2011). From the late 1990s, interventions funded by donors became more systematic and wide-reaching and, in the 2000s, culminated in a series of relatively large donor-funded projects that nurtured the foundations for a now-burgeoning socio-technical innovation system around the technology. A proliferation of private sector actors is now exploiting these foundations, and the market for PV – whether as solar home systems (SHSs) or solar portable lanterns (SPLs) – is flourishing, with an estimated penetration of installed PV systems exceeding 25 per cent of households as of 2016 (NBS and REA, 2017: 46). According to Karjalainen et al. (2018: 72), there are more than 50 companies active in the PV market in Tanzania. And, based on figures from Tanzania's National Bureau of Statistics and Rural Energy Agency along with analysis from the Global Off-Grid Lighting Association (GOGLA), Tanzania may have in excess of 1.3 million PV systems installed (NBS and REA, 2017: 46) (GOGLA et al., 2019: 27).

This case study traces how this successful market was established, demonstrating that it was not simply the outcome of private sector actors competing in a free market to deliver solar-powered electrification. Instead, the market has been established through the many and deliberate actions of both the public sector (mainly involving donors) and private sector; actions over an extended period that, in effect, nurtured the building of a socio-technical niche around PV. Much of the significant work to build this niche took place during the 1990s and 2000s, and so the case study focusses more on this period than others. And much of this niche-building in Tanzania resembles the work done in Kenya in general around PV (Ockwell and Byrne, 2017) and in particular around SPLs (Ockwell et al., 2019), as well as resembling work elsewhere (e.g. Bhamidipati et al., 2019 on PV in Uganda). Thus, an important lesson arising from this case and others is that establishing a successful market is not just about developing the right business model and, as we have argued elsewhere, focussing on financing the deployment of technological hardware (e.g. Ockwell et al., 2017a). It is fundamentally about nurturing the essential components of socio-technical innovation systems.

In the next two sections, we briefly explain our theoretical framework and our methodology. We then provide the case study itself followed by a discussion of its implications before summarising and drawing conclusions.

Theoretical framework

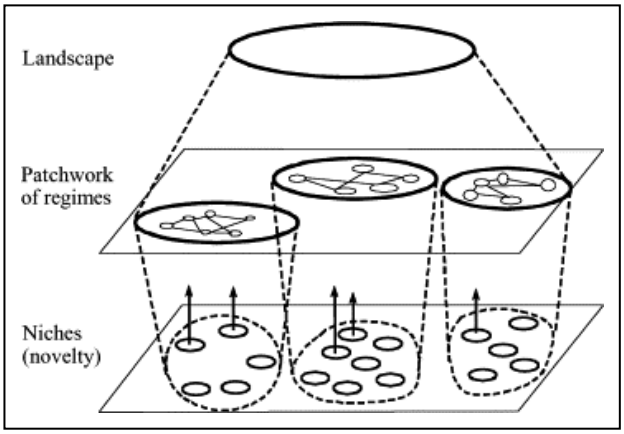
We use the theoretical framework Strategic Niche Management (SNM) to guide our data collection and analysis. According to SNM, new or novel technologies and practices emerge from experimentation in real settings. Within these spaces, interested actors help to protect novel socio-technical configurations[4] from the potentially rapid failure that could result from having to compete under mainstream market selection pressures (Raven, 2005). Experimentation generates learning, builds networks of sympathetic actors, and gradually embeds the novel socio-technical

[4] Technologies are considered to exist together with social, cultural and other practices and so are referred to as socio-technical configurations in order to capture this multi-dimensional view.

configurations into the mainstream (Byrne, 2011). SNM refers to such protected spaces as *niches*, while the mainstream consists of *regimes* (the dominant ways in which a societal needs are met, such as the technologies and practices around biomass-based cooking in many poor countries) and the broader context is referred to as the *landscape*. Niches, regimes and landscape are related hierarchically (see

Figure **2**) in a multi-level perspective (MLP) where the hierarchy reflects the increasing strength and obduracy of the structure at each level (Geels, 2002). When analysing the evolution of a novel socio-technical configuration, SNM directs us to investigate various interacting processes identified from novel technological experiments in a (protected) social context. These can be summarised as: the quality of learning; the composition and quality of actor networks; the evolution of collective socio-technical expectations and visions; and processes of institutionalisation.

Figure 2. The multi-level perspective



Source: Geels (2002: 1261)

Learning is conceptualised in first- and second-order forms within SNM. First-order learning arises when technologies are tested in practical settings. It is instrumental learning, concerned with the functioning of technologies, not with the assumptions on which their use rests. In contrast, second-order learning arises “when conceptions about technology, user demands, and regulations are … questioned and explored” (Hoogma et al., 2002: 194). Second-order learning results in a change of assumptions about the novel socio-technical configuration and has implications for the kind of experimentation that actors then pursue (see the methodology section for more on this). Networks of actors are important for attracting resources to experiments, building constituencies of support, and providing multiple sites for experiments from which lessons can be drawn and translated to other contexts (Raven, 2005). Broad networks (i.e. involving a diversity of actors) are more helpful for novel technologies than networks of mainstream actors, who may be more interested in maintaining the status quo (Hoogma et al., 2002).

Socio-technical expectations and visions are descriptions of future states of the world in which particular socio-technical configurations perform better than others (Berkhout, 2006). When expectations and visions are shared by many actors, they guide the activities of those actors in

similar directions (Geels and Raven, 2006). This creates the possibility for similar experiments to take place in multiple settings and for many different lessons to be learned simultaneously about any specific socio-technical configuration.

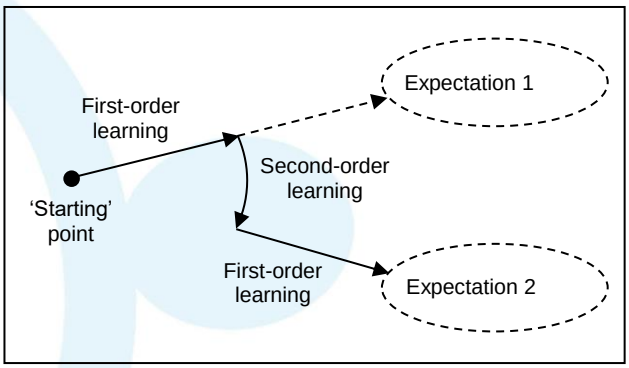
Institutionalisation is the process of embedding practices into the routines of actors – whether users or producers, policy makers and others – and the creation of relevant policies, laws, regulations, etc. (Deuten et al., 1997, Raven, 2005). As practices become more widely embedded so the niche structure becomes more stable and the niche is able to grow, eventually becoming competitive with the current regime. In time, the niche could replace the regime altogether.

Methodology

We follow Byrne (2011) in operationalising the niche concepts explained above. A socio-technical expectation is taken here to be a 'target' towards which actors align their activities, while a socio-technical vision specifies the means to achieve the expectation and defines the expectation in greater detail. First-order learning is generated when actors pursue a particular expectation. They hold assumptions that guide their learning while they experiment with a socio-technical configuration, and the learning fills in detail to develop a vision. Second-order learning results in a change to assumptions and a new direction; a new expectation, different experiments and new first-order learning to envision the expectation.

Figure 3 shows these ideas. Actors initially work towards Expectation 1, which could be experimenting with SHSs in a pastoralist setting, making progress through first-order learning that involves gathering factual data about SHSs, users' perceptions of the technology, the results of marketing efforts, and so on. Second-order learning changes their assumptions, resulting in Expectation 2. Here, niche actors might realise that fixed SHSs are less amenable to the semi-nomadic practices of pastoralists and so might decide to experiment with SPLs as these can be carried easily from place to place. Learning about SPLs in such settings will mean conducting different experiments and this will require gathering new facts – about the technology, users' preferences, etc. – and so will mean generating new first-order learning to develop a new vision. Other niche actors might continue to pursue experimentation and learning around SHSs, as they might continue to hold an expectation that these will work well for other users.

Figure 3. Representation of first and second-order learning related to expectations and visions



Source: Byrne (2011: 37)

In the course of experimenting, niche actors will interact with many others and so they will build a widening network of interested actors. Some of these will bring further resources to bear, enabling further experimentation and learning, and further network-building. Over time, new practices will become established, and knowledge about the effects of policies, laws and regulations will become clearer, enabling niche actors to argue for changes that would better suit the promotion of the emerging socio-technical configuration.

The data for the bulk of this case study were gathered in field research conducted in East Africa from July 2007 to July 2008, supplemented by later interviews in Europe. The research included semi-structured interviews with a wide range of actors involved in PV activities, and reference to various documentary materials collected from Internet searches and from access to organisational collections (some of this material is not available in the public domain).

Case study of the evolution of the Tanzanian PV niche

Having briefly explained the theoretical framework and methodology, this section provides an analytical narrative of the Tanzanian case and draws substantially on Byrne (2011). We begin with a brief account of the arrival of PV systems into Tanzania, but the bulk of the section focuses on the PV niche during the period from the early 1990s to the late 2000s.

Early interest and activities around PV in Tanzania

During the late 1970s, PV systems were introduced to Tanzania to power telecommunications equipment (Mwihava and Towo, 1994) and other applications such as lighting for remote railway stations (Sawe, 1989). In the early 1980s, donors began to fund community-service systems: e.g. for clinics (Roberts and Ratajczak, 1989); PV-powered vaccine refrigerators (McNelis et al., 1988); and other applications such as community-scale water pumping (Sawe, 1989). These stimulated a local 'project market' that remained important (ESD, 2003). An earlier interest in using PV in villages was explored at a workshop in Dar es Salaam in 1977 (UTAFITI, 1978) but little immediate action came of these discussions. The Ministry of Water and Energy later developed some interest in PV (URT, 1992) but never secured resources to implement projects (Sawe, 2008, interview), and PV was anyway very expensive at the time (Byrne, 2011). In any case, the more pressing concern during the 1980s was the issue of wood-supply for household energy-use (Nkonoki, 1983).

A few international companies set up offices in Dar es Salaam to service the project market described above (Sawe, 1989). Only BP expanded (cautiously) beyond this market, selling about 150 "domestic systems" in the period 1989 to 1994 (Mwihava and Towo, 1994: 73-76). Outside Dar es Salaam, there were very few companies active in PV, and only occasional PV activities in Tanzania up to the early 1990s (Byrne, 2011).

The birth of the Tanzanian niche

A significant event in the development of the PV niche in Tanzania occurred in 1992 when a PV workshop was held in Nairobi and Meru in Kenya (Kimani, 1992). The workshop brought together participants from 10 African countries for an intensive period of practical PV training. Two actors – Harold Burris and Mark Hankins – who were pioneers in the rapidly growing Kenyan SHS market organised the workshop to disseminate more widely their knowledge of how the Kenyan market

had developed (Byrne, 2011). The socio-technical vision they had developed from their experiences in Kenya was one in which they would train a number of technicians in PV using a mix of classroom-based theory and practical installation over an intensive two-week period. Following such training, the technicians would then exploit their new skills through entrepreneurial activity that would see a PV market develop. This had worked in Kenya and so Hankins and Burris assumed it would work elsewhere.

An immediate outcome of the 1992 workshop was a project in Tanzania to develop such a training model at the Karagwe Development Association (KARADEA), a non-governmental association (NGO) in the north-west of the country. Hankins worked with Oswald Kasaizi – KARADEA's Executive Director, who had attended the 1992 workshop – to develop a proposal for what they called a Solar Enterprise Centre (Byrne, 2011). The proposal encompassed a set of activities (Kasaizi and Hankins, 1992): a solar business; training courses; development of affordable small systems; installation of demonstration business PV systems; and a credit scheme. Despite the project proposers' common vision for market development, the donors were unconvinced, funding only the training. The resulting KARADEA Solar Training Facility (KSTF) continued to host training courses in Tanzania up to 2004 (Hankins, 2007, interview, KSTF, 2009). In the process of running the courses over the period 1994 to 2004, the implicit vision that developed narrowed (from the initial one articulated in the Solar Enterprise Centre proposal) to one of rural electrification by PV to be achieved via a private market (Byrne, 2011). Many actors, who later became influential in the Tanzanian PV niche, received their training at KSTF where they adopted this vision and attempted to realise it in their own activities.

However, most Tanzanian trainees were unable to continue PV activities once they had returned home. They had no resources to implement projects, there were no nearby PV suppliers, and there was no awareness of PV that could translate into market demand (Jackson, 2008, interview). For many technicians in Tanzania, setting up a PV business – especially in a rural location – would have been extremely risky. Even if a customer were willing, getting equipment would mean taking the customer's cash and travelling by bus to Dar es Salaam (or Kampala in Uganda, or Nairobi in Kenya) to buy the equipment. If the supplier had no stock, the technician would have to stay in the city searching for alternatives. Once the equipment was bought it would have to be transported by bus again back to the site for installation. The technician would have to possess enormous entrepreneurial energy and hold very deeply an expectation of PV business, as well as persuade the customer to trust them with their cash, to undertake such an endeavour.

Evolving the model of niche development

Similar problems to those seen following KSTF's training emerged during a PV project started in 1999 by the Tanzania Traditional Energy Development and Environment Organisation (TaTEDO). Funded by Hivos and Norad, the project included networking, training, awareness-raising, demonstration systems, and market development (Arkesteijn, 2000). Prior to the project, in 1998, TaTEDO had been involved in a study with Hifab International to provide an evidential basis for the formulation of project proposals to improve energy services for people in rural Tanzania (Byrne, 2011). Commissioned by Sida – the Swedish development assistance organisation – and using a participatory rural appraisal methodology, the study identified a number of reasons for the under-use of renewable energy technologies in rural Tanzania: lack of awareness and information; no demonstration systems; few training possibilities; poor infrastructure and framework for energy

services; lack of credit facilities; and immature market behaviour (Hifab and TaTEDO, 1998: 5-6). In other words, the 1999 project addressed many of the issues identified in the Hifab-TaTEDO study, including some attention to the needs of users.

Running until 2002, the project covered Dar es Salaam, Mwanza and Kilimanjaro Regions (Sanga, 2008, interview), selected because of their poor grid infrastructure, potential for renewable energy use, and strength of the local cash economy (Arkesteijn, 2000). After internal capacity-building, the project moved into a training phase that borrowed heavily from the KSTF model (Byrne, 2011). The first course took place in Dar es Salaam in May 2000 at the end of which the Tanzania Solar Energy Association[5] (TASEA) was formed (Arkesteijn, 2000). Although the hope had been that those trained by TaTEDO would include PV activities in their organisations, very few were able to do so (Sanga, 2008, interview). Only those who were already involved in PV prior to the course – mostly from PV retailers – continued after the training. Reflecting on this, TaTEDO experienced a degree of second-order learning that resulted in a shifted expectation. For the second round of courses, this new expectation included targeting those either working in PV companies or those who demonstrated promising entrepreneurial energies. This was a more successful approach than in the first round of courses and was continued in a second project that ran until 2005, building both technical and entrepreneurial capabilities (Sanga, 2008, interview).

Despite the activities of KSTF and TaTEDO (and others not mentioned here – see Byrne, 2011), the market for SHSs did not grow in Tanzania up to the early 2000s. Nevertheless, we can identify other outcomes. For example, KSTF trained about 175 technicians (KSTF, 2009), while many others were trained in replica courses elsewhere. As mentioned above, some went on to influential positions in Tanzania's PV niche. TaTEDO's projects facilitated network-building in the Tanzanian niche, as well as further collectivising a particular PV expectation, especially through TASEA (Byrne, 2011). And, the delivery of similar training curricula through KSTF and TaTEDO (and others) helped to institutionalise technical practices. Without these activities, the subsequent interventions (see below) would have been much more difficult to implement. By the time these subsequent interventions began, there was a burgeoning constituency of support for PV in Tanzania (including among governmental actors), which constituted a growing network of actors who held a shared PV expectation (or perhaps vision), a number of skilled Tanzanians, knowledge of some of the problems in the Tanzanian PV niche, an evolving understanding of customers' preferences and the first links of a private sector supply chain.

Sharpening the model of niche development

The first of the subsequent interventions followed the development in the late 1990s of a relationship between TaTEDO and the Dutch PV manufacturer Free Energy Europe (FEE). FEE wanted to sell into Tanzania, having already adopted a positive expectation of PV market development from success with FEE modules in Kenya (Byrne, 2011). In 2000, FEE conducted the first PV actor survey in Tanzania and found that, apart from the network in Dar es Salaam, most PV actors in the country were working in isolation: i.e. the networks were weak and fragmented. Nevertheless, the views on what was needed to develop the market were highly convergent. An overwhelming response was the need for a central actor who could coordinate information and knowledge exchange (Byrne, 2011). Beyond this, there seemed to be a lack of awareness of PV;

[5] TASEA is now the Tanzania Renewable Energy Association (TAREA) (TAREA, 2011).

difficulty sourcing equipment; lack of standards; taxes were too high; there was not enough training; and there was no finance (Arkesteijn, 2000).

The study informed FEE's 2002 entry into the Tanzanian market, such as it was at this time (van der Vleuten, 2008, interview). This became the company *Umeme Jua* – a joint venture between FEE, TaTEDO and Fredka International (a Tanzanian consultancy). Umeme Jua had intended to distribute their modules through the dealer network of a large player, as they had successfully done in Kenya. However, no such player existed in Tanzania and so the company identified dealers individually in the regions in which it decided to operate (van der Linden, 2008, interview, van der Vleuten, 2008, interview). As part of the effort to identify where to operate, they commissioned a number of market surveys that also helped to articulate a finer description of market demand (EAA et al., 2002a, b, c, d).

The methodology for each market survey included an overall view of the socio-economic situation in the focus region, and interviewing householders in a number of villages and in the region's urban centre. Past experience with PV was assessed; wealth, and willingness and ability to pay, were evaluated by analysing assets purchased (radios, TVs, cars, bicycles, refrigerators, mobile phones, and so on); and awareness of PV was investigated. Both householders and retailers were asked about either their interest in buying PV (if householders) or how many enquiries about PV were received (if retailers). Battery charging stations were included as an indication of the demand for low power electrical services. And seminars were conducted for businesses during which they were presented with the commercial opportunities in PV (Arkesteijn, 2009, interview).

The same constraints were found in every region studied: low awareness of PV, low technical and business capacity, poor supply of components. Where PV was on sale, the prices were found to be substantially higher than in Dar es Salaam. In some places – Mwanza and Mbeya – modules were being smuggled in from Kenya, and Zambia or Zimbabwe respectively, so as to avoid paying duties and VAT. In Mwanza, some of the dealers were not advertising because they feared they would then attract the attention of the Tanzania Revenue Authority. As Arkesteijn's (2000) study found, the extent to which actor-networks did exist, they were poorly connected within themselves and to others. Retailers tended to have their own supply systems and their own agreements with companies in Dar es Salaam or elsewhere, so there was no bulk purchasing or sharing of information.

In addressing the findings of the market surveys, over the period of a few years, Umeme Jua built a network of dealers and complemented this with a network of technicians who could service the local demand (van der Linden, 2008, interview). Because of the need to train both dealers and technicians, this was a slow and expensive process that is unlikely to have occurred without the significant funding received from the Dutch government (Arkesteijn, 2009, interview). Initially, Umeme Jua used the KSTF training model. However, they began to realise this was unsuitable for most retailers and so developed a course that could be delivered in repeated short visits to a shop (van der Linden, 2008, interview). The extensive travel required to achieve the various outcomes described above, especially the in-situ training, was burdensome, but it generated other benefits, including the building of trust with the retailers by cultivating long-term relationships (Arkesteijn, 2009, interview).

Umeme Jua offered incentives to these dealers to sell more modules, including better terms depending on quantities sold and supported by guaranteed delivery (van der Vleuten, 2008, interview). They also demonstrated systems in public locations and advertised on local radio stations (Arkesteijn, 2009, interview), and made extensive use of marketing provided through the Free Energy Foundation, also funded by the Dutch government (Schuurhuizen, 2008, interview, van der Vleuten, 2008, interview). As they began to better understand users' preferences, so they introduced standard systems that reduced the need for long explanations to customers in shops, as well as simplifying design and supply requirements (Byrne, 2011). And, in an attempt to address the high upfront cost of systems, they experimented with microfinancing. A number of these attempts failed but hire purchase was successful (van der Linden, 2008, interview), although it was only open to those with salaried income and so did not extend PV access to the poor. Eventually, "the numbers [of modules being sold] began to get interesting" (van der Vleuten, 2008, interview). By 2008, Umeme Jua had an annual turnover of about USD 1 million, which was estimated to be 50 per cent of the Tanzanian PV market at the time (Sawe, 2008, interview).

Stabilising niche development

In 2004, the Global Environment Facility (GEF) funded a project through the UN Development Programme (UNDP) in Mwanza Region (URT et al., 2003). The project suffered a long delay before implementation. However, after it had commissioned a survey that helped to articulate the Mwanza market in finer detail (TaTEDO and Fredka International, 2001), the delay afforded Umeme Jua an opportunity to influence the project's final design (van der Linden, 2008, interview). The project concentrated on the Mwanza Region for the first three to four years and was to be replicated in nearby regions thereafter (Musa, 2008, interview). While it had been influenced by the Umeme Jua approach, it was not identical. It donated some systems, which were placed in strategic locations as demonstrations, and experimented with productive uses of PV: powering barber shops, providing mobile phone charging services, and others (Byrne, 2011). Furthermore, it included a policy dimension, which involved the development of PV standards in collaboration with the Tanzania Bureau of Standards. It experimented with microfinance but, as with Umeme Jua, was unsuccessful (Musa, 2008, interview). Nevertheless, the project did achieve its main goal to expand the PV market significantly in Mwanza Region.

In 2005, a Sida-funded project in cooperation with the Ministry of Energy and Minerals (MEM) got underway, known as the Sida-MEM project. Like the UNDP-GEF project, it suffered a long delay before implementation (Kårhammar, 2008, intervew). Its final design was informed by the earlier Sida-funded Hifab-TaTEDO rural energy study (Hifab and TaTEDO, 1998) (see above), but was also based on consultations between the incoming project manager, Jeff Felten, and local PV actors such as Umeme Jua (Felten, 2008, interview). So, as with the UNDP-GEF project, there was interaction and influence among those implementing projects in Tanzania. Although not identical to the other projects, it shared their multi-dimensional market development approach, and included a policy aspect that successfully saw the removal of taxes on PV equipment (TASEA, 2005, Magessa, 2008, interview). It also supported TASEA, paying for a website, annual solar days in Dar es Salaam, and the regular publication of SunENERGY, a magazine focussed on the Tanzanian renewable energy sector (Byrne, 2011). In terms of stimulating sales of PV modules, the project was highly successful, surpassing its targets in the first two years of operation. According to Sida-MEM figures, the market grew by 57% between 2006 and 2007 to an estimated

285 kWp (Felten, 2008). If the average size of a system[6] were 20 Wp, this would amount to about 14,000 modules. Also, according to Sida-MEM, the price per watt-peak of PV in Tanzania fell from USD 12.07 in 2006 to USD 9.85 in 2007 (Felten, 2008).

Discussion

From the case study, we can see that the early activities of (mainly) donors were useful to build some capabilities relevant to SHSs and connect together local actors who could form a constituency of support for PV technology. However, apart from the relatively consistent commitment to KSTF, donor-support was uncoordinated, fragmentary and unfocussed. It was also less than coherent in that the guiding expectation was one of PV for rural electrification, including access for the poor, that could somehow be achieved through a private market. Nevertheless, this provided some practical basis on which to build the PV niche as well as to help identify some of the issues that needed addressing.

The entry of Umeme Jua brought a sharper and more coherent expectation to the emerging niche, an expectation more easily grasped by more actors and therefore more easily shared. Envisioning and realising this expectation still required huge effort, but this was supported by donor funds and the commitment of those involved in the joint venture, who already held strong positive expectations about PV in the region. The increasing success of the approach helped to collectivise the expectation beyond Umeme Jua to other projects, and something of a self-reinforcing dynamic began to take hold. Problem-solving thus focussed on establishing a SHS market for whomever the customers might be: understanding the needs of supply-side actors, and then connecting together and developing the supply chain; understanding the characteristics of user preferences and demand, and then raising that demand through advertising and other awareness-raising activities; and connecting supply and demand together.

One of the benefits of this ‘articulation of the market’ was to lower risk. The risks for supply-side actors were lowered by the support of other actors: Umeme Jua (who, in turn, were supported by a donor) and the various donor-funded projects. These included risks associated with stocks of components and the sources of supply, as well as prices. They also included the risks associated with finding the market demand and understanding it. Again, these risks were borne by others – mostly donors – in commissioning market surveys and sharing knowledge gained through activities on the ground. For customers, risks were reduced by articulating and demonstrating for them the functionality of PV and how it could meet their electricity needs, as well as making sales and technical support easily available.

But lowering risk – whether real or perceived – was not the only important aspect of the way in which the market was established. It should be clear that the activities of niche actors, both public and private, amounted to what in effect can be described as socio-technical innovation system building. This was achieved by nurturing what was initially a fragmented set of experiments into an

[6] The figure of 20 Wp is chosen based on reports that the most popular modules were 14 Wp amorphous (van der Linden, 2008, interview), as has also been documented in the Kenyan SHS market (van der Plas and Hankins, 1998). The average size is then an estimate to allow for the presence of larger modules. However, the point here is to give an estimate of the number of modules sold rather than to report an exact figure.

increasingly connected set of interventions that can each be described as systemic in character: they worked on many dimensions of the emerging niche simultaneously. Gradually, this nurturing strengthened and stabilised the niche, laying the foundations upon which the many new private sector actors who have entered the market could build and develop their business models. Without the earlier support of donor funding for niche-building it is doubtful the market would have become established. Indeed, many of the business models – such as pay-as-you-go – are still experimental even if they are currently securing thousands of customers, and so donor-support continues to be a feature of the evolution of the Tanzanian PV market (Karjalainen et al., 2018).

The case shows the considerable amount of effort involved in developing a market for SHSs; effort over three decades if the initial fragmented activities are included, or two decades if we consider the increasingly more focussed efforts from the mid-1990s. This reflects the complex nature of markets, something that is not so apparent when markets already function in some sense efficiently. In Tanzania, the case demonstrates that an assumption of functioning market systems is unsafe. This is partly attributable to Tanzania's relatively recent emergence from its experiment with African socialism (Oman and Wignaraja, 1991, Gordon, 1994). There is a relatively weak business culture and many market institutions are still in development. It is likely that many poor developing countries face similar problems, even if they have had more experience with market economies.

Our case study investigated the adoption of PV systems for household electrical services. Electricity is in high demand and there are few ways to provide it in the household, particularly in rural areas. Nevertheless, the effort involved in Tanzania to establish a market in PV systems was extensive. It is likely that similar situations can be found for other energy services, such as clean cooking. But cooking can be achieved using various cheap technologies and techniques, and these are already deeply embedded in social practices across many poor countries. Nurturing niches that will promote clean cooking therefore presents a more complex challenge than achieving electrification with PV systems (Ockwell et al., 2019). This brings us to a final set of points in this discussion: the more general lessons we can learn from this case for how to meet the challenge of nurturing niches that can provide better ways of achieving wider and deeper access to other modern energy services.

Our case suggests that the particular expectation adopted by actors guides their problem-solving and so influences what sort of socio-technical trajectory might become established. This is not to say that any particular expectation is the right one that will lead to success, while others will lead to failure. Some problems are easier to solve than others, but we cannot know in advance which ones these are and so cannot say in advance which expectations to adopt. However, we can say that being clear about what we are trying to achieve can help us recruit actors, direct resources and attend to the appropriate problems that prevent us achieving our goals. If those problems can indeed be solved, we raise the chances of doing so by sharing the learning generated in many different experiments. But we need to be able to experiment in ways that generate learning about the context-specific problems of energy provision systems and associated markets. This requires risk-taking, the bulk of which can only be borne by the public sector. If we want markets to provide longer term solutions, the private sector needs to be deeply and meaningfully involved in these experiments. However, this is not enough. We also need to understand the demand for services, and this suggests that our experiments should involve the expected beneficiaries of those services.

Where it is not possible for these users to turn needs and desires into market demand – such as is likely the case for the poorest – then we need to consider other forms of service-provision; perhaps through community-scale interventions such as in health centres and schools. But the poor themselves need to be included in the experiments so that learning is focussed on their context-specific problems. To underline this final point, as we have seen elsewhere, the power of sharply focussing on user needs and preferences is demonstrated by the Lighting Africa programme and the resulting success of the SPL market (in particular) in Kenya (Ockwell et al., 2019).

Conclusions

We have examined the case study of the evolution of the PV market in Tanzania, a market that now boasts extensive penetration in terms of households using PV as their source of electricity generation. The case focussed most carefully on the interventions of actors during the 1990s and 2000s, as this is the period during which much of the foundation-building of the Tanzanian PV market took place. By using a Strategic Niche Management framework to drive our analysis, our case reveals some of the complexities involved in market development. This stands in contrast to the still-dominant approach of seeing market development as simply the financing of technological hardware. Instead, as recounted in other cases (e.g. Ockwell and Byrne, 2017 on Kenya, Bhamidipati et al., 2019 on Uganda), market development is more likely to be achieved – especially in poor countries – by nurturing socio-technical niches centred on promising technologies such as PV. Financing the adoption and deployment of such technologies remains important, but this is only part of the problem. Overcoming the complex entirety of the challenge is more likely if effort is focussed on what we have called elsewhere socio-technical innovation system building (Ockwell and Byrne, 2017)

Case study of innovation system building: LPG in Ghana

Introduction

Whilst a focus on innovation systems and the socio-technical dynamics of new technology adoption is vital to achieving transformations in clean technology uptake, it is also essential to understand the broader political economy dynamics at play. Such dynamics can be definitive of whether or not conditions are favourable for success. In this case study, we look at the example of Liquified Petroleum Gas (LPG) for cooking in Ghana. This provides an insight into how, even where it looks like policy regimes may be favourable towards the uptake of clean cooking technologies, political economy dynamics can act to prohibit change. Commissioning political economy analyses around specific clean cooking technologies in specific country contexts is therefore one recommendation this report suggests for consideration under MECS.

Insights from a political economy perspective

Let us begin by briefly outlining some of the key insights from the literature on the political economy of energy access, before proceeding to describe the case study in more depth. Political economy analysis can be particularly revealing when considering, in any given context, which technologies are likely to be adopted, who will gain and who will lose from this adoption and why. Given the marginalised nature of many poor communities that might gain from access to clean cooking technologies, such considerations can be valuable in explaining or predicting the likely success of different energy access initiatives in different contexts. They cast analytic light on the actors, interests, ideas and institutions that define the power dynamics at work in any given context that need to be understood and engaged before change in new directions is likely to occur (Newell et al., 2014) (e.g. widespread improvements in clean cooking technology access and use amongst poor and marginalised people).

Whilst it has roots in academia, political economy analysis has also, more recently, been picked up by the donor community as a potentially useful tool (see Appendix 4 for a critique of these). Political economy analysis has its roots in decades of academic research spanning a range of different disciplines and a range of different analytical foci. Although, at its core, Mason et al. (2016) are probably right to defer to Harold Lasswell's shorthand in describing political economy analysis as concerning "who gets what, when, how" (Lasswell, 1936), the roots of this field of enquiry are more extensive and nuanced in their various perspectives and analytic emphases. In an effort to both inform interested readers and to provide a basic critique of the treatment of political economy analysis in some recent policy/practice oriented "how to do political economy analysis" type reports, Appendix 4 provides a note on the background and roots of political economy analysis.

Essentially, there is nothing new about using political economy-based approaches to either understand and/or plan interventions across different aspects of international development. To date, however, very little work has been done that explicitly attends to the political economy of energy transitions in developing country contexts and the ways in which political economy considerations can constrain or enable different pathways (c.f. Leach et al., 2010) of energy transition that might facilitate access to energy for poor women and men. What is new, then, is the small emerging literature that attempts to apply such analysis in the context of energy access.

DFID has signalled an interest in this as an area of enquiry having commissioned a rapid evidence review on the political economy of energy (more broadly than just energy access) in relation to economic growth (Barnett, 2014). The Barnett (2014) report includes a short (less than one page) discussion on the political economy of energy access, with no reference to any specific examples of political economy analyses of energy access. For Barnett (2014, p.24):

> "… the fundamental truth is that poor people do not have access to modern energy services because they are poor. And we can therefore expect that the forces in society that keep people poor will be among the same forces that prevent poor people gaining access to modern energy services."

A number of different practitioner oriented "how to" type manuals have also recently emerged, including a report published by DFID (DFID, 2009, Harris, 2013, Harris and Booth, 2013) – see Appendix 4 for critique of these. Within the peer-reviewed literature, there is only a handful of authors – as far as we are aware – who have attempted to analyse energy access from a political economy (or broader politics informed) perspective in the peer reviewed literature to date[7] (see Appendix 4).

Ghana's stalled LPG policy reforms

In 2015, Ghana looked like a favourable environment in which to work on clean cooking, due to its significant high-level policy support for increasing access to LPG. At that time, the Ghanaian government was in the advanced stages of developing a major policy reform that would change the nature of LPG distribution in Ghana, resulting, it was claimed, in increased safety and access to LPG across the country. The government had announced an ambition to increase access to LPG for clean cooking from 20 per cent to 50 per cent.

The policy reform essentially involved changing the distribution system for LPG in Ghana. At present, the downstream LPG sector in Ghana is quite complex, characterized by myriad small and medium sized enterprises (SMEs) that provide the service of refilling LPG cylinders for household customers. Gas cylinders can be bought at small roadside stalls, whilst refilling of cylinders happens at larger outfits, such as petrol station forecourts or forecourts dedicated to LPG (there is also a market for LPG for transport in Ghana, driven in part by past subsidies for LPG that have since been removed). Customers using LPG for cooking own their own cylinders and take them with them when empty to be refilled by one of the LPG vendors. This has led to a range of safety concerns. First, as customers own their own gas cylinders, they are often left in use long after the safety of the cylinder has been compromised (e.g. due to damage or degradation).

[7] Barnett (2014) observes a similar lack of peer reviewed literature on the political economy of energy and development more broadly, although for him this is "more than made up for" (page ii) by practitioner-produced grey literature. This does, however, raise potential problems. Much of the grey literature often fails to conform to the quality criteria (e.g. explicit description of methodology to allow for verification of rigour applied in any analysis) that would be applied in any systematic review of the literature. This therefore risks insights from this grey literature being lost in future (see, for example, the experience of Watson et al., 2012 in their systematic review of the energy access literature on sub-Saharan Africa). As there is little or no practitioner-based literature on the political economy of energy access, this is less of an issue in relation to the current report, but it is a consideration that ought to be borne in mind by any organisation commissioning future political economy analyses in relation to energy access.

Second, there is an incentive for LPG vendors to overfill cylinders, beyond the safe pressure level, in order to keep customers (who have often travelled long distances) happy. This is apparently widespread practice. The compromised quality and overfilling of cylinders has resulted in regular incidences of LPG-related household fires in Ghana, which receive significant press attention: around 100 cases of LPG-related burns are reported each year (GVEP, personal communication). There have also been reports of more catastrophic accidents where tankers full of LPG (necessary to supply the distributed network of small vendors) have crashed, resulting in large explosions and multiple deaths. The latter, again, has attracted press attention. As a result, LPG is perceived by many potential users to be unsafe, despite the significant health benefits of cooking on LPG relative to wood fuel or charcoal. An additional barrier relates to people having to sometimes travel long distances to refill their cylinders, sometimes to find prices are prohibitively high or that no LPG is currently available.

The proposed policy reform in Ghana was designed to address these safety issues and thereby to attract new investment to increase the use of LPG for cooking. This would be achieved by moving to a different distribution model, one advocated by the Global LPG Partnership, which engaged with the Government of Ghana in the design of the proposed reforms. This new distribution model would move to a system (which did in fact previously operate in Ghana for a period of time but was then disbanded) where consumers do not own gas cylinders. Instead, a deposit is paid on the gas cylinder, which is then exchanged for a full cylinder when empty – the same system as exists for LPG (e.g. for camping or heating applications) in countries in the Global North like the UK. The LPG itself would be stored at a small number of new central storage facilities away from populated areas. Filled cylinders would then be transported by lorry to distributed vendors across the country – a safer way of moving LPG into populated areas than in large tankers, and a way in which a wider area of Ghana could be served than is the case under the present system.

The reform arguably had potential, therefore, to both increase access to LPG for clean cooking and increase the safety of distribution and consumption. The government in Ghana had demonstrated buy-in at presidential level to this policy reform, with public announcements around it having been made as part of Ghana's early engagement with the UN Sustainable Energy for All (SE4All) initiative. The policy reform was already at an advanced stage, having been developed with international support and collaboration with the Global LPG Partnership (GLPGP), an alliance of the LPG industry, World Bank, African Development Bank and several African governments[8]. This implied clear alignment with the aims of a programme such as MECS in terms of government policy, clear buy-in from development partners and other stakeholders (nationally and internationally) and clear consideration of the needs of potential beneficiaries (i.e. poor women and men's increased access to clean cooking technologies).

In early 2015 the Ghanaian policy reforms seemed to be proceeding at pace and reaching the point where implementation would begin to be rolled out. By around the summer of 2015, however, it became clear that the policy reforms had stalled. No formal announcement not to proceed has ever been made, but no further progress in implementation has occurred to date (Asante et al., 2018). This stalling coincided with the (very late) consultation, in summer 2015, for the first time with the existing actors in the LPG downstream distribution sector: i.e. those businesses and

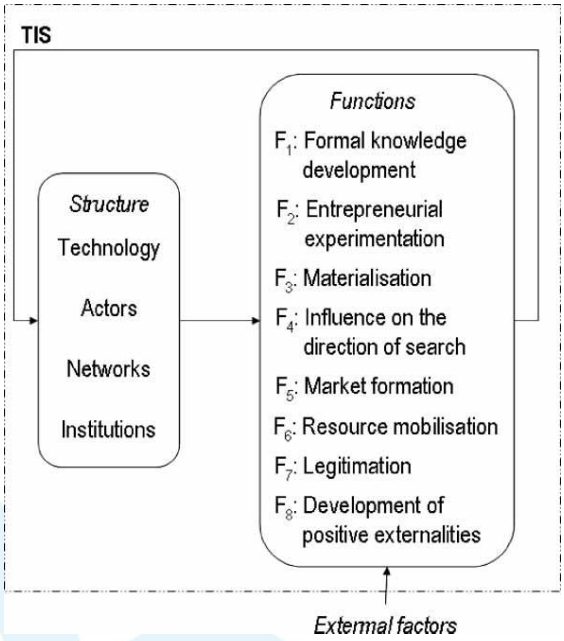
[8] See http://www.glpgp.com/

franchises who currently profit from refilling LPG gas cylinders for consumers, many of whom had significant sunk investment in refilling-infrastructure and whose existing business practices around LPG would be rendered redundant under the planned policy reforms.

How would political economy analysis have been of use?

The unexpected stalling of the policy reforms to LPG distribution in Ghana present potentially significant barriers to any interventions in support of Ghana's ambitious targets for increasing LPG use for cooking. Certainly, any planned interventions in support of these reforms would have been frustrated. In this section, we demonstrate what political economy analysis can add, where an approach based on a more traditional innovation studies perspective might have been left wanting. To some extent, more traditional, managerially-oriented theories of innovation systems, such as the Technology Innovation System (TIS) framework (e.g. Bergek et al., 2008b, Bergek et al., 2008a, Bergek et al., 2015), do draw analysts' attention to political conditions. The Ghanaian government's decision not to go ahead with the policy reform could be situated within two different parts of the TIS framework. It might be considered as part of the "structure" of the TIS – the left-hand box in **Figure 4** below, where policies are captured within Institutions.

Figure 4. Relations between external influence, structural elements and functions in the Technology Innovation System framework



Source: Bergek et al. (2008b)

Certainly, from the perspectives of both the socio-technical transitions literature and, more so, the political economy literatures explored below, the kind of policy decision that led to the stalling of the LPG policy reforms would be related to more structural-level considerations. As originally conceived by Bergek et al. (2008b), however, policy or policy reform is not treated as structural.

Rather, it is seen as forming part of what Bergek et al. (2008b) argue to be "legitimation", one of a number of critical functions of any TIS (function F7 in Figure 4). They describe legitimation as: "The socio-political process of legitimacy formation through actions by various organisations and individuals. Central features are the formation of expectations and visions as well as regulative alignment, including issues such as market regulations, tax policies or the direction of science and technology policy" (Bergek et al., 2008b: 578).

However, the core critique of the TIS treatment of policy processes rests on the fact that it treats technology as a neutral – almost endogenous – concept, completely divorced from the socio-cultural and political realities within which innovation and technology adoption occur. This is not to say that the TIS framework does not recognise a nexus of different considerations that influence whether a technology enters the mainstream. Rather it is to argue that the TIS perspective on this nexus is overly removed and managerial in its treatment of them.

In reality, politics is pervasive across all of the functions of the TIS (Kern, 2015), not just legitimation. Moreover, politics in its real, messy, interest-oriented sense does not seem to be properly described in the concept of "legitimation" above. As (Kern, 2015: 68) asserts:

> "… this weakness leads TIS scholars to provide instrumental policy recommendations on the basis of their studies which are oversimplified because they neglect an understanding of the political aspects of transitions [towards more sustainable socio-technical systems] rather than being based in political realities of the particular case."

Here, we begin to get closer to what, perhaps, lies at the heart of what happened in Ghana – drawing our attention to the possibility of reflecting in more detail and more systematically on the politics and political economic contexts that define a given area within interventions, such as the MECS Programme, that are being considered.

Both the innovation studies and the socio-technical transitions literatures have been criticised for their tendency to be overly managerial and for their failure to properly attend to the (often highly) political contexts within which the uptake of new technologies occurs (see e.g. Smith and Stirling, 2007, 2010, Kern, 2011, Kern, 2015, Meadowcroft, 2011, Lawhon and Murphy, 2012). Whilst this criticism is difficult to respond to in the context of the overly rational presentation of technology uptake in the TIS literature's "functions", proponents of the socio-technical literature might (and do) argue that it is possible to conduct solid, politically-attuned analysis within the confines of a socio-technical conceptual framework. In particular, the concept of dominant socio-technical regimes with which new socio-technical practices have to compete provides potential analytic purchase here (Kern, 2011, Geels, 2014). But this is still open to critique insofar as it is not clear how politics at the regime level intersects with what socio-technical transitions scholars refer to as the landscape level. As Newell and Phillips (2016) and Baker et al. (2014) demonstrate, significant analytical purchase can be achieved by considering broader political economy dynamics that transcend the regime and landscape levels spoken of by socio-technical transitions scholars. This final section of the analysis in this case study therefore looks explicitly at what such a political economy perspective can add to our understanding of the LPG experience in Ghana.

In what feels like a stark juxtaposition with the neat, managerial frameworks presented in the TIS literature (and, many would argue, similarly managerial tendencies evidenced in the socio-technical transitions literature), interventions around clean cooking through policy and practice on the ground in low income countries intersect with messy context-specific and deeply political realities. As Keeley and Scoones (2003) demonstrate through a number of rich empirical case studies of natural resource management across multiple sub-Saharan African countries, attending to the historical relationships between science, local knowledges and political styles, (influenced, as they are in Africa, by different – current and past – experiences with colonialism, post-independence development efforts and international science, technology and innovation), is essential. This leads to an understanding of these contexts that defies universalist description and prognosis (Naess et al., 2015, Scoones et al., 2015). It implies much more than simply the assertion that context matters, rather it begs fundamental questions of transitions and TIS theory and galvanises a call to extend the thinking to (particularly low-income) developing country contexts that resists easy categorisation within the usual niche, regime, landscape typology of transitions terminology, or the neat managerial frames of a TIS analysis. As Newell and Phillips (2016: 39) emphasise:

> "… forms of power derived from control over production, finance and technology should assume a central place in accounts of the politics of transition. We also emphasise the specificity of these processes in the global South, where configurations of power between states, donors and transnational capital have distinct characteristics that have not been well captured by the Euro-centric origins and focus of socio-technical transitions literature to date (Baker et al., 2014, Swilling and Annecke, 2012)."

Despite these repeated calls for more explicit attention to the politics of transition, and even a contribution by one of the literature's key proponents seeking to extend one of its core conceptual frameworks to attend to politics (Geels, 2014), only a handful of examples exist where empirical analysis has explicitly tried to deal with politics (Levy and Newell, 2002, Avelino and Rotmans, 2009, Grin, 2010, Kern, 2011, Normann, 2015), with a small subset of these dealing with issues that intersect with energy access in developing country contexts (e.g. Baker et al., 2014, Newell et al., 2014, Tyfield et al., 2015, Newell and Phillips, 2016, Ahlborg, 2017, Shen and Power, 2017, Byrne et al., 2018).

It is to this final, political economy perspective, that this report now turns. This offers perhaps the most tangible explanation of the LPG experience in Ghana. It also provides us with a final, albeit perhaps most important, area that needs to inform any intervention around clean cooking via policy and practice in future, such as via the MECS Programme.

It is impossible, without targeted empirical fieldwork that engages with key relevant actors in Ghana, to provide a definitive picture of the political economy of LPG in Ghana. The following analysis is therefore predominantly based on the three expert interviews conducted in 2015. Where possible, it also draws on available relevant grey literature, as well as several confidential reports to which the author was given access but that it is not possible to cite for reasons relating to political sensitivities.

Through the use of various strands of political economy based theory (based on empirical analyses of other contexts in the peer reviewed literature, including other – non-energy – sectors in Ghana and the emerging literature noted above on the political economy of energy access), together with what has been gleaned from the expert interviews conducted for the current report, the analysis below provides us with at least two convincing hypotheses as to what happened. Such analysis also serves to demonstrate the potential value provided by an analysis of the political economy of clean cooking in any given context prior to any future intervention, including via MECS. This might assist in avoiding similar barriers as were experienced around LPG in Ghana. This is not to say that the political economy in any given context will necessarily present insurmountable barriers. Rather, it is to suggest that a more systematic application of political economy analysis in relation to clean cooking initiatives could add value in providing a more detailed assessment of the political economy with which interventions necessarily intersect and thus provide a more informed perspective on the potential risks and barriers that might be encountered in any given context.
As alluded to above, the Ghanaian LPG reforms intersected with a context that is highly politicised. National agendas around energy access, energy supply more broadly and the oil and gas sectors in particular are sites of high politics, with hugely significant attendant political and economic interests and conflicts constantly at play. The next two sub-sections deal, in turn, with the political economy of energy access and oil and gas in Ghana in order to make sense of the stalling of reforms in LPG distribution.

Political economy of energy access in Ghana

To understand the politics of energy access in Ghana, it is first necessary to consider the broader energy context in the country. Since the mid-1980s, policy discourses in the country have been increasingly influenced by growing concerns with energy security. This has emerged in response to growing problems with energy supply, relating in particular to variability in hydropower as it accounts for around 50 per cent of Ghana's generation capacity (World Bank, 2013), and significant growth in electricity demand as the country's economy grew at a faster pace than growth in generation capacity could match. As a result, electricity in Ghana is characterised by frequent blackouts and brownouts, with subsequent impacts on economic productivity and domestic users. Not surprisingly, then, as with many other countries (e.g. Kenya, see Newell and Phillips, 2016), electricity and energy policy more generally has become a key electoral issue.
In line with this political and economic emphasis on energy security, the ways in which the energy security agenda has been framed is also of relevance. The core focus has been on grid extension and efficiencies via energy sector reform (World Bank, 2013). The recommended reforms follow the standard lines advocated by neoliberal institutions such as the World Bank. The (political) power dynamics that emerge here are significant. Many donors have their own political commitments to seeing energy reforms driven via market-based mechanisms and deregulation/privatisation of the energy sector. As such, in a country like Ghana where a key limitation to increasing energy security (read "electricity supply") is access to finance (World Bank, 2013), the disciplinary nature of such neoliberal requirements for accessing international capital should not be underestimated (Newell and Phillips, 2016).

In Ghana this is all the more significant as the country is essentially broke at present. In April 2015, a USD 918 million loan from the IMF was approved (IMF, 2015). This places the period during which the terms of the loan were being negotiated at the same time that the LPG distribution reforms stalled. Power sector shortages are central to the explanation given by the IMF (2015) for

the economic difficulties faced by Ghana between 2012-2014, which included inflation rates of up to 17%. Deregulation of the energy sector and removal of energy subsidies form key parts of the fiscal reform programme imposed by the IMF as part of the terms of the loan.

This national picture of the political economy of energy in Ghana is further complicated by dynamics within the oil and gas sector. These are covered in more detail in the next sub-section further below. Suffice to note, for now, that the discovery of significant indigenous oil and gas reserves in recent years, as well as heavy reliance on Nigeria for oil and gas imports, muddies the waters yet further.

In parallel to these national level energy sector concerns, Ghana has also in recent years, again with significant influence from the international donor community, been developing a new Climate Change Policy (see MESTI, 2013). The DFID-funded Climate and Development Knowledge Network (CDKN) is viewed as having had significant influence over the development of this policy, in particular via its influence on the production of a position paper "Ghana Goes for Green Growth" (Government of Ghana, 2010) that preceded the country's climate change policy. The commitments to decarbonising energy supply and increased use of renewable energy therefore present potential tensions and imply trade-offs with aims to expand access to clean cooking via LPG. LPG is, of course, a fossil-based energy source. Despite its important health benefits, it therefore implies attendant greenhouse gas emissions – although this needs to be considered in relation to any reduction in deforestation from fuel wood and charcoal production, and LPG has lower emissions than natural gas or electricity (depending on the source of electricity) for cooking. Emissions from LPG used for cooking are likely to make up a small percentage of aggregate national emissions, meaning a strong argument can be made in favour of LPG for cooking due to the significant associated health benefits. Either way, these potential tensions with the emerging climate policy agenda cannot be completely ignored.

So where does all this leave energy access in Ghana? Here, once again, an interesting story unfolds around international political influence as well as domestic political economy and electoral politics. Ghana has been a leading light in the emergence of the UN's SE4All agenda. The SE4All initiative[9] seeks to support universal access to modern energy services by 2030. As a result of engagement by certain key individuals, Ghana was the first country to produce a national SE4All Action Plan (see Government of Ghana, 2012). These efforts are perceived to have been led in particular by the late Professor Abeeku Brew-Hammond, an academic who occupied both academic and political positions in Ghana and internationally. These included positions as director of an energy policy focussed Ghanaian NGO (KITE), director of The Energy Centre (TEC) at the College of Engineering of the Kwame Nkrumah University of Science and Technology (KNUST), Chairman for the Energy Commission of Ghana and member of the Technical Group under the UN Secretary-General's High-Level Group on SE4All.

From early on, through both his academic and political work, Brew-Hammond promoted the issue of energy access and poverty (e.g. see Brew-Hammond and Kemausuor, 2009, Brew-Hammond, 2010). The Ghana SE4All action plan places particular emphasis on LPG for clean cooking. This is further supported by the National Energy Policy (2010), which aimed to increase the percentage of

[9] See http://www.se4all.org

households using LPG for cooking to 50 per cent by 2015. Questions have been raised by stakeholders around participation in the SE4All process. Interviews conducted with a range of stakeholders within the energy access space in Ghana as part of a doctoral research project at the University of Sussex have implied that there is a perception that private sector representation within the SE4All process in Ghana was heavily influenced by the LPG industry, without sufficient representation from the off-grid solar PV sector (although this is perhaps not so surprising given the focus of the SE4All process on cooking).

Whilst, if true, this might be cause for concern, it nevertheless suggests that initiatives to support the LPG industry would, in fact, be pushing on an open door in Ghana. Bear in mind the SE4All plan was being promoted on an international political stage, with Ghana, including its President, using it to hold Ghana up as a leading light. Furthermore, this support for LPG expansion within the SE4All agenda is further strengthened by the Government of Ghana's international engagement with the then Global Alliance for Clean Cookstoves (GACC, now the Clean Cooking Alliance, CCA) and the World LPG Association in developing the LPG policy reforms. These organisations are significant global players. The World LPG Association represents large economic interests and the planned reforms would potentially open the door to new inward investment in Ghana by big oil companies – companies that are reportedly unwilling to engage in Ghana due to safety concerns with the existing LPG distribution structure. This could arguably be interpreted in line with the lobbying direction of the GACC/CCA around market-based solutions and subsidy removal. It would be interesting to know what the implications of such restructuring mean in terms of the profitability of the Ghanaian sector for large international oil companies. The latter is something that does not seem to be obviously discussed in any of the documents consulted for this report.

If so much national and international political will is evident around intentions to expand access to LPG in Ghana, what went wrong? To understand this, or at least to be able to hypothesise a potential answer, we need to understand more about both the politics of oil and gas in Ghana, as well as Ghanaian electoral politics. This includes close attention to the trade-offs between the intended LPG policy reforms, the structure of economic interests in the existing LPG regime in Ghana and the electoral politics that characterise Ghana's political system.

Political economy of oil and gas in Ghana

Let us first consider the political economy of oil and gas in Ghana, bearing in mind that LPG is an integral part of this sector. Oil and gas have a hugely important role in the political economy of Ghana. The country is heavily reliant on (and therefore exposed to price and supply fluctuations in) Nigerian oil and gas. For example, in 2010, Ghana experienced significant power shortages due to the cut-off of natural gas from Nigeria (World Bank, 2013). The discovery of indigenous oil and gas reserves in recent years has therefore been hugely influential on Ghana's political and economic strategies for addressing serious existing problems in both energy supply and economic growth. There are high expectations for the oil and gas industry to drive industrialisation. Not surprisingly, the forecast revenue from indigenous oil and gas reserves occupies a central place in the terms of Ghana's current IMF loan and plans for its repayment (IMF, 2015).

Simultaneously, it is important to note that the story of the stalling of the LPG policy reform process happened at the same time as a period of massive upheaval in the Ghanaian oil and gas sector. Indigenous oil and gas reserves, discovered circa 2007, began coming online in 2010. Significant

delays were, however, experienced in bringing indigenous refining capabilities online – the problem being that Ghana's TEMA oil refinery was built to deal with lower grade oil than the high-grade oil that characterises Ghana's newly discovered indigenous reserves.

At the same time, responsibility for commercialisation, transportation and processing of natural gas was shaken up by the creation of the Ghana National Gas Company (GNGC, or "Ghana Gas") in 2011. This responsibility had previously been the mandate of the Ghana National Petroleum Company (GNPC). The GNGC was, however, not properly resourced and its place within the mid-stream gas sector was structurally flawed as a result of subsequent decisions by the Energy Commission. This included awarding the exclusive licence for gas transportation to the state-owned wholesaler, Bulk Oil Supply and Transport Company (BOST). BOST was given responsibility for operating and maintaining the pipeline, whilst ownership of the pipeline remained with GNGC, meaning the latter owned a pipeline it neither operated nor controlled (World Bank, 2013). There is an impression of consistent tensions existing between GNGC and GNPC, manifested in uncertainty as to GNGC's role in the sector and how the complex commercial structure this created might deliver against investment requirements and commercial payment contracts. By 2013, against a backdrop of high inflation and economic uncertainty, it was difficult to get a clear picture of what the Ghanaian oil and gas sector would look like. Bulk oil companies were having difficulties in importing oil as the government was not paying, pushes for greater price deregulation were resulting in huge uncertainties around how prices would be set and energy subsidies had been removed across the board, leading to an increased price of LPG. Around the same time that the LPG reforms were expected to come into force, the decision was made to reintegrate GNGC into GNPC.

These kinds of political dynamics and uncertainties also play out in more complex ways that intersect with international investment streams. For example, in September 2014, GNGC came under fire domestically for entering into a 25-year joint venture with a Ghanaian private company Quantum Terminals to become the sole off-taker of the LPG produced at a new gas processing plant owned by GNGC. This was predicted to provide around 50-70 per cent of Ghana's LPG domestic needs. This raises the question as to whether it implied a change in government policy or priorities. At the time, GNGC is described by some observers as being run by a management enclave, with little accountability to government. As a limited liability company 100 per cent owned by government, GNGC were supposedly accountable to their board, but, as noted above, relations with government and with the national oil company in particular (GNPC) had become fraught. The Ministry of Energy, and potentially the Presidency, did not have full oversight of them, and they were on the defensive for mismanaging construction of a new gas processing plant by Chinese energy giant SINOPEC. It is therefore feasible that the government-owned GNGC was not on the same page as the Ministry of Energy, which was driving the LPG reforms. As noted above, due to problems with the structuring of GNGC in relation to the rest of the oil and gas sector, GNGC also lacked a proper commercial basis for their company, since they did not own the gas that they would sell.

Ghana Gas entered the joint venture with Quantum Terminals without any transparency, and without any competitive bidding process. Quantum Terminals is a Ghanaian subsidiary of Quantum Pacific, an industrial investment group owned by Israeli billionaire Idan Ofer. At the same time, Quantum were also approved by the Ministry of Energy to build a USD 500 million floating re-

gasification plant, which would process new LNG (liquefied natural gas) imports to arrive by sea, a key project for the government aiming to address Ghana's expensive shortage of cheap fuel for power generation. Could all this have meant that they were looking for ways to expand their business into the distribution of LPG? And would this have had implications for the planned LPG distribution reforms? Indeed, is it possible to tell whether GNGC and the Government were on the same page on LPG? Did the Quantum Power-Ghana Gas joint venture constitute a change in government position on LPG distribution? And how does the unwilling takeover of GNGC by GNPC relate to all this? It is impossible to say, but it certainly muddies the waters of what perhaps on the surface seemed like a relatively straightforward policy reform process around LPG.
This level of uncertainty in the mid-stream of the oil and gas sector in Ghana raises significant questions about how this may have played out downstream. Did the shifting political and economic alliances in the mid-stream also play out downstream? And to what extent did they intersect with the proposed reforms to LPG distribution in the country? Without further empirical research in Ghana it is not possible to answer these questions. At the very least, however, it provides the basis for one hypothesis as to what contributed to the stalling of the LPG reform process: i.e. that these shifting alliances in the mid-stream had implications downstream, which intersected with and ultimately destabilised the proposed changes to LPG distribution in the country.

Electoral politics in Ghana

Having noted the potential hypothesis around the difficult shifting and seemingly murky political economy dynamics that were playing out around oil and gas in Ghana at the time the LPG reforms stalled, it is now important to consider the role of electoral politics in the story. It is here that perhaps the most convincing hypothesis emerges as to what played out (albeit still a hypothesis requiring empirical testing), although, of course, in practice electoral political pressures are likely to have exerted simultaneous pressures to those described above in relation to the oil and gas mid-stream.

In 2015, Ghana was looking towards its next presidential and parliamentary election (to be held in November 2016). Energy prices, including LPG, as well as energy security and grid extension, against the chaotic backdrop painted above of regular blackouts and rapidly increasing energy demand, play a prominent role in pre-election politics. Presidential elections in Ghana operate under a winner-takes-all system. In the last election in 2012, incumbent president John Mahama of the National Democratic Congress (NDC) won with just 50.7 per cent of the vote, narrowly avoiding the 50 per cent threshold that would have triggered a run-off election. The main opposition candidate Nana Akufo-Addo of the New Patriotic Party (NPP) received 47.74 per cent of the votes (Ghana Web, 2012). This demonstrates just how close presidential elections have been and are likely to continue to be in Ghana. Particularly in light of Ghana's current economic and intricately linked energy challenges, many commentators are talking up the prospects of an NDC defeat by the NPP opposition party. As Bigg (2015) reports in an article on difficulties faced by the TEMA oil refinery:

> "The sagging economy presents an opportunity for the opposition New Patriotic Party, whose leader Nana Akufo-Addo blames the National Democratic Congress government for the problems. Akofo-Addo lost narrowly to President John Mahama in 2012 and is set to run against him again next year in what is likely to be a close election between two parties with government experience and similar ideological stances."

This brings into sharp focus the role that energy security plays in contemporary electoral politics in Ghana. When one begins to better understand the informal systems of patronage that characterize Ghanaian politics then it becomes even easier to see why a planned policy reform that would restructure the LPG sector, resulting in economic losses to a range of SMEs that are invested in the current distribution system, could quickly become a potential electoral issue. Local level politics and power in relation to energy is all about promises of grid extension and improved security of existing electricity supply – it is through this that politicians gain political capital and attract votes. For example, in the run up to the election the government was spending vast sums on emergency power generation barges to minimize the extent to which people were experiencing load shedding in the run up to the election. It is far from clear that access to LPG for cooking would garner similar political capital, particularly bearing in mind the safety concerns that pertained to LPG in Ghana. Electricity access gets you votes – it's not clear whether LPG does, and it might be hypothesised that it does not given the public health issues that the policy reforms sought to address.

This sits within the context of a long tradition in Ghana of redistributing resources prior to an election. The incumbent political leader controls the resources to be distributed during any election. The executive holds a huge amount of power through the constitution and appoints everyone. But, as with many African countries, traditional customary systems exist alongside a colonially imposed constitution and traditional chiefs also hold a lot of power. Their blessing is required in order to go ahead with most projects and they play a key role in the pre-election redistribution of resources. This implies that these local political elites would have had to be brought on board in order to go ahead with any changes in the infrastructure and distribution of LPG.

Although we have no hard evidence to support such a claim, the implication is that the downstream LPG vendors (who were set to lose out as a result of the restructuring of the LPG sector via the policy reforms) were likely much better politically connected than one might assume. People owning service stations, for example, are likely well-connected business people and powerful business interests control voting in local areas. In this context, therefore, SMEs potentially weald more power than big oil companies.

In an intricately detailed empirical analysis of the Ghanaian cocoa bean industry (which they contrast with the case of the sugar industry in Mozambique) Whitfield and Buur (2014) demonstrate the relevance of their "political survival of ruling elites" approach (Whitfield et al., 2015) to understanding the conditions under which industrial policy, such as the reforms to the LPG sector in Ghana, is successfully implemented or avoided. This approach:

> "…emphasises that government's policy choices and its ability to implement them, as well as its interactions with businesses, are shaped by incentives arising from the imperatives of ruling elites to remain in power and thus build and maintain political support. It argues that the state is never completely insulated, and no set of ruling elites is completely autonomous. Rather, what matters is how coalitional pressures shape the political costs of certain policies and the ability to implement them, given the resistance or support from factions and individuals within the ruling coalition and those financing it." (Whitfield and Buur, 2014: 127)

This kind of approach to political economy analysis arguably provides for a deeper account than the kinds of donor "how to" approaches mentioned further above – one that can engage with African politics and aspects of patronage that often cut across the artefacts of colonially imposed constitutional landscapes. Rooted in studies of African political economy, in this way Whitfield and colleagues are able to explain the Ghanaian way in which power is distributed and how this results in active incentives not to build technological capacities in specific sectors. As they say, "This literature focuses on explaining why some forms of rent-seeking support productivity improvements and learning, while others do not" (Whitfield and Buur, 2014: 127). Through this, they are able to explain why reforms seemingly in everyone's best interests are never likely to happen pre-election (and in many cases, not at any time). As they go on to say:

> "Whether (a faction of) ruling elites have mutual interests with a particular group of capitalists depends on whether they need those capitalists for their primary objective of political survival through building and maintaining their ruling coalition in order to remain in power. In democratic political systems that includes winning elections… In short, political survival means accommodating powerful groups, which can include financiers of political parties; firms or families who dominate key sectors in the economy; political elite factions with strength derived from their organisational capabilities; and lower levels whose support is needed to mobilise votes." (Whitfield and Buur, 2014: 129)

As Barnett (2014: 27) emphasizes towards the end of a report that is otherwise quite upbeat in expounding the value of political economy analysis in assisting practitioners and policy makers in better designing development in interventions around energy sectors; "… it must be accepted that the over-arching political environment in Africa may not be conducive to change."
Politics and power in Ghana therefore differ in important ways from many Northern countries, rendering traditional (European/American produced) accounts of state politics redundant. So, for example, Michael Mann's "infrastructural power" thesis (Mann, 1984), where states are able to extend their power by extending infrastructure (such as energy infrastructure), does not play out in the same way in many African contexts. In these places, state power is achieved and exercised more through social networks. This resembles a far more distributed and responsive (to local constituents) model of the state – but not in a Weberian sense (Weber, 1922)[10] – states are not accountable, but are pulled in multiple different directions.

From this perspective, then, our attention is drawn away from the infrastructural shape of the LPG or broader energy sector in Ghana when seeking to understand what happened with the stalled policy reforms. Rather, it suggests that an understanding of what happened is more likely to be rooted in personal connections and Ghana-specific political economy dynamics – dynamics that ultimately, particularly in the face of a forthcoming election, are likely more immediately influenced by domestic, local political power dynamics than by international political economy concerns of the kinds that most likely led to Ghana's engagement with international organisations like the World LPG Association and SE4All around the proposed LPG reforms. As Newell and Phillips (2016) observe in relation to the Kenyan government's "Vision 2030", it could well be that the proposed and internationally high profile reforms to the LPG sector in Ghana may well have obscured some

[10] Weber contrasted state bureaucracies that achieve legitimacy through their relation to legislative order with traditional forms of authority arising, for example, from kinship.

of the key trade-offs that the Ghanaian government had to marshal, and may well have sought to accommodate via political deal brokering behind the scenes, leading to the eventual stalling of the reforms.

Two hypotheses on the LPG experience in Ghana

From the political economy analysis above, two hypotheses emerge as to what explains the stalling of what seemed to be a policy reform process with a lot of momentum, underpinned by high profile international engagement (either independently, or in combination):

- **Hypothesis 1:** Shifting alliances and instabilities in the mid-stream of the Ghanaian oil and gas sector had implications downstream, which intersected with and ultimately destabilised the proposed changes to LPG distribution in the country.
- **Hypothesis 2:** The actors with vested interests in the current LPG distribution system had, and were able to exercise, greater political influence than the international actors who were pushing for reform of the LPG distribution model in Ghana. This may well have been augmented by the upcoming election. It is also likely intricately intertwined with historical contingencies that define the way in which political power is distributed and exercised in Ghana – a picture that is not reflected in more visible, colonially imposed constitutional commitments in the country.

Of course, none of this analysis answers the question as to whether the planned LPG reforms will come back online post-election. To understand this, a deeper analysis of the interests at play (which demands empirical fieldwork) and a clearer idea of the extent to which either of the above hypotheses can explain the stalled LPG distribution reforms is necessary.

Conclusions

As we stated in the introduction to this case study, a focus on innovation systems and the socio-technical dynamics of new technology adoption is vital to achieving transformations in clean technology uptake, but it is also essential to understand the broader political economy dynamics at play. The clean technology of interest could have clear technical merit, be cost-competitive and attractive to potential users, and official policy could be supportive. However, broader political economy dynamics can easily intervene to scupper efforts to achieve transformational change, as have seen in the complex case of LPG in Ghana. It is therefore crucially important that the MECS Programme commissions appropriate political economy analyses around clean cooking technologies in the Programme's countries of focus in order to increase the chances that its interventions will achieve transformative change.

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