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Beyond technology and finance: pay-as-you-go sustainable energy access and theories of social change

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Abstract. Two-thirds of people in sub-Saharan Africa lack access to electricity, a precursor of poverty reduction and development. The international community has ambitious commitments in this regard, e.g. the UN's Sustainable Energy for All by 2030. But scholarship has not kept up with policy ambitions. This paper operationalises a socio-technical transitions perspective to analyse for the first time the potential of new, mobile-enabled, pay-as-you-go approaches to financing sustainable energy access, focussing on a case study of pay-as-you-go approaches to financing solar home systems in Kenya. The analysis calls into question the adequacy of the dominant, two-dimensional treatment of sustainable energy access in the literature as a purely financial/technology, economics/engineering problem (which ignores sociocultural and political considerations) and demonstrates the value of a new research agenda that explicitly attends to theories of social change – even when, as in this paper, the focus is purely on finance. The paper demonstrates that sociocultural considerations cut across the literature's traditional two-dimensional analytic categories (technology and finance) and are material to the likely success of any technological or financial intervention. It also demonstrates that the alignment of new pay-as-you-go finance approaches with existing sociocultural practices of paying for energy can explain their early success and likely longevity relative to traditional finance approaches.

Keywords: sustainable energy access, socio-technical transitions, finance, solar PV, Kenya

Introduction

A total of 1.3 billion people globally lack access to electricity, which is fundamental to human and economic development. Almost half of these people are in sub-Saharan Africa (SSA). In recent years, significant policy interest has arisen in addressing this energy access challenge via the use of low-carbon, sustainable energy technologies – raising the possibility of tackling poverty whilst simultaneously tackling climate change. This has led to ambitious regional and international policy commitments. Most ambitious of all is the UN's Sustainable Energy for All (SE4ALL) initiative, which aims to achieve universal sustainable energy access by 2030.

But scholarship has not kept up with policy ambitions in this field. The literature on energy access in sub-Saharan Africa, for example, is characterised by a range of disparate and uncoordinated efforts with little of high enough quality to contribute to more systematic learning (Watson et al., 2012). Studies consist of project-by-project, or policy-by-policy, 'barriers' analysis, predominantly on financial and technical barriers. Cultural and political considerations are significantly under-represented and regular references to 'enabling environments' for change remain vague and un-theorised.

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In the same way as Shove (2010) problematises the failure of climate policy research more generally, the literature (and related policy) on sustainable energy access can be criticised for its failure to attend to theories of social change. Rather than Shove's 'A, B, C' (Attitude, Behaviour, Choice) of climate policy, the energy access literature suffers from an over-emphasis on 'T and F', technology and finance. And similar to the dominance of economics and psychology that Shove bemoans, we see domination by economics and engineering in the sustainable energy access field. There is an implicit (and often explicit) assumption that solving these two dimensions (T and F) of sustainable energy access is enough to support the kind of transformation that initiatives like SE4ALL seek to achieve (Byrne et al., 2012). But the problem is far from two-dimensional.

Shove highlights the socio-technical transitions literature as one field with potential to overcome such shortcomings. A socio-technical perspective on energy access emphasises the importance of attending to the social practices that energy access facilitates for poor people, e.g. light for reading or charging mobile phones to facilitate social connectivity, as opposed to the technologies that facilitate these practices. The co-evolutionary and mutually reinforcing nature of technological change and changes in social practices are also emphasised. This co-evolution is situated within an understanding of the ways through which energy is currently accessed (e.g. kerosene and diesel generators) and the stable, incumbent regimes of practice and power that exist around the present, fossil-dominated, energy regimes – regimes that are likely to be resistant to new, sustainable energy technologies. And it is here that we are also offered a theory of change. Change occurs through: successful nurturing of niches of sustainable energy technologies to the extent that they compete with existing dominant fossil-based regimes (Kemp et al., 1998); landscape level dynamics such as widespread changes in social and political demands for low-carbon energy (Geels, 2002) or the destabilisation of incumbent socio-technical regimes (Turnheim and Geels, 2013).

Notwithstanding the value of any analysis that better attends to theories of social change in relation to sustainable energy access, this paper seeks to make a specific and important point in this regard. Namely, that even when analysis does only focus on T or F (in the case of this paper we focus on finance), operationalising a theory of social change significantly increases the explanatory value of any analysis. In other words, whilst explicit analysis of sociocultural aspects of the sustainable energy access problematic is urgently required, this dimension of the problem is not a stand-alone consideration but cuts across the literature's traditional technology and finance foci. Analysis of either finance or technology via a conceptual lens that explicitly attends to sociocultural considerations can therefore significantly increase the explanatory value of such analysis. We demonstrate this by analysing the emergence of new, mobile phone-enabled pay-as-you-go (PAYG) finance approaches for sustainable energy technologies which are being rolled out in some developing countries, facilitated by advances in both real-time machine-to-machine monitoring technologies and mobile payments (payments made via mobile phone-based banking facilities). By applying a conceptual framework, based on a socio-technical transitions perspective, that explicitly attends to how well aligned these new PAYG finance approaches are with existing sociocultural practices of paying for energy, the paper demonstrates that these new PAYG finance approaches have significantly greater potential than traditional finance approaches for facilitating more widespread access of sustainable energy technologies.

These PAYG finance approaches are emerging in areas where finance for sustainable energy technologies like solar home systems (SHSs) previously consisted mostly of hire-purchase and microfinance models. Studies in sub-Saharan Africa suggest such past finance approaches achieved little success in facilitating electricity access for poor households. The vast majority of sustainable energy technologies were bought via cash payments and therefore were the preserve of relatively wealthy (albeit relatively poor by international standards)

people (Hankins, 2004; Jacobson, 2004). Whilst the improving cost and reliability of solar PV in recent years has, as one would expect, led to significant increases in the number of SHSs sold per year in Africa, this has had little impact on the energy access figures highlighted above. Indeed, in Kenya, the country of focus in this paper, energy access rates are worse than the figures for sub-Saharan Africa as a whole, with only 23% of Kenyans having access to electricity (World Bank, 2015), despite Kenya being the largest per capita market for SHSs in the world (second only to China) (Ondraczek, 2013). This implies that whilst, as Lay et al. (2013) emphasise, affordability is a key consideration in driving technology adoption, current prices remain prohibitive for poor people.

We focus our analysis on emerging PAYG approaches for SHSs in Kenya. These provide a suitable case study as they represent a country and technology which have seen the most significant emergence of the use of PAYG finance approaches for sustainable energy technologies to date. This is largely due to the success of mobile payments in Kenya via the M-PESA system. At the time the original research for this paper was undertaken in 2013, it was too early to know how successful these PAYG approaches were likely to be in the long term. More recent data on the expansion of PAYG finance approaches for solar PV in Kenya and elsewhere in Africa, however, suggest that PAYG finance is indeed being met with a significant level of success. A recent report by the World Bank's Lighting Global (Alstone et al., 2015) suggests the number of PAYG solar companies in Kenya has increased by around 60%, with several of the companies analysed in this paper having significantly increased the size of SHSs being offered. Alstone et al. (2015) also suggest that PAYG solar companies are now active in at least 20 SSA countries. It is important to note, however, as mentioned above, that electricity access rates in Kenya remain stubbornly low, despite significant decreases in the price and increases in the reliability of solar PV and the emergence of these new finance approaches.

The new PAYG approaches to financing poor people's access to SHSs in Kenya therefore provide us with suitable case studies for exploring the extent to which analysis that includes social practices can generate insights on the ability of these new approaches to overcome the failures of past sustainable energy technology finance models. Using a socio-technical approach to analysis, this paper seeks to answer the following question: 'To what extent can analytic approaches that explicitly attend to social practices shed light on the likely ability of new PAYG finance approaches to overcome the failures of past finance models in facilitating sustainable energy access for poor people?' In doing so, the core contributions of the paper are two-fold. Firstly, it demonstrates that sociocultural considerations cut across the literature's traditional two-dimensional analytic categories (technology and finance) and are material to the likely success of any technological or financial intervention. Secondly, it demonstrates that the alignment of new PAYG finance approaches with existing sociocultural practices of paying for energy can explain their early success and likely longevity relative to traditional finance approaches.

As well as these core contributions, the paper also makes a number of additional contributions. To date, although mobile-enabled approaches to consumer finance for sustainable energy access are beginning to get attention in the peer-reviewed literature, we were unable to find any published scholarly work that systematically analyses PAYG finance in the context of prevailing social practices and emerging social change. Indeed, in their review article on financing energy access in Africa, Gujba et al. (2012) make no mention of new, mobile-enabled PAYG finance, giving some insight into how new this type of finance is, but see Ladd (2015) for a brief analysis of more traditional microfinance versus PAYG in terms of their viability as business models. There has also been only limited application of a socio-technical transitions perspective within developing country contexts (e.g. see Baker et al., 2014; Berkhout et al., 2010; Romijn and Caniëls, 2011; Van Eijck and Romijn, 2008) and almost none in low-income countries. Furthermore, the transitions literature is yet to deal

explicitly with the issue of electricity access for poor people. These observations are significant as the transitions field emerged from detailed historical case studies from post-war Europe, raising questions as to how well it can work in developing (particularly low-income) country contexts that do not conform to what Furlong (2014) refers to as the 'modern infrastructure ideal'. The paper therefore seeks to make an additional contribution by applying a transitions perspective to the issue of sustainable electricity access in a low-income, sub-Saharan African country. The paper begins by outlining its methodological approach, including the theoretical approach applied. It then reviews both past finance approaches and emerging PAYG approaches before presenting comparative analysis of the two.

Methodology

The explosion of mobile banking in Kenya (via the M-PESA system) and related emergence of new mobile-enabled finance approaches for SHSs, together with Kenya's history of alternative SHS finance approaches (widely considered to have failed to provide access for poorer households – see Byrne et al., 2014), together with its stubbornly low electricity access rates mentioned above, rendered it an appropriate case study for this research.

In order to attend explicitly to theories of social change, the paper applies a socio-technical transitions perspective (as suggested by Shove (2010)). More specifically, it uses the analytic categories from strategic niche management (SNM). This allows finance for sustainable energy access to be situated within an understanding of technologies as co-evolving with the social contexts within which they are used. New technologies will therefore be widely adopted not simply because they successfully harness technical principles, but also if their form and function are 'aligned' or 'fit' with dominant social practices, or offer opportunities to realise new practices (or 'stretch' existing socio-technical practices) that are attractive in particular social and geographical settings (Raven, 2007). This perspective foregrounds the social practices and related energy services which access to sustainable energy facilitates – with finance understood as one part of the enabling infrastructure necessary to pay for the technology that facilitates these services. This is significant for an interest in new mobile-enabled finance models as these fit within existing (or rapidly emerging) social practices within Kenya around mobile banking. It also draws our focus to the practices that characterise the ways in which poor people in Kenya currently pay for the energy services that SHSs can provide (e.g. buying kerosene for lighting, paying to charge mobile phones or power televisions and radios from batteries or diesel generators).

SNM understands sustainable energy technologies as part of a 'niche', or protective space, in which the normal selection pressures that help the dominant fossil (and, in many developing-country contexts, wood fuel) based energy 'regime' to reproduce itself are weakened or absent (Smith, 2007). A socio-technical regime includes incumbent technologies as well as established socially embedded values and practices which follow an established pathway that reinforces the current, stable technological system; '… incumbent systems, such as large-scale, centralised, fossil-fuel electricity generation, constitute more structured and structuring "socio-technical regimes"' (Smith et al., 2013: 2). SNM then, in turn, recognises the potential for low-carbon niches to be nurtured, developed and adopted via a number of processes that might eventually result in the sustainable energy niche influencing, transforming or replacing the dominant fossil or wood fuel regime.

Five categories are identified to guide analysis of the extent to which a niche could influence, or is already influencing, a regime:

(1) *Protective space.* SNM argues that sustainable innovations need 'protective spaces' where experimentation and development of new technologies can take place within a supportive environment (Smith et al., 2013). The subsequent analytical categories within

SNM are embedded within the protective space but focus attention on the dynamics of interacting processes.

(2) *Experiments and learning.* Experiments can be perceived as being part of the process of nurturing (Smith et al., 2013), defined as '… initiatives that embody a highly novel socio-technical configuration likely to lead to substantial sustainability gains' (Berkhout et al., 2010: 262). Experiments generate lessons which lead to learning (Smith and Raven, 2012).

(3) *Actor-networks.* Networks of actors are important for building robust support for socio-technical practices, for facilitating knowledge exchange, for enabling interactions between stakeholders and for providing access to resources.

(4) *Expectations and visions.* Expectations and visions are variously specific articulations of the future in which particular socio-technical configurations are usually central (Byrne, 2011). For example, rural electrification based on SHSs can be considered an expectation. A vision would be clearer than this relatively vague articulation by including the means by which the expectation can be realised. Such means might include business models, supportive policies and technical specifications for the SHSs themselves.

(5) *Institutions.* Institutions include laws, regulations and policies as well as social practices, norms and conventions regarding a particular socio-technical configuration (Byrne, 2011: 19). A critical process in developing from a niche to a regime is the structuring of practices that can be adopted widely, contributing to institution building.

Data were collected between May and September 2013 via a combination of grey and published literature review and semi-structured interviews. Initial information on financing was drawn from a larger socio-technical analysis of the growth of the market for SHSs in Kenya which had not focussed explicitly on finance (see Byrne et al., 2014). Interrogation of the contact database and 100 h of recorded interview testimony collected by Byrne et al., plus discussions with the project's researchers led to the identification of: a focussed subset of interviewees (including some not interviewed by Byrne et al.) knowledgeable on the issue of past and new finance approaches; and an initial overview of key literature sources and finance initiatives to analyse within the current study. Literature sources were augmented by a wider literature review. Identification of additional grey literature (e.g. project review documents, donor reports, research and consultancy documents, government documents and press articles as well as websites, etc.) was assisted by the use of a snow-balling technique using email, telephone and Skype calls with various actors engaged in, or researching, the SHS or broader sustainable energy market in Kenya.

As well as identifying broader contextual issues, the literature review yielded a total of eight past finance approaches and four new mobile-enabled finance approaches from which six past and three new approaches were selected for the focus of analysis (see below). Data gathered from the literature review were triangulated with interviews with seven key actors (conducted in July 2013), spanning a range of backgrounds, who have worked, or are working, on financing SHSs in Kenya. These included four interviewees who were able to comment on past finance approaches and three working on new mobile-enabled financing approaches (currently the three biggest schemes in Kenya). They were (note: interviewee numbers are used as references in the remainder of this paper):

(1) Nick Hughes, M-KOPA – new PAYG company.
(2) Simon Bransfield-Garth, Azuri – new PAYG company.
(3) Klara Lindner, Mobisol – new PAYG company.
(4) Charlie Miller, Sunny Money/SolarAid (an NGO) – past finance approaches.
(5) Mark Hankins, African Solar Designs (private company) – past finance approaches.

(6) Arne Jacobson, Schatz Energy Research Center, Humboldt State University, USA (academic) – past finance approaches.
(7) Teddy Ongamo, former employee at Kenya Union of Savings & Credit Co-operatives (credit union/advocacy body) – past finance approaches.

Interview questions were structured around the five analytical concepts of SNM (see supplementary online data). Analysis of the data was structured using the five SNM categories to facilitate comparative analysis of the reasons for past or future successes and failures.

The interviews and literature review identified the following case studies of past and new finance approaches, all of which form the basis of the analysis in this paper. This was augmented with information from interviews and the literature referring to more generic experiences with other finance types such as hire-purchase agreements. For further details on these, see the detailed tables supplied as online supplementary data.

Past finance approaches analysed, the type of finance they represent and the dates they ran were:

(1) World Bank Energy Sector Management Assistance Program (ESMAP), 1995–1997 (Type: Group loan).
(2) GEF/World Bank Photovoltaic Market Transformation Initiative (PVMTI), 1998–2009 (Type: Subsidised loans as working capital).
(3) Michimikuru SACCO (Savings and Credit Cooperative) solar electrification project, 2002–2004 (Type: Soft loans).
(4) Faulu Kenya Deposit Taking Microfinance, from 2007 (Type: Microfinance).
(5) Kenya Union of Savings and Credit Cooperatives (KUSCCO), energy lending from 2004 (Type: Microfinance).
(6) Kenya Women Finance Trust (KWFT), from 2004 (Type: Microfinance).

New finance approaches analysed, the type of finance they represent and the dates they ran were:

(1) M-KOPA, initiated 2009, launched 2011 (Type: new PAYG model).
(2) Azuri, initiated 2010, launched 2011 (based on existing UK start-up company) (Type: new PAYG model).
(3) Mobisol, launched 2011 (Type: new PAYG model).

Note: At the time the fieldwork was conducted, at least six companies were trying to establish real-time monitoring and PAYG payment plans for SHSs in Kenya and several others were trying to establish other PAYG finance plans for SHSs (Pueyo, 2013; Interviewee 7). This study focussed on the three largest at the time of the research**.**

The data were then analysed using the analytic categories specified by the SNM literature. It should be noted that the paper's unit of analysis is explicitly the finance models used by the companies listed above – not the consumers of the technology. However, by virtue of its focus on theories of social practice and change, the SNM framework facilitated consideration of these companies' finance models within the context of the social practices of consumers of the SHS technologies that the PAYG models were designed to finance. The analysis below therefore considers both the characteristics of past and new finance models and their implications in relation to the social practices of consumers with which the energy technologies they finance interact.

Past finance approaches

Nature of past finance approaches

Past finance approaches were characterised as either loans and microfinance or hire-purchase arrangements. Case studies of the former are harder to find. They are thought to account for a far smaller proportion of the Kenyan SHS market than cash sales and hire-purchase.

Hire-purchase, by 2004, accounted for over 20,000 sales annually compared to only a few hundred via microfinance and other loans (Jacobson, 2004: 183).

Perhaps due to the lack of involvement from international development organisations, relatively little documentation exists on hire-purchase agreements for SHSs in Kenya. Only three sources were identified that touch on it, none of these at any length (see Hankins, 2004: 22; Jacobson, 2004; and, on Tanzania, Byrne, 2011: 168–188). From these limited sources plus the interviews, it was possible to identify the following insights. Hire-purchase is a common way of financing consumer goods like cars, TVs and other household devices. Typically, hire-purchase credits are given to customers who have stable employment as the credit is deducted from the person's salary. In Kenya, typically, teachers' associations have contracts with a specific hire-purchase company. This leads to a quasi-monopoly for finance companies, resulting in high interest rates of around 40%, increasing the price of SHSs by 80–150%. Loan periods are usually short (between six and 18 months).

Hire-purchase credits are perceived to have underpinned high SHS sales numbers from the late 1990s until around 2003 (Interviewee 5). The first effort to establish hire-purchase finance in the early 1990s was not successful, but the second attempt initiated in 1997 resulted in high sales and a general trend began for companies importing solar PV modules to supply their products via hire-purchase schemes (Hankins, 2004: 22; Jacobson, 2004: 181). The market share of hire-purchase-financed SHSs was estimated to be around 15% by 2004 (Hankins, 2004). However, those credits mainly targeted the rural, employed middle-class population and so excluded poorer households. Lack of technological knowledge amongst hire-purchase agents leading to missing technical support has also been problematic (Interviewee 5; Jacobson, 2004). There is no publicly available documentation on numbers of sales by hire-purchase companies to support assertions around market share and success levels (Ondraczek, 2013) and case studies which would facilitate more in-depth analysis of the hire-purchase experience could not be identified.

Summary of barriers faced by past finance approaches

Analysis of the data yielded through the interviews and literature review identified three broad types of barriers faced by past finance approaches: access to finance, customer support and after-sales service, and cooperation among technology and finance providers.

Access to finance

Realising access to finance through these past schemes was a major restriction. One cause was high interest rates to compensate for high transaction costs, especially in relation to lending to widely dispersed rural customers and to Kenya's weak infrastructure (Interviewee 4). The exclusiveness of several schemes to certain groups like SACCO members, employees or small businesses further served to restrict access.

Hire-purchase facilitates easy access to credits, but only for those who are employed and whose employers have an agreement with a hire-purchase agency. The approach therefore excludes poor and marginalised households. This is confounded by the high interest rates in hire-purchase arrangements. Likewise, microfinance projects experienced the problem of reaching poorer parts of the population due to high interest rates and inability to reach dispersed rural populations (Interviewees 4 and 6). These are seen as the main reasons why traditional microfinance has not been as successful in providing finance for SHSs in Kenya and other SSA countries as it has in countries like Bangladesh (Lighting Africa, 2010). Furthermore,

> … microfinance organizations … face a number of risks: finding a suitable partner is not easy; as consumption-oriented loans are normally based on credit-worthiness of recipients, mass-scale penetration of energy consumption loans may be difficult; and the risk of non-recovery of energy equipment cost is high. (Bhattacharyya, 2013: 471)

As a result, the conditions of past finance approaches consistently favoured the rural middle class, many of whom often favoured (modular) cash purchases to avoid the extra costs of loans (Jacobson, 2004).

Customer support and after-sales service

Most of the models and projects faced problems with unsatisfied customers due to technical issues that could not be, or were not, solved. As finance institutions (FIs) did not provide solar loans as their core business, they lacked knowledge about the technology and were not able to offer sound customer support. Instead, FIs depended on the technology supplier, but in many cases support was not forthcoming. 'Product loan was the direction that everyone was taking… but MFIs had no expertise on the solar product' (Interviewee 7). This was confounded by needing to reach remote rural areas when technology suppliers were generally based in urban centres. 'This was a challenge faced across the board' (Interviewee 7). When technical support was not forthcoming, customers either had to continue paying for malfunctioning systems or refused to pay the loans.

Cooperation among partners

The main reason for inadequate customer care and customer dissatisfaction seems to be embedded in insufficiently coordinated allocation of roles within partnerships of technology and finance providers. 'One of the barriers has always been that there is a lack of agreement between the banks and the solar companies and the consumers' (Interviewee 5). This caused issues of accountability, as seen in the cases of ESMAP, PVMTI, Faulu Kenya and KUSCCO. For example, KWFT had to change the technology provider several times because of the low quality of products, and problematic cooperation between competitive FIs involved in one project under the PVMTI initiative led to project cancellation. From the FI's perspective, depending on technology partners for product-specific loans due to a lack of in-house knowledge and capacity is perceived as a key problem (Interviewee 5 and 7).

Key characteristics of new PAYG approaches

In Kenya there are around six companies offering payment plans for SHSs based on real-time monitoring via machine-to-machine technologies and PAYG payment plans. Several companies are currently trying to establish other PAYG finance schemes for both SHSs and solar portable lights (Pueyo, 2013; Interviewee 7). The analysis in this section is focussed on the largest three providers at the time of the study: M-KOPA, Mobisol, and Azuri. The key characteristics of these companies are summarised in Table 1 (see online supplementary data for further detail). Whilst, as Table 1 illustrates, there are differences between the three companies (e.g. repayment terms and structures) they all share some common core attributes.

All companies offer a one-stop-shop model where they integrate provision of the SHS technology, finance and after-sales service. All interviewees emphasised provision of energy services to the rural poor (e.g. light and mobile charging) as their business' core motivation. This highlights a focus on overall energy service provision as opposed to finance. None of the businesses emerged from existing technology or finance providers. This is significant in that it describes a business approach which emphasises the social practices for which energy is needed and then works back from there to understand how it might best be facilitated (technologically and financially).

Of additional importance is the fact that all three companies developed their business models based on close attention to people's existing payments for energy, particularly buying kerosene and paying for mobile charging. They all did careful research on existing energy expenditure by rural households to inform the structuring of their payment plans. The payment plans are deliberately structured so as to be more affordable than many people's existing energy-related outgoings and to mimic to some extent the (sometimes irregular) timing of

Table 1. Key characteristics of new PAYG finance approaches in Kenya (based on data collected in July 2013 and updated in August 2015).

Company	Payment method	Repayment term and structure and SHS system size(s)	Electricity payment structure	Size of customer base	Sales approach and after-sales technical support	Finance for company's development
M-KOPA	M-PESA (Kenya's mobile money system)	- Flexible repayments over maximum of 12 months - USD 28.50 deposit, remaining USD 165 via instalments - System locked if payment overdue - SHS system size: 8W	Daily minimum of USD 0.34	- 25,000 customers by April 2013 - 200,000 customers in Kenya, Tanzania and Uganda by June 2015	- Sales via 700 strong M-KOPA dealer network - Customer helpline - Technical team monitor performance remotely - If system diagnosed as faulty, customer returns to a dealer for replacement - Dealer then sends system to M-KOPA for repair - Partnership with Safaricom, Kenya's leading mobile network operator, who operate M-PESA, sharing some shops with them and using the brand for marketing purposes	- Shell Foundation funded initial trial (building on existing links with M-KOPA founders) - Shell Foundation and Africa Enterprise Challenge Fund (AECF) continued to give grants post-trial phase - Sold parts of the company to impact investor Grey Ghost Ventures who invest in innovative emerging market technologies - Revolving debt fund - Consortium of partners provide working capital for equipment purchase
Mobisol	M-PESA and other mobile banking services (depending on country)	- 36-month maximum repayment term - Down payment USD 27 to USD 86 depending on system size - Monthly minimum repayment USD 10 to USD 47 depending on system size - Discounts for early repayment	Energy payment integrated with monthly repayment	- 250 customers in Kenya by April 2013 - 50 in Ghana (with Toyola) - 700 in Tanzania - 15,000 customers in Tanzania and Rwanda by June 2015 (Mobisol seem to focus now only on the markets in Tanzania and Rwanda)	- Work with local partners to develop marketing strategies, customer education and pilot customer bases - Sales via local marketing agents and village presentations - Due diligence process to assess ability to pay and energy game (adapted to educational background) to assess appropriate system size	- Grants and loans from AECF, European Union Development Fund and German Entrepreneurial Development Corporation to develop business models and provide some capital - Consortium of international and local corporate partners

(Continued)

Table 1. *Continued*

Company	Payment method	Repayment term and structure and SHS system size(s)	Electricity payment structure	Size of customer base	Sales approach and after-sales technical support	Finance for company's development
		- Payments bound to specific day - Yearly grace period of one month allowed to avoid default - Flexible repayment amounts (seasonal workers encouraged to pay more when incomes are higher) - System locked if payment overdue - SHS system sizes: 30, 80, 100, 120 to 200 Wp			- Service hubs where customers collect units and watch video demonstration - 36 months after-sales service - Real-time mobile maintenance monitoring - Maintenance visits where necessary - Customer helpline - Distribution of products bound to areas where technicians have been trained by Mobisol - Partnership with Vodacom (Vodafone E Africa) to enable payments	
Azuri	Scratch cards validated by SMS (number entered into SHS to operate)	- Repayment term 18 months - USD 10 for system installation - Variable down payment determines subsequent payments - Energy escalator system allows customers to upgrade - System won't work if scratch card number not entered each week - Different sizes, but mainly 10W	Scratch cards cost around USD 1.50 a week (USD 0.21 a day)	- 3500 customers in Kenya by March 2013 - 20,000 customers across Kenya, Uganda, Tanzania, Ethiopia, Rwanda, South Sudan, Zimbabwe, South Africa, Sierra Leone, Cote d'Ivoire and Nigeria - No updated figures publicly available	- Local dealer network for sales and maintenance - Diagnostics collected by local dealers in the field - Azuri trained dealers responsible for installation, selling scratch cards and maintenance - No partnership with a mobile provider	- Grants from USAID and AECF - Collaborated with investors for working capital - Local partners for distribution, installation and maintenance

these outgoings (e.g. Mobisol encourages seasonal workers to make higher payments at times when incomes are higher). This again foregrounds a focus on current social practices; this time, around current expenditure on energy. The results are payment structures that allow poor people to purchase high-quality equipment with after-sales support and maintenance at less than their current outgoings on energy. Interestingly, only Mobisol mentioned doing any explicit research on the failure of past finance models to inform its business model development. All three companies also base their payment methods around people's existing widespread use of mobile phones across Africa, emphasising further attention to existing social practices in informing the nature of the finance approaches.

Other aspects of social practices around energy and spending more generally were also emphasised by interviewees as key to structuring payment plans. M-KOPA, for example, experimented with different deposit sizes to secure a sense of ownership and identify customers who were likely to repay in full. Mobisol also provides different system sizes, based on pre-sales engagement and assessments with customers to suit different energy requirements. This includes the use of games tailored to help customers of different levels of literacy assess their energy needs. Both Mobisol and Azuri also offer opportunities for customers to upgrade their systems once they pay off their initial system. This is based on recognition that customers' electricity usage is likely to increase over time as their social practices adjust to their newly obtained access to electricity. It also means there is potential for customers to access SHSs powerful enough to run products such as sewing machines. The consequences could be that poor people are able to pursue new productive, income-generating activities (with the subsequent transformative implications for social practice such energy access might catalyse).

All three companies had explicit plans in place for delivering after-sales service. These approaches, however, differ between the three companies (Table 1). Mobisol and Azuri have more of an emphasis on locally available technicians, whereas M-KOPA relies on remote assessment and repair, relying on dealer networks to facilitate the relationship with the customer and send back faulty systems. Mobisol also uses remote assessment before sending technicians to villages to undertake maintenance, whereas Azuri is more hands-on with diagnostics being regularly collected by technicians in the field. All three companies emphasised the importance of their local networks of dealers and technicians as critical to their business' success, including for building trust and brand awareness with customers.

Networking also arose as a significant issue in different ways across the interviews. For example, existing contact with the Shell Foundation, through M-KOPA's founder's previous role in establishing M-PESA, was mentioned as being important in being able to approach the Foundation for pilot funding. Interviewee 3 (Mobisol) mentioned interactions through SE4ALL's practitioner network as significant, as well as workshops facilitated by the Alliance for Rural Electrification. It is also notable that public funding played a key part in the establishment of all three businesses.

Interviewees also alluded to some barriers to the development of new finance models. This included access to equity finance and working capital, particularly due to the small and new nature of these businesses. Financing capital costs is a critical concern within business models where the energy service providers remain the owners of the hardware whilst providing credit to customers (Pueyo, 2013). As emphasised by Interviewee 1, fund raising for working capital is difficult because commercial FIs estimate the risk of financing a new product in an emerging market as being too high. 'Working capital is now the bottle neck – before it was demand and distribution' (Interviewee 4). It is probably due to the emerging interest in funding 'green' markets in developing countries that funding for socially oriented energy enterprises is available at all. Access to grant funding therefore seems to have been critical to all businesses' development. Questions have been raised, however, as to the availability

of extensive enough funding from donors or investors to support more widespread trials and innovations (GSMA, 2013: 36).

Political uncertainty was also identified as a potential problem. This included concerns regarding the possibility of the reintroduction of import duty on solar products. The government's commitment to kerosene reduction via the flagship 'Kerosene free Kenya' initiative was, however, cited as a reason for confidence in government commitment to solar. This might now be in doubt again following the imposition of 16% VAT on solar products in October 2013 (Byrne et al., 2014: 62). The possibility of the government raising duty on the relatively young mobile money sector was also cited as a concern – this is what happened in Uganda and is credited as the key reason for M-PESA not taking off in that country.

Comparative analysis of past and new consumer finance approaches

Having identified the key characteristics and strengths and weaknesses of past and new finance approaches, here we use the analytical categories from SNM to compare them. This also serves to demonstrate the usefulness of SNM's theory of socio-technical change in analysing finance approaches. To assist this, key terms from SNM theory are italicised.

Protective space

SNM argues that sustainable innovations need *protective spaces* where *experimentation* and development of new technologies can take place within a supportive environment (Smith et al., 2013). Jacobsson et al. (2004: 24) emphasise that spaces offer opportunities for *learning* and that *protection* goes beyond technology policy instruments. *Protection* is essential at the initial stage of innovations as it *shields* them from mainstream selection pressures. *Shielding* can be passive through the use of pre-existing configurations or active through strategic intervention. The process of *nurturing* enables socio-technical niches to grow and become able to influence or enter the regime. After this, *protection* shifts to *empowerment*. Empowerment is mainly achieved by advocates and networks around the socio-technical niche. Actors within the niche become outward oriented, which means they are active within the regime and interact with others (Smith and Raven, 2012; Smith et al., 2013: 3). The subsequent analytical categories within SNM are embedded within the *protective space* but focus attention on the dynamics of interacting processes.

In several past finance approaches, *active shielding* took place in the form of donor funding and support by international organisations. Hire-purchase agreements, however, did not emerge through *active shielding*. Instead they benefited from *passive shielding* by utilising established lending models. Through this they were able to fill a gap that microfinance was not able to fill. However, the reported success of hire-purchase for SHSs was only temporary, probably due to loan access restrictions (middle class employees only) and high interest rates.

This highlights the importance of donor funding in *nurturing* a *protective space* for energy enterprises to *experiment* with new finance models and suggests donor funding for new finance models might be significant in its potential success:

> There has been a tremendous growth in the donor driven support for energy access within the last five years. Donors have created the foundation, so many companies have been built on patient capital and grants provided by donors … Donors are excited by the new toys, the new technical solutions. (Interviewee 5)

Interviewee 1 indicated that without public funding M-KOPA would not have been able to conduct sound trial phases, as commercial banks were not willing to take the risk. Interviewee 3 also highlighted the opportunities afforded by the recent 'green growth mainstream' in Africa. This can be seen as a form of *shielding* by making use of this new international development *expectation,* which is articulated, for example, in the SE4ALL initiative.

However, it might not always be easy for new businesses to access resources that lead to the development of financially sustainable models (Koh et al., 2012; Pueyo, 2013). In the case of M-KOPA, personal contact already existed with the Shell Foundation which was likely to have been significant in facilitating access to funding. It is not clear whether future businesses will be able to access the same support. It may well be that the *protective space* provided by donor funding could be removed once business models have been proven, a market for PAYG products has become well established and commercial banks and more investors have been attracted to the market. In this sense, the *protective space* provided by donor funding can be seen as critical to reducing the risks associated with early investment in new, *niche* technologies and new business models.

Experiments and learning

Experiments can be perceived as being part of the process of *nurturing* (Smith et al., 2013), defined as '… initiatives that embody a highly novel socio-technical configuration likely to lead to substantial sustainability gains' (Berkhout et al., 2010: 262). *Experiments* generate lessons which lead to *learning* (Smith and Raven, 2012). *Learning* is conceived in two forms (Byrne, 2011). *First-order learning* is instrumental, focussed on trying to make a particular socio-technical configuration work. It is concerned with refinements to the particular socio-technical configuration and tends to result in the accumulation of facts and data, e.g. about the technical performance or characteristics of a specific technology or finance model. *Second-order learning* is more fundamental. It can occur when the framing assumptions of a particular socio-technical configuration are challenged (e.g. dominant energy-consumption practices) and can therefore result in a new set of framing assumptions and a new configuration. Given the experimental nature of niches and the uncertainties associated with any particular socio-technical configuration, it is likely that *second-order learning* is especially critical to developing configurations that work and that can be successfully – and widely – deployed (Byrne, 2011; Schot and Geels, 2008).

The early donor supported finance models can be viewed as *experiments* that aimed to learn lessons and build a basis for future finance approaches. It seems that at least between ESMAP and PVMTI some form of experience exchange took place. However, finance approaches were repeating each other's mistakes in terms of after-sales coordination between the FI and the technology provider. Some overall *learning*, however, seems to have taken place. The reduction of transaction costs and the need for lower interest rates to reach poorer parts of the population appear to be widely recognised but could not be overcome by past microfinance approaches (Interviewee 4, 5, 6).

New finance models have recognised the opportunity to decrease costs by the use of technologies that enable real-time monitoring and controlling as well as mobile payment. The three companies represented in this study were aware of the problems of traditional solar loans. However, based on the interviews, only Mobisol actively built on that experience by taking into account previous research on problems of microfinanced SHSs. Nevertheless, even implicit recognition of past problems can be seen as a base on which to build new approaches, implying *second-order learning* in the form of changes relative to previous assumptions and explicit attention to a different way of doing things.

All the PAYG start-ups were conducting trial phases which helped them to test and modify assumptions about consumer needs and capacity to pay. This can be seen as new *first-order learning* in relation to these different approaches to finance that built on the *second-order learning* above. The inadequacy of loan amounts and payment terms that many of the past models were facing indicates that former finance models did not follow the assumption that payment rates have to be linked to local costs of kerosene and phone charging as part of common energy consumption practices. In other words, they did not sufficiently take into

account *consumer needs and behaviour* around solar electricity and lighting. In this sense, the *second-order learning* of new finance approaches can be seen as particularly significant.

It seems, however, that each enterprise was doing the same kind of research, which indicates that little knowledge exchange between them was taking place. It is yet to be seen whether their *experiments* with new business models will lead to an overall *learning effect* through the communication of experiences between each other which would benefit the whole niche. Their will to share experiences seems to be limited, probably due to issues pertaining to competitiveness. This feature of free market-based donor-supported interventions seems to be somewhat inadequate, as public grants should not serve a single business but rather the establishment of a whole market for affordable SHSs.

An analytic focus on *learning and experimentation* also highlights some potential weaknesses of new PAYG approaches. For example, there is not yet sufficient experience of the performance of the real-time monitoring system. Some interviewees mentioned cases of abuse (Interviewee 4, 7). Receiving information on the system only through mobile network signals is also a new approach so might encounter technological issues if, for instance, the network is down (and see Ladd, 2015 for the impact on business model viability). The three PAYG suppliers have also adopted different approaches to after-sales services. It is not yet clear the extent to which these alternative approaches have *learned from*, and hence will address the shortcomings of, past finance approaches in this sense. M-KOPA also relies heavily on technology to assess system functioning. It is yet to be seen if that can replace onsite operation and maintenance.

Actor-networks

SNM asserts that *networks of actors* are important for building robust support for socio-technical practices, for facilitating knowledge exchange, for enabling interactions between stakeholders and for providing access to resources. *Networks* might be more effective if they are broad, which means the involvement of a large variety of stakeholders, and if they are deep, meaning there exists strong commitment amongst all actors and organisations (Schot and Geels, 2008).

As part of the *nurturing* process that enables the development of innovations, interactions and *networks of actors* were established via past finance approaches, although there are questions as to the extent to which these were well *aligned* enough to properly *nurture* the *niche*. Interaction within previous finance models took place primarily between development agencies as well as local FIs. Within the *protective spaces*, however, *intermediating work* between the actors seemed to have been weak. For instance, many partnerships between FIs and technology providers were lacking in coordination and exact distribution of tasks, which led to accountability issues and client dissatisfaction. This might indicate that donor funding is not necessarily sufficient to facilitate a *protective space* if it is not well coordinated. Many interviewees also indicated that *networks of actors* have been insufficiently *aligned*. Even though many partnerships between technology and finance providers evolved, they failed to work in ways that clearly defined roles.

Another problem seems to be rooted in the complexity of such *networks*: ‘All the actors – technology and finance providers and donors – have a different view of what the consumer wants and come up with various solutions, whereas the consumer just wants a simple thing; which is cheap electricity’ (Interviewee 5). *Knowledge exchange* took place within donor-based networks, but was promoted less once donor support phased out and finance was mainly offered by private businesses:

> After the donor driven projects, businesses started offering product loans … they were doing their own thing and there has not been much knowledge sharing … It should have been done differently. If there is no sharing of information on how to mitigate risks and

> why energy loans are so expensive, it is difficult to reduce the high interests rates of around 25% and to solve the problems that finance providers were facing. This should be changed. (Interviewee 7)

Interviewee 7 suggested the Kenya Renewable Energy Association (KEREA) could take over the task of linking all relevant players in relation to technology and finance provision for solar lighting, as KEREA has access to all practitioners in the market and could find 'best matches'.

New business models partly overcome the barrier of finance and technology *interaction* as they provide both services as one-stop-shop models. Furthermore, *actors from different backgrounds*, like the strong mobile money sector, are now active within the SHS *niche*, with *interactions* evident between PAYG initiatives, international organisations and local partners, which might indicate a form of *niche empowerment*. However, *knowledge exchange* between the enterprises remains an issue, as described above.

Interviewee 3 indicated a number of workshops with potential to bring *experiences* and ideas together. Likewise, Lighting Africa could act as a facilitator for diffusion of *lessons learned* from new business models. Lighting Africa was acknowledged by several interviewees as a helpful platform of *knowledge exchange*, mainly in the field of solar portable lights, but with evidence which is also important for the area of SHSs (Interviewees 4, 5, 6). 'Lighting Africa is an important network at the pico level. They have workshops which enable technology and finance providers to meet and identify opportunities of collaboration' (Interviewee 6).

A need was also identified for *broad and deep networks*, involving many committed stakeholders to overcome barriers that past finance approaches were facing:

> GOGLA [Global Off-Grid Lighting Association] wants to do a study on all finance options available. Research is coming, but slowly. This is a critical role of networks ... because many actors in the arena are repeating each other's mistakes. It is crucial to facilitate the sharing of information, promoting good practice and documenting case studies on what has worked and what hasn't … and to bring all actors together and generate more interest from investors. (Interviewee 4)

This also emphasises again the need for *knowledge exchange*.

Institutions

Institutions include laws, regulations and policies as well as social practices, norms and conventions regarding a particular socio-technical configuration (Byrne, 2011: 19). They therefore capture more traditional ideas of formal *institutional structures* as well as less formal *institutional practices* such as existing practices around payment and consumption of energy. A critical process in developing from a *niche* to a regime is the structuring of practices that can be adopted widely. *Institution building* (whether formal or non-formal) is therefore an important process that *co-evolves* with those outlined above as a *niche* develops. This category also directs analytical focus towards consumer behaviour, sociocultural practices and the relevant services that sustainable energy technologies might facilitate.

Interviewees did not indicate many constraining or enabling factors regarding governmental *laws and regulations*. An enabling factor was undoubtedly the removal of import duty on solar products (Interviewee 3), although VAT has now been imposed. Accounting for *consumer behaviour* and *social practices* around solar electricity seems to have been less prevalent among previous finance approaches which did not reflect the *consumers' payment behaviour*. This is the opposite of new PAYG approaches which are tailored to *consumers' current payment patterns*, enabled through widely established mobile banking and payment *practices*:

> The concept is relevant for how they live their lives. They buy things in small amounts because it's the way their cash flow works, they cannot afford the up-front cost. This is

> true of washing powder, food … It's not that they don't have money, it's that they have small amounts and their income is very irregular. (Interviewee 1)

Mobisol goes even further in that it tries to adapt to the low education level of low-income customers. It promotes customer education, taking into account people's ability to receive information, for example though games, videos and a user manual with comic drawings. PAYG enterprises are therefore much better adapted to *consumer behaviour*, matching *existing payment practices* for energy, such as small, regular payments for kerosene.

All three PAYG companies interviewed also aim to provide a whole service rather than a technology and try to take the risk associated with that new technology and the investment away from the customer (Interviewee 1, 3, 4). This overcomes one of the key barriers identified in relation to past finance approaches in terms of the lack of *integration* of technology and finance providers.

Nevertheless, it is not yet clear how far they will reach poorer households. For instance, the start-ups assume expenditure levels on kerosene equivalent to that of wealthier rural populations. As Interviewee 3 states, the current real-time monitoring technology used is too expensive to be applied for smaller and cheaper pico systems which might be more realistic for poorer households.

Expectations and visions

Expectations and *visions* are variously specific articulations of the future in which particular socio-technical configurations are usually central (Byrne, 2011). For example, rural electrification based on SHSs can be considered an *expectation*. A *vision* would be clearer than this relatively vague articulation by including the means by which the *expectation* can be realised. Such means might include business models, supportive policies and technical specifications for the SHSs themselves. Both *expectations* and *visions* can be linked directly with *first- and second-order learning*. That is, an *expectation* can act as a goal, arising from a set of framing assumptions, towards which actors engage in *first-order learning* as they try to realise the *expectation*. In doing so, they begin to detail the means by which that *expectation* can be realised and therefore begin to detail a particular *vision*. When framing assumptions change through *second-order learning* a new *expectation* is generated and further *first-order learning* in this new direction will begin to detail a new *vision*. However, both *expectations* and *visions* need to be sufficiently robust, specific and stringent (and be 'shared' collectively) to have long-term effects on the evolution of a *niche* (Raven, 2005).

Different *expectations* and *visions* can be identified across the *many actors* involved with SHS provision. Most past finance providers had the *expectation* that the major constraint to SHS uptake is lack of access to adequate finance, and that they could make profit by providing that finance:

> The expectation of finance institutions is to get into that market as a penetration strategy, to diversify the portfolio and to have a quick win, as there is demand for this product and this loan... but it has not always worked out as the loans are very expensive. (Interviewee 7)

Likewise, technology providers hope to expand the market for their products through financing.

International development organisations and donors seem to have shifted their *expectation* from a belief in microfinance as a market catalyser towards the need for *capacity building*. Recently, however, there has also been a stronger focus on supporting energy access through making finance available through the private sector. Hence, support of socially oriented private enterprises seems to be prioritised, providing a key opportunity for new PAYG start-ups.

The government seems to have established a *supportive policy environment* for actors providing finance for SHSs through 'Kenya Vision 2030' and 'Kerosene free Kenya'. According to Interviewee 4, Kenya is the only country in Africa that has a flag-ship

commitment for the eradication of kerosene for lighting. Its commitment gives investors and companies confidence that policies will not change within the next five years. 'It is as simple as the promise "I won't touch solar lights within the next five years"' (Interviewee 4). In this way, before the imposition of VAT, the *expectations and vision* of the government were perceived as *aligned* with the interests of actors seeking to expand the solar market in Kenya, providing a powerful impetus for engagement from investors.

New PAYG finance providers have the *expectation* that they can reach a larger part of the population by offering clean and affordable electricity. All three start-ups shared the *expectation* that clean and affordable electricity access can be achieved by offering a payment plan that is based on *baseline expenditure patterns*. Their further emergence and development might be influenced by, and dependent upon, the *expectations and visions* of international development organisations and the Kenyan government's commitments.

Conclusion

The application of SNM analytic categories in the discussion above yielded a range of insights on why new PAYG finance approaches are likely to better facilitate poor people's access to sustainable energy than past finance approaches. Moreover, the explicit focus on how socio-technical change is theorised to occur casts specific light on the potential of these new finance approaches to effect future change, including some of the barriers they face. In different ways, protective spaces, experiments and learning, actor networks, institutions, and expectations and visions have played roles in defining the limits and potential of past and new finance approaches. The explicit, energy service-oriented focus of new PAYG approaches (including the integration of technology provision, finance and after-sales maintenance) and their attention to the social practices that sustainable energy can facilitate (e.g. light, mobile connectivity), and the social practices through which energy is currently obtained and purchased (e.g. kerosene, diesel generators), are shown to play a significant role throughout on the relative potential of these new finance approaches.

The analysis demonstrates the potential of socio-technical transitions theory to contribute both to research in low-income country contexts and to the specific problem of sustainable energy access. Furthermore, it provides us with a vivid insight into the importance of extending analysis beyond the traditional T and F (technology and finance/engineering and economics) focus of the existing literature to also attend to theories of social change when seeking to understand sustainable energy access. Even when our attention is focused on the T and F that have until now preoccupied research and policy/practice in this field, it is not enough to rest on the two disciplinary silos of economics and engineering that continue to dominate. Functioning technological hardware and access to finance are of course necessary parts of achieving sustainable energy access – but they must be understood within a broader perspective of social (in our case, socio-technical) change.

There are, of course, much more than simply the T and F dimensions of this problem that need to be understood. At present there is hardly any research on the sociocultural or political aspects of sustainable energy access, highlighting a need for further interdisciplinary expansion. This might be achieved, for example, by operationalising approaches and insights from social anthropology, geography, political science and international relations. The key point of this paper, however, is to demonstrate that, even when we do just focus on the T or the F, then, in the same way that Shove (2010) emphasised in relation to climate policy more generally, it is critical that analysis and policy/practice are explicitly informed by theories of social change. Without this, scholarship stands little chance of informing policy approaches that live up to the ambitions of programmes like SE4ALL.

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