Sustainable energy for whom? Governing pro-poor, low carbon pathways to development: Lessons from solar PV in Kenya

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Energy access

Sustainable energy for whom? Governing pro-poor, low carbon pathways to development: Lessons from solar PV in Kenya

Using a combination of insights from innovation studies, socio-technical transitions theory and the STEPS pathways approach, this paper analyses the evolution of the Kenyan photovoltaics (PV) market. Considered by many to be an exemplar of private sector led development, the Kenyan PV market has witnessed the adoption of more than 300,000 solar home systems and over 100,000 solar portable lights. The notion of an entrepreneurially driven unsubsidised solar market has proved to be a powerful narrative amongst development actors who, paradoxically, have provided millions of dollars of funding to encourage the market's development. We argue that this donor support has been critical to the success of the market, but not simply by helping to create an enabling environment in which entrepreneurs can flourish. Donor assistance has been critical in supporting a range of actors to build the elements of a PV innovation system by providing active protection for experimentation, network-building, and the construction of shared visions amongst actors throughout supply chains and amongst users. This analysis gives important clues for designing climate and development policies, with implications for the governance of energy access pathways that are inclusive of poor and marginalised groups in low income countries.

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Today's world is experiencing rapid social, technological and environmental change, yet poverty and inequality are growing. Linking environmental sustainability with poverty reduction and social justice, and making science and technology work for the poor, have become central challenges of our times. The STEPS Centre (Social, Technological and Environmental Pathways to Sustainability) is an interdisciplinary global research and policy engagement hub that unites development studies with science and technology studies. We are developing a new approach to understanding and action on sustainability and development in an era of unprecedented dynamic change. Our pathways approach aims to link new theory with practical solutions that create better livelihoods, health and social justice for poor and marginalised people. The STEPS Centre is based at the Institute of Development Studies and SPRU Science and Technology Policy Research at the University of Sussex, with partners in Africa, Asia and Latin America. We are funded by the ESRC, the UK's largest funding agency for research and training relating to social and economic issues.

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Sustainable energy for whom? Governing pro-poor, low carbon pathways to development: lessons from solar PV in Kenya

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The work was conducted as an equal partnership between STEPS and ATPS. However, certain tasks were clearly delineated between the two organisations. In particular, ATPS conducted an analysis of the Kenyan policy environment and this work is to be published by them as another working paper.

Rob Byrne spent three and a half months conducting fieldwork in Kenya, assisted for some of that time by Sarah Becker, and hosted by ATPS in Nairobi. Others in Kenya also helped in different ways to support the research. In particular, thanks are due to Andrew Kilonzo for facilitating access to the Solarnet archive, which is held by Mike Harries at his farm in Thika. And Mike Harries, too, along with the staff at the farm, are due our gratitude for their kind hospitality and cooperation. Our driver for the two visits to Mike Harries' farm – John Ng'anga Kimani – went far beyond the call of duty to help us make sense of the Solarnet archive and so we thank him for his valuable and friendly assistance. And the staff at Ubbink East Africa in Naivasha were kind enough to provide an impromptu tour of the factory. Finally, Mark Hankins and family hosted Rob Byrne for an entire weekend at their place outside Nairobi. So, apologies to Mark's family for using his time to talk solar, taking him away from what should have been a relaxing weekend break. But thank you for the transport, accommodation, food, conversation and entertainment.

All the written outputs from the project, and further information, are available via its web page hosted by the STEPS Centre http://steps-centre.org/project/low_carbon_development/

Funding is currently being sought for a programme of research which builds on the current study to apply the conceptual approach developed here across a range of different countries, low carbon technologies and energy services. Please contact d.g.ockwell@sussex.ac.uk for further information

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Acronyms

ABM	Associated Battery Manufacturers
AC	Alternating Current
ADF	African Development Foundation
AIBM	Automotive and Industrial Battery Manufacturers
APSO	Agency for Personal Service Overseas
AT	Appropriate Technology
ATPS	African Technology Policy Studies Network
BOP	Bottom of the pyramid
BOS	Balance of Systems
CDKN	Climate and Development Knowledge Network
CDM	Clean Development Mechanism
CER	Certified Emissions Reduction
CIC	Climate Innovation Centre
CSC	Commonwealth Science Council
CTCN	Climate Technology Centre and Network
DC	Direct Current
DFID	Department for International Development
DIY	Do-it-yourself
EAA	Energy Alternatives Africa
ERC	Energy Regulatory Commission
ESD	Energy for Sustainable Development
ESDA	Energy for Sustainable Development Africa
ESMAP	Energy Sector Management Assistance Programme
EU ETS	European Emissions Trading Scheme
FIT	Feed-in tariff
GCF	Green Climate Fund
GEF	Global Environment Facility
GOGLA	Global Off-Grid Lighting Association
GTZ	German Organisation for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit) now merged into GIZ, German Organisation for International Cooperation (Deutsche Gesellschaft für Zusammenarbeit)
Hivos	Humanist Institute for Development Cooperation
ICE	Impact Communications and Engagement
IDS	Institute of Development Studies
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IGAD	Intergovernmental Authority on Development
ISO	International Organization for Standardization
ITDG	Intermediate Technology Development Group

JICA	Japan International Cooperation Agency
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARADEA	Karagwe Development Association
KEBS	Kenya Bureau of Standards
KENGO	Kenya Environmental Non-Governmental Organizations
KEREA	Kenya Renewable Energy Association
KES	Kenya Shilling
KESTA	Kenya Solar Technician Association
KEEI	Korea Energy Economics Institute
KSTF	KARADEA Solar Training Facility
LCEDN	Low Carbon Energy for Development
LDC	Least (Less) Developed Country
LED	Light-emitting diode
MDGs	Millennium Development Goals
MERD	Ministry of Energy and Regional Development
MESP	Micro-Enterprises Support Programme
MFI	Micro-Finance Institution
MLP	Multi-level perspective
MOE	Ministry of Energy
NASA-LeRC	North American Space Agency Lewis Research Center
NGO	Non-governmental organisation
NITA	National Industrial Training Authority
PS	Permanent Secretary
PV	Photovoltaic
PVGAP	Photovoltaic General Approval Program
PVMTI	Photovoltaic Market Transformation Initiative
RAEL	Renewable and Appropriate Energy Laboratory
ROK	Republic of Kenya
SACCO	Savings and Credit Cooperative
SE4All	Sustainable Energy for All
SELF	Solar Electric Light Fund
SHS	Solar home system
Sida	Swedish Development Cooperation
SNM	Strategic niche management
SPL	Solar portable light
SSA	Sub-Saharan Africa
STEP	Science, Technology and Environmental Policy Program, Princeton
STEP	Solar Technician Evaluation Project
STEPS	Social, Technological and Environmental Pathways to Sustainability
TEDAP	Tanzania Energy Development and Access Expansion Project
UK	United Kingdom

UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	UN Framework Convention on Climate Change
UNIDO	UN Industrial Development Organization
UON	University of Nairobi
US	United States
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value Added Tax
VDC	Volts DC
WHO-EPI	World Health Organization Expanded Programme on Immunization
Wp, kWp, MWp, TWp	watt-peak, kilowatt-peak, megawatt-peak, terawatt-peak
WP	Work Package

Executive Summary

Access to modern energy services is a critical human development priority. A tension is sometimes perceived between increasing energy access and pursuing low carbon development. However, multiple synergies potentially exist between human and economic development priorities and access to low carbon energy technologies. Renewable energy can facilitate access to energy in areas where grid-based provision is prohibitively expensive and unreliable, energy efficient technologies can improve availability of energy services and a combination of the two can increase local and national energy security and economic resilience

The grid-based electricity access rate in Kenya remains well below the average for sub-Saharan Africa despite significantly intensified efforts over the past decade to increase grid-penetration. Although the rhetoric of these efforts promotes the deployment of a range of low carbon technologies at different scales, there is little in the way of practical support for off-grid low carbon electrical services and so little policy attention to the role of rural household energy access in pro-poor development. Instead, much of the attention to the pro-poor agenda is being paid by donors, who have tended to adopt the 'bottom-of-the-pyramid' rhetoric that claims poor people can participate in energy technology markets and so the private sector can deliver pro-poor energy services. Within this rhetoric, the challenge is said to be one of creating an enabling environment within which private actors can compete freely to service the energy demands of the poor.

Insights from innovation studies and socio-technical transitions theory suggest that this view of enabling free markets to deliver energy services is misguided at best. The innovation studies' literature tells us that an enabling environment is certainly important but it is not sufficient. These studies also tell us that the development benefits associated with innovation can only be fully exploited if local innovative capabilities are built, including innovation systems. A socio-technical understanding of innovation tells us that context matters and that innovation processes are shaped interactively with political, social and environmental forces, as well as with those actors who possess economic and institutional power.

The Solar Home System (SHS) market in Kenya provides a case with which to examine these ideas. There are estimated to be in excess of 300,000 SHSs in Kenya, sold through a vibrant private market that is considered one of the most dynamic per capita solar markets historically. Recent years have also seen the growth of a market for pico-solar products. The rhetoric used to describe the successful growth of these markets has sustained the notion that they have been private sector led. However, closer inspection reveals that neither has been simply private sector led and that neither success is simply down to an enabling environment. Instead, important innovations have been driven or facilitated by donor involvement throughout the local supply chain, along with detailed understanding of user needs and desires. Moreover, the Kenyan policy environment has at times been hostile to the promotion of photovoltaic (PV) technology. Analysing this evidence suggests that interventions to widen, deepen and enhance low carbon energy access need to be sophisticated and systemic. They should attend to the entire local supply chain; find, understand and raise demand for low carbon energy innovations; build capabilities that support development towards local innovation systems, including at the policy level; and do so in ways that are reflexive in relation to the local (evolving) context. Furthermore, much closer attention to those in poor and marginalised groups could yield effective low carbon energy innovations that are more likely to be pro-poor. To achieve this closer attention, we would argue, it is better to include the poor and marginalised pro-actively in the innovation processes.

1 Introduction

1.1 Aims and objectives

This working paper presents some of the core empirical analysis from the STEPS Centre affiliated research project "Pro-poor, Low Carbon Development"[1]. This Project represents a partnership between the African Technology Policy Studies Network (ATPS) in Kenya and the University of Sussex in the United Kingdom (UK) (including the STEPS Centre, Sussex Energy Group and Tyndall Centre), and is funded by the Climate and Development Knowledge Network (an initiative which is, in turn, funded by the UK Department for International Development (DFID)). It responds directly to demand from the Government of Kenya and broader international demand for research that can inform more effective policy approaches to facilitating the uptake of low carbon energy technologies in low income countries. In particular it is interested in informing recent developments around the idea of Climate Innovation Centres as a delivery model, both in Kenya and internationally (including recent initiatives under the United Nations Framework Convention on Climate Change, UNFCCC, initiatives led by DFID and InfoDev and initiatives by various regional development banks). At the heart of the project is a normative commitment to poverty reduction and social justice, and a focus on supporting development pathways that deliver against the human development needs of poor and marginalised people whilst simultaneously responding to the challenges posed by climate change.

The project focuses on learning policy lessons from the case study of the Solar Home System (SHS) market in Kenya, together with recent advances in pico-solar in the country, as an example of successful uptake of low carbon energy technologies in a low income country. Based on in-depth historical analysis developed through consultation with stakeholders, critical analysis is conducted to assess the factors that led to the widespread uptake of these solar electrical applications in Kenya and the extent to which policy might proactively replicate these factors. The analysis is facilitated by an innovative theoretical approach drawing on insights from innovation studies and socio-technical transitions operationalised within the overall context of the STEPS Centre's Pathways Approach (Leach *et al.* 2007). This enables a more holistic approach to understanding how low carbon energy technology transfer and adoption might be effectively facilitated, particularly in lower income countries whose needs have not been addressed by existing climate policy architecture.

The project's aims can therefore be summarised as three-fold:

- To provide policy insights on the potential for Climate Innovation Centres (CICs)[2] and the related Climate Technology Centre and Network (CTCN)[3] to act as innovation system builders facilitating pro-poor, low carbon development via the adoption of low carbon energy technologies in LDCs and other developing countries;
- To contribute empirically by examining the role of innovation system builders in developing innovation capacities that facilitate the uptake of pro-poor, low carbon technologies in LDCs;

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[1] see http://steps-centre.org/project/low_carbon_development/

[2] These are currently being trialled in India and Kenya by DFID and infoDev in the form of a network of Climate Innovation Centres across developing countries (Sagar and Bloomberg New Energy Finance 2010).

[3] The CTCN began official operations in December 2013 as part of the Technology Mechanism under the UNFCCC that aims to enhance delivery of low carbon technology to developing countries.

- To contribute theoretically by developing a framework for analysis that builds on relevant insights from socio-technical transitions and innovation studies and testing this in an LDC context.

Alongside this paper, there are three other working papers each presenting different aspects of the overall research conducted in the project and these are available, along with other outputs described below, on the project website. One paper is dedicated to an analysis of past consumer finance for scaling up the adoption of solar home systems in Kenya, and compares these approaches with those now emerging with the pico-solar market. Another paper provides an overview of the Kenyan policy environment relevant to low carbon development, especially in regard to the increased adoption of photovoltaic (PV) systems. The other working paper examines the implications of the entrepreneurial identity on gendered access to resources from climate finance. This subtle but potentially important critique is relevant, given the focus of much carbon mitigation effort on catalysing entrepreneurial action to diffuse low carbon technologies.

In addition to these working papers, there are three policy briefings. One gives a non-technical overview of the project. One draws insights from the practical experience of conducting an Innovation Histories workshop to facilitate a more participatory research approach. This briefing is likely to be of use to others who might wish to experiment with such an approach. And the last briefing summarises the key policy recommendations that flow from the analysis conducted in this paper and presented in the other three working papers. All these briefings are available in both English and Swahili.

Finally, two conference papers have been produced, each developing the conceptual work of the research and presenting interim findings. All these outputs are available on the project website.

1.2 Background and Rationale

1.2.1 Energy access, climate change and development

Access to modern energy services is a critical human development priority and can be transformative to the livelihoods of poor people and their economic potential. A tension is sometimes perceived between increasing energy access and pursuing low carbon development. High carbon, conventional energy options are often viewed as cheaper and hence easier for poor countries to pursue. However, multiple synergies potentially exist between human and economic development priorities and access to low carbon energy technologies. Renewable energy can facilitate access in areas where grid-based provision is prohibitively expensive and unreliable; energy efficient technologies can improve availability of energy services, such as lighting and heat; and a combination of the two can increase local and national energy security and economic resilience by reducing exposure to the price fluctuations and political constraints of fossil fuel imports. Access to low carbon energy technologies is, therefore, potentially critical to meeting the Millennium Development Goals (MDGs) (Modi *et al*. 2006).

At 18 per cent, the grid-based electricity access rate in Kenya remains well below the average for sub-Saharan Africa, despite significantly intensified efforts over the past decade to increase grid-penetration. Alongside these efforts, there are several large generator projects intended to address the shortages and vulnerabilities in current energy supply that result in frequent brown and black-outs for those who are connected to the grid. Some of these generator projects involve low carbon energy technologies, which form part of the Kenyan Government's recently published climate resilient development plans. However, although the rhetoric of these plans promotes the deployment of a range of low carbon technologies at different scales, there is still little in the way of practical support for off-grid low carbon electrical services and so little policy attention to the role of rural household energy access in pro-poor development. Instead, much of the attention to the pro-poor agenda is being paid by donors, who have tended to adopt the 'bottom-of-the-pyramid' (BOP) rhetoric that claims poor people can participate in energy technology markets and so the private sector can deliver pro-poor energy services. Within this rhetoric, the challenge is said to be one of creating an enabling environment within which private actors can compete freely to service the energy demands of the poor.

Insights from innovation studies and socio-technical transitions theory suggest that this largely technocratic view of enabling free markets to deliver energy services is misguided at best. The innovation studies literature tells us that an enabling environment is certainly important, but it is not sufficient. We also need to be concerned with what drives innovation, both as process and outcome, and understand that markets are replete with failures that weaken innovation processes and so deter potentially desirable innovation outcomes. In the context of developing countries, these studies also tell us that the development benefits associated with innovation can only be fully exploited if local innovative capabilities are built, including innovation systems. It is not enough simply to adopt innovations. For productive innovations, the economic benefits are likely to be short-lived as the global 'frontier' of those productive innovations moves on and, in any case, the value-added available to innovators will be appropriated elsewhere. Consumption-based innovations can be helpful for improving quality of life, such as enhancing access to energy services, but, as with productive innovations, much of the value-added will be unavailable to the consumers and to the local economy. But further, a socio-technical understanding of innovation tells us that context matters and that innovation processes are shaped interactively with political, social and environmental forces, as well as with those actors who possess economic and institutional power. Combining these insights, we can understand that innovation is not a uni-dimensional process, driven by inalienable economic logic and measureable only in terms of rate of change. Rather, innovation processes can be multiple and proceed simultaneously in different directions (and different rates), each favoured by sympathetic actors who do political work to persuade others to bring their support to any particular trajectory of development. In such a landscape of possible pathways, we can expect that actors who possess significant economic and institutional power will be more likely to see their favoured pathway realised, that there will be dominant pathways of development alongside smaller ones, and that some potential pathways will not get started.

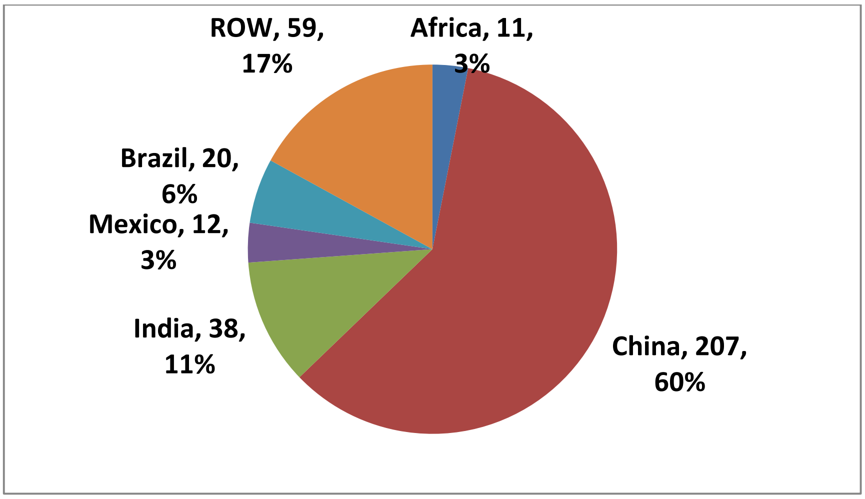
The SHS market in Kenya provides a case with which to examine these ideas. There are estimated to be in excess of 300,000 SHSs in Kenya, sold through a vibrant private market that is considered one of the most dynamic *per capita* solar markets historically. Recent years have also seen the growth of a market for pico-solar products – essentially, solar lanterns that, in some products, also have provision for charging a mobile phone and powering a radio. For many years, the rhetoric used to describe the SHS market's evolution has sustained the notion that it has been private sector led, and the rise of the pico-solar market is similarly described but uses BOP rhetoric. However, closer inspection of the evolution of these markets reveals that neither has been simply private sector led and that neither success is solely down to an enabling environment. Instead, important innovations have been driven or facilitated by donor involvement throughout the local supply chain, along with detailed understanding of user needs and desires. Moreover, the Kenyan policy environment has at times been hostile to the promotion of photovoltaic technology and policy support remains somewhat ambivalent. There is also some evidence that innovation in the Kenyan market is moving beyond the selling of imported technologies towards the development of an innovation system around PV. Several donors are supporting the implementation of a Climate Innovation Centre, and a PV module assembly plant, also involving donor support, began operations in August 2011.

Analysing the evidence in the Kenyan SHS case as a whole suggests that interventions to widen, deepen and enhance low carbon energy access need to be sophisticated and systemic. They should attend to the entire local supply chain; find, understand and raise demand for low carbon energy innovations; build capabilities that support development towards local innovation systems, including at the policy level; and do so in ways that are reflexive in relation to the local (evolving) context. Furthermore, considering that an important contribution to the success of the Kenyan SHS market has been detailed understanding of the needs and desires of users, much closer attention to those in poor and marginalised groups could yield effective low carbon energy innovations that are more likely to be pro-poor. To achieve this closer attention, we would argue, it is better to include the poor and marginalised pro-actively in innovation processes, including those processes that engage political and social forces. In other words, the case gives us useful clues for working towards effective and just governance of the transition to sustainable and inclusive energy systems. But to aid a proper understanding of the veracity of these assertions, let us first begin by examining the way in which existing international policy approaches which seek to increase uptake of low carbon energy technologies in developing countries are framed, and what these existing approaches have delivered for poor countries.

1.2.2 Existing international policy approaches

Existing international policy mechanisms for low carbon development have had mixed results, with little impact on poor developing countries, particularly Least Developed Countries (LDCs). For example, only 0.2 per cent of Certified Emissions Reductions (CERs) under the Clean Development Mechanism (CDM) are expected to come from LDCs (De Lopez *et al*. 2009). We have argued elsewhere that this problem is in part due to a tendency to frame low carbon energy access in developing countries around the notion of low carbon 'technology transfer', where technology is understood narrowly as simply consisting of hardware (Byrne *et al*. 2012). This narrow understanding steers policy towards financing incremental costs of low carbon hardware, such as via credits for investing in low carbon projects under the CDM. Whilst hardware is clearly important, these financing mechanisms have led to an uneven distribution of investment, both technologically and geographically, with the poorest nations benefiting least, if at all. The majority of support is concentrated towards rapidly emerging economies, where financing and deployment environments are already attractive. The technologies funded tend to be low risk or mature, and mostly relate to large project based initiatives that are less likely to attend to the needs of poorer groups.

Figure 1.1: Accumulated investment through the CDM



Key: Country or Region, accumulated investment (USD billion), accumulated investment (percentage)
USD billion by selected countries and regions as at end of January 2014
Source: Authors' (Rob Byrne's) analysis of CDM pipeline, available from http://www.cdmpipeline.org

Furthermore, as the CDM in particular is based on private sector investment in individual projects, it is concerned primarily with generating profit from emissions reductions, not with building local innovation systems and the capabilities within them to foster innovative development of technologies. Indeed, we could argue that the incentive is to reduce the potential for building local innovative capabilities so that project developers maintain control over technologies (e.g. see Douthwaite 2002 for a discussion on the protection of knowledge and how it hinders innovative activity). Where the CDM has been used to build innovation systems it has been done through the strategic intervention of the state, as is the case in China (Watson *et al*. 2011). For poor developing countries, where capabilities for policy implementation are generally weak and the potential to generate emissions reductions at present is low, the CDM or similar policy instruments are unlikely to be of any benefit in regard to low carbon innovation system building.

Recent reform of the European Emissions Trading Scheme (EU ETS) might go some way to address the critique discussed above. From 2013, only new projects in LDCs can trade CERs in the EU ETS (Torvanger *et al*. 2013: 472). However, there is an over-supply of permits already in the system and so there are question marks over whether there will be demand for offsetting through the CDM. In response to this over-supply, the EU has voted to withhold 400 million permits starting in March 2014 (Iqbal 2014). The carbon trading price in the scheme rose to around EUR 6.50 following this decision, a 13-month high, but there remain many uncertainties about the EU ETS and so it is too early to assess the impact on both carbon prices (Botzki 2014; Nichols 2014) and the demand for CERs from LDCs.

1.2.3 Promising emerging policy approaches

If we accept the analysis above then it is clear that a different approach is necessary in LDCs and other poor developing countries. This project therefore adopts a conceptual framework (described in Section 2 of this Report) which attempts to do just this. It builds on the literature on socio-technical transitions, but develops this on the basis of insights from innovation studies. Importantly, this alternative conceptual approach and the project's empirical analysis of the emergence of the market for off-grid solar electric services in Kenya is directly targeted at informing a specific policy approach that has the potential to overcome the shortfalls of past, hardware financing oriented approaches. This concerns the proposed climate innovation centre-based approaches (Sagar and Bloomberg New Energy Finance 2010), the most prominent being the Climate Technology Centre and Network (CTCN) under the United Nations Framework Convention on Climate Change (UNFCCC) and the Climate Innovation Centres (CICs) currently being trialled in India and Kenya by DFID and infoDev (with other emerging initiatives now underway by the Latin American and African Development Banks). These have the potential (but are not guaranteed) to depart from the dominant hardware financing approach to technology transfer and may be particularly important to facilitating uptake of low carbon technologies in LDCs. There is, however, a danger that these centre based approaches could fall prey to the same problems as past 'centres of excellence' type initiatives in developing countries (e.g. in relation to bioscience, livestock research and space science) which have been widely criticised for bringing together elite actors (academics, researchers, business leaders, etc.) whilst failing to deliver broader benefits to society, not least to poor and marginalised men and women (Leach and Waldman 2009). This project therefore aims to contribute insights on how such centre-based approaches could maximise their potential to deliver benefits to poor developing countries and poor and marginalised people therein.

1.3 Pro-poor, low carbon development: A Pathways Approach

This project is concerned with the role of policy in fostering low carbon technology uptake as part of development pathways that serve the needs of poor and marginalised people. As such it makes inherent normative assumptions, viewing poverty reduction and climate change mitigation as priority development commitments that might be simultaneously achieved. Such normative commitments cannot be taken as given. Each can be contested, and the particular solutions to any commitment – even if not contested – are the subject of sometimes fierce debate. These contestations and debates have material consequences for the choice of action undertaken and so it is important that we include attention to these politics in both our analysis of potential interventions and the way we conduct those interventions. Therefore, we begin our discussion of low carbon development pathways by considering the notion of framing and its implications.

Societal services or functions (e.g. energy production via low carbon technologies to serve the needs of poor rural communities) are realised dynamically out of the interplay of various co-evolving complex systems (social, technological, environmental) and any particular unfolding of these dynamics constitutes a specific development pathway amongst multiple possible pathways (Leach *et al*. 2007). Each of these complex systems themselves, and their combination, can be framed in different ways. And each framing informs, and is informed by, a narrative that interprets the world in a particular way, reflecting and reinforcing the perspective of the narrator. As understood here, a narrative is used to 'suggest and justify particular kinds of action, strategy and intervention' (Leach *et al*. 2010: 3) and so attempts to enrol actors and their resources into particular ways of achieving development goals. If this enrolment is successful then a particular direction of development is privileged, the result of which is an unfolding pathway co-evolving contingently and uncertainly in the interplay between these privileging forces and the various complex systems noted above.

Implicit in this description is the notion that multiple framings, narratives and pathways are possible. Different groups of actors will interpret the world in different ways; arising from their own experiences, situations, understandings, values and interests. Favouring certain framings over others, they will seek to promote narratives that would help to create their preferred development pathways. Some narratives will be more dominant than others, perhaps because they are promoted by powerful actors, and are likely to become manifested in interventions. Other narratives remain marginalised, perhaps because they are promoted by groups who are themselves marginalised or powerless (Byrne *et al*. 2012).

But this is not to argue that dominant narratives and pathways are immune to influences from the margins. As evidenced in the literature on socio-technical transitions, dominant socio-technical practices come under pressure from external dynamics, and experience internal tensions between the many dimensions (social, cultural, political, technical) that constitute those practices (e.g. see Geels 2002; Raven 2005; Smith 2007). Climate change, for example, is creating increasing pressure on the dominant fossil-fuel based development pathway. And the climate change narrative has enrolled increasing numbers of actors and their resources, spawned the UNFCCC and instruments of climate governance such as the Kyoto Protocol, promoted certain strategies such as investment in renewable energy technologies, and argued for interventions, such as carbon pricing. Of course, the fossil-fuel based development pathway remains dominant but it is clearly under mounting pressure and we could argue that its dominance is beginning to erode.

In trying to analyse how dominant practices come to be eroded, or how new practices come to be accepted, we can draw from the socio-technical transitions literature. Here we see that there are various ways in which marginal, experimental or sometimes radical socio-technical practices can come to influence mainstream practices and even to thoroughly transform them over time (Geels and Schot 2007). Technology can play a central role in such transformations by affording opportunities for entirely new practices that create demands for widespread institutional change (Deuten 2003). But if we are to make use of these transformational possibilities to realise normative goals, such as pro-poor low carbon development, then we need to be careful how we understand technology itself (Watson *et al*. 2011). Our argument here is that an inadequate conception of technology will likely produce, at best, inadequate technology policy, such as with many 'technology transfer' efforts and instruments such as the CDM. Worse, such policy could be ineffective or even counterproductive (Byrne *et al*. 2011). For instance, inadequately conceived low carbon technology transfer to developing countries could see the failure of those technologies, resulting in pressure to turn to carbon-intensive options instead, locking development pathways into high carbon directions. For insights on the nature of technology, and its role in helping to realise pro-poor, self-determined, development pathways we will turn to the innovation studies literature, which is where we will begin in Section 2 when we elaborate on the conceptual framework used in this research. First, we outline the working hypothesis and research questions driving the analysis.

1.4 Hypothesis and research questions

Building on the above discussion, this paper uses in-depth, historical analysis of the development of the market for off-grid solar electrical services in Kenya to test the following hypothesis:

> *H_1: The success of the market for solar home systems and other off-grid solar electrical services in Kenya was due to a range of capability and innovation system building activities undertaken by key actors over time (activities that could be replicated by policy initiatives such as Climate Innovation Centres)*
>
> This is translated into the following **overarching research question**:
>
> *What factors can explain the success of the off-grid PV market in Kenya?*
>
> and the following **sub-questions**:

- *What role has hardware financing played in fostering the off-grid PV market in Kenya?*
- *What technological capability and innovation system building activities can be identified?*
- *Can 'innovation system builders' (i.e. key actors undertaking the above activities) be identified?*
- *How can this inform policy (especially Climate Innovation Centres)?*

By testing this hypothesis and answering these questions, the paper concludes with a range of policy recommendations together with empirical and theoretical insights of relevance to future research in this field.

1.5 Structure of the paper

The remainder of this paper is structured as follows. Section 2 articulates in more detail the conceptual/theoretical approach adopted. Section 3 outlines the methodology. Section 4 presents the findings from the project's overall historical analysis of Kenya's PV market development. The paper then concludes in Section 5 with a discussion of the evolution of the Kenyan PV market and a summary of the key policy lessons from this analysis.

2 Conceptual framework

In this section we set out the conceptual framework that guided the project's analysis. This is based on a combination of insights from the socio-technical transitions literature and the innovation studies literature, operationalised within the guiding framework of the STEPS Centre's Pathways Approach (the latter having been described in Section 1.3 above).

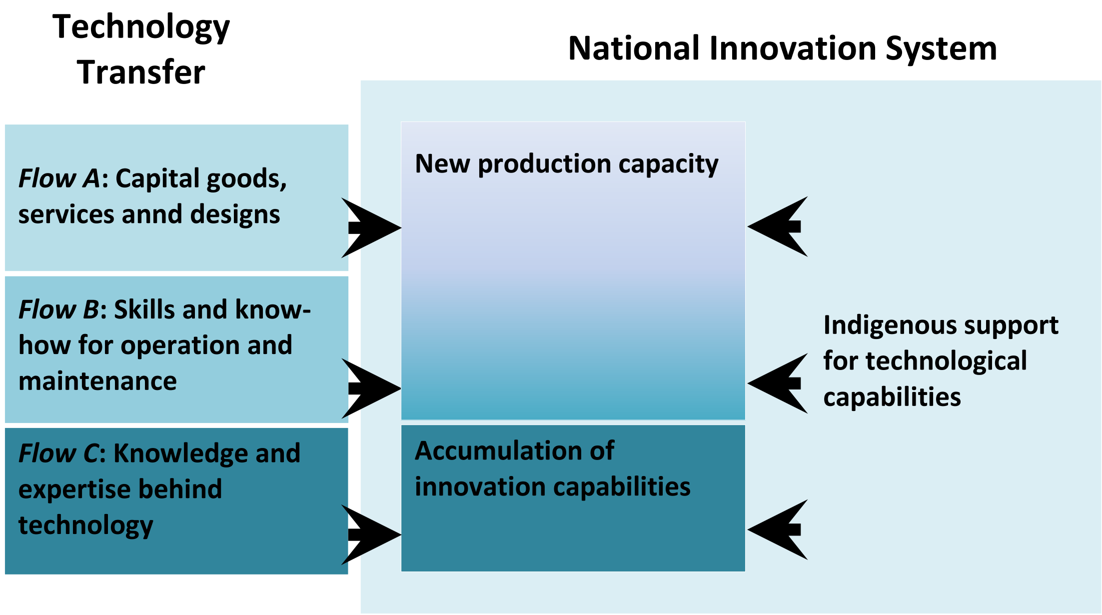
2.1 Technology and innovation systems

An important insight from the innovation studies literature is that technology is not simply hardware. Embedded in the hardware is a reflection of the knowledge required to create it; and knowledge and skills are needed to adopt, use and adapt it, sometimes referred to as the software, (Bell and Pavitt 1993; Ockwell *et al*. 2010). Extending this idea, some authors demonstrate that hardware is also embedded with social or cultural assumptions (Agarwal 1986; Pacey 1983; Wynne 1995). An essential characteristic of this 'software' is tacit knowledge, a fundamental aspect of knowledge and skills that is difficult or impossible to articulate but can be cultivated through practice (Polanyi 1966). Combining these ideas, we begin to form the notion of socio-technology, echoing the language of socio-technical transitions thinking discussed above. Flowing from these ideas, and demonstrated in the literature, we see that technologies are created, adopted and adapted within a systemic environment. This idea has long been studied in regard to innovation systems, with particular attention to the linkages between firms and other actors, and the institutional setting of policies, laws, regulations and norms (e.g. see Bell 1990, 1997, 2009; Bell and Pavitt 1993; Freeman 1992; Hobday 1995a, 1995b; Katz 1987; Kim *et al*. 1989; Lundvall 1992; Ockwell *et al*. 2008; Radošević 1999; Watson *et al*. 2011).

One way to understand the significance of some of these ideas is depicted in Figure 2.1, especially in regard to innovation systems and the ways in which the knowledge and skills required for self-directed development can be accumulated. Based on Bell (1990), the diagram shows three types of possible technology flow (A, B and C) during transfer projects into a local innovation system. Flow 'A' includes hardware, as well as the engineering and managerial services that are required for implementing such transfer projects. Flows of type 'B' consist of information about production equipment, operating procedures, routines, etc., and training in how to operate and maintain such hardware. Bell (1990: 77) describes these flows as 'paper-embodied technology' and 'people-embodied knowledge and expertise'. Both flows 'A' and 'B' add to or improve the production capacity of a firm or economy, but do little or nothing for developing the skills needed for generating new technology. Flows of type 'C', however, are those that help to create the capability to generate new technology. In other words, they help to build innovation capabilities (see Bell 2009).

Within the context of a concern with low carbon development, this idea of technology flows building local capabilities to generate broader technological change is of central importance, in this case building capabilities to generate technological changes that facilitate lower carbon social and economic practices. The existing technological capabilities in the local context are sometimes referred to as absorptive capacity, defined originally by Cohen and Levinthal (1990: 128) as the ability of a firm to 'recognize the value of new information, assimilate it, and apply it to commercial ends'. However, it has also been used to demonstrate the impact of individual firms' absorptive capacity on the ability of clusters of firms to adopt and adapt new technologies (Giuliani and Bell 2005), and to explain the ability of countries to achieve technological learning through the CDM (Doranova 2009).

Figure 2.1: Technology transfer and indigenous innovation



Source: Adapted from Watson *et al*. 2011: 16, based on Bell (1990)

The diagram in Figure 2.1 does not show explicitly the importance of the institutional environment, although the innovation literature does so, especially with regard to formal national and international policies. These can help to enhance existing industrial activity, to raise the level of capabilities to increase competitiveness, for example, but they are also important for fostering new industrial activity that would otherwise not be pursued (e.g. see Cimoli *et al*, 2009). In the case of low carbon technologies, and a concern with broader processes of low carbon technological change, this latter point is particularly relevant (Ockwell *et al*. 2010). Many existing low carbon alternatives are not yet competitive with carbon-intensive technology options and so market demand for many low carbon technologies tends to be weak or marginal. But it is likely that we will need a range of low carbon technologies, and the need is becoming increasingly urgent. In principle, appropriate policies could foster the improvement of low carbon technologies, and the local capabilities and innovation systems that can sustain and develop them. The result could be a multiplicity of co-existing pathways, each appropriate to its context, promoting more equitable human development (Stirling 2009).

2.2 Building low carbon innovation systems: A socio-technical perspective

More recently, the broader dimensions of the systemic environment in which innovation and development takes place (social, cultural, political together with the economic, institutional and technical) have received attention in the socio-technical transitions literature (e.g. see Berkhout *et al*. 2004; Byrne 2011; Geels 2002; Geels and Schot 2007; Raven 2005; Rip and Kemp 1998; Smith 2007; Smith *et al*. 2010). Adopting a socio-technical perspective facilitates attention to several key issues of relevance to the uptake of low carbon energy technologies, considerations that are not addressed by mainstream policy thinking at present. Firstly, a socio-technical perspective allows us to understand technologies as co-evolving with the social contexts within which they are used, recognising that new technologies will 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 (Hoogma 2000; Raven 2007). This allows analysis to focus on the services for which electricity is desired/used (e.g. light or mobile phone charging), thus representing a much more salient focus for understanding how and why people might use any technology (e.g. SHSs) that facilitates such service provision.

Having emerged from research within industrialised country contexts, the socio-technical approach has, in recent years, begun to be applied in the context of developing countries. For example, see the special edition of *Environmental Science & Policy* introduced by Berkhout *et al*. (2010) for the application of these ideas to developing Asia, and see Byrne (2011) for their application in Kenya and Tanzania. Specifically, these papers focus on the use of strategic niche management (SNM, or 'niche theory' – in effect, a discrete section of the socio-technical transitions literature) to understand the dynamics of how novel technologies were tested in real-world settings, and whether or not they resulted in wider use and further development. A key feature of niche theory is that it directs our attention to the co-evolution of actors' expectations about a technology in the future, their learning as they experiment with that technology in real-world settings, the networks of other actors they develop, and the societal embedding of various socio-technical practices relevant to that particular technology. These co-evolutionary dynamics are assumed to happen in what amounts to a protective space, or niche, in which the normal pressures of market forces and technical performance are weakened, enabling essential learning to take place (Smith *et al*. 2014). Of course, these dynamics unfold within a broader context, which is conceived as consisting of various 'regimes' (mainstream, normal or dominant ways of doing things) and a wider 'landscape' (difficult to influence changes such as demographics, events such as wars, etc.) (Romijn *et al*. 2010). Some niches come to influence regimes over time, and can even replace them entirely.

Understanding the processes of how and where niches have been successful and unsuccessful in influencing regimes therefore raises the potential to understand where policy might deliberately intervene to nurture low carbon niches. A policy might aim, for example, to widen and deepen access to low carbon energy technologies to benefit poor and marginalised groups and to do this by creating new, or nurturing existing, niches of low carbon energy technology applications amongst poor communities and households. Importantly, niche theory emphasises the role that key actors, known as 'cosmopolitan actors' (Deuten 2003) or what we refer to as 'innovation system builders', can play in developing a niche, raising potential for policy makers and other actors (e.g. NGOs or private companies) to emulate the actions of past successful innovation system builders to achieve wider impacts and broader uptake of low carbon energy technologies. In this project we therefore explicitly theorise policy interventions such as Climate Innovation Centres as having potential to play the part of innovation system builders and as such facilitate the development of effective innovation systems around low carbon energy technologies in developing countries, resulting in wider uptake and greater access for poor countries and poor people.

2.3 Strategic Niche Management: Operationalising a socio-technical perspective

This project therefore adopts a socio-technical perspective to its analysis, operationalised via theoretical perspectives from the literature on SNM. SNM has been used as both a management tool to design policies and experiments around socio-technical niches (see Caniëls and Romijn 2008; Schot and Geels 2008) and, as we use it here, as a theory to analyse niche processes *ex-post* (although note that our explicit intention is for the outcome of this *ex-post* analysis to inform future policy design). For the purposes of this project we conceptualise SHSs and the related energy services they provide, along with associated actor-networks and relevant institutions, such as the *socio-technical niche*. Solar portable lights (SPLs) could also be considered as being part of the niche, as they offer solar lighting, and in some cases phone charging (Lighting Africa 2010). We therefore attend to SPLs as and when they arise as significant in the interviews, workshop and other empirical data collated as part of our research.

The key focus of SNM is understanding low carbon energy technologies as part of a low carbon 'niche', or protected space, in which normal selection pressures that help the dominant fossil based energy 'regime' to reproduce itself are weakened or absent (Smith 2007). A socio-technical regime includes incumbent technologies as well as established values and practices which are socially embedded and 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*. 2014: 117) In the context of this project, and indeed in many developing country contexts across many low carbon technologies, any large-scale, stable system is difficult to identify. Solar electricity as a provider of lighting and phone charging is supposed to replace kerosene and batteries or other fossil fuel powered charging devices. This common practice of lighting and phone charging can be conceptualised as the regime in which the SHS niche competes/seeks to influence. It is not the same kind of stable, large-scale regime that socio-technical transitions studies traditionally incorporate, but it seems to be a suitable way to frame the regime in the case of the SHS socio-technical niche, as any large-scale incumbent technology is absent. Moreover, whilst on the face of it a regime characterised by kerosene and batteries might not seem as pervasive as, say, coal fired, grid-based versus off-grid solar electricity provision in an urban, developed country context, the chain of power dynamics and vested interests that pertain to the supply of kerosene or batteries to rural communities in developing countries should not be underestimated. Nor, therefore, is the uptake of alternative, low carbon technologies for providing the same energy services any less exposed to the kind of challenges that niche technologies face in many contexts when seeking to influence or compete with existing regimes.

Geels' (2002) Multi-level Perspective (MLP) also posits the existence of the socio-technical landscape over and above the regime*,* constituted by exogenous factors which put pressure on the regime and open up windows of opportunity for niche configurations to break through (Markard *et al*. 2012: 957). In the case of solar lighting and phone charging, external influences might include climate change and health concerns regarding kerosene and fossil-fuel based electricity, as well as the need for poverty alleviation, especially energy poverty alleviation. All these aspects are motives for clean and affordable electrification solutions.

Within SNM studies, five categories are identified to guide analysis of the extent to which a niche could influence or is already influencing a regime. We outline these below with a short explanation of how each category is operationalised within this study.

2.3.1 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*. 2014). Jacobsson *et al*. (2004: 24, cited in Smith *et al*. 2014: 117) emphasises that spaces offer opportunities for learning and that their 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 from actors. The process of 'nurturing' enables socio-technical niches to grow and become able to influence/enter the regime. Nurturing is defined as support processes that enable the development of innovations. Dedicated intermediating work is needed for interactive learning to take place, expectations to develop, and supportive networks to build (Smith 2007). After that stage, the protection of the niche shifts to 'empowerment'. Empowerment is mainly achieved by advocates and networks around the socio-technical niche. Actors within the socio-technical niche become outward-oriented, meaning they are active within the regime and interact with others (Smith and Raven 2012; Smith *et al*. 2014: 117). The subsequent analytical categories within SNM are embedded within the protective space, but constitute important additional foci because they force our attention towards the dynamics of interacting change processes.

2.3.2 Experiments and learning

Experiments can be perceived as being part of the process of nurturing (Smith *et al*. 2014: 118). They are defined as, 'initiatives that embody a highly novel socio-technical configuration likely to lead to substantial sustainability gains.' (Berkhout *et al*. 2010: 262) Experiments can be 'local', which means that they take place within local contexts in specific places, supported through local networks. They generate lessons which lead to learning (Smith and Raven 2012). Within the SHS niche in Kenya, finance projects, programmes and, recently, business models by socially oriented enterprises have been experimenting with the provision of end-use-level finance. These experiments might generate learning that could strengthen the SHS niche.

In SNM, learning is conceived in two forms (Byrne 2011). First-order learning is instrumental, focussed on trying to make a particular socio-technical configuration work. As such, it is concerned with refinements to the particular socio-technical configuration and tends to result in the accumulation of facts and data. For example, these could be 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 and can therefore result in a new set of framing assumptions and a new configuration. This new configuration will then require further first-order learning to accumulate relevant facts and data and to establish working refinements. To the extent that niches are protective spaces in which to experiment, learning can generate a range of socio-technical configurations and each can develop in parallel with the others. But, 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 (Schot and Geels 2008; Byrne 2011).

2.3.3 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. 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: 540-541). The key official networks around SHSs and other solar applications in Kenya are Lighting Africa, the Global Off-Grid Lighting Association (GOGLA) and the Kenya Renewable Energy Association (KEREA). Lighting Africa is an International Finance Corporation and World Bank programme that seeks to catalyse sustainable markets for affordable, off-grid lighting technologies for low-income households in sub-Saharan Africa (SSA) (Lighting Africa 2013a). GOGLA aims[4] to represent all companies and market participants who are involved in off-grid lighting around the world. KEREA's aim[5] is to facilitate the growth of renewable energy businesses. It provides information on markets and technologies and promotes capacity building and networking.

2.3.4 Expectations and visions

In SNM, 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 include more than this relatively vague articulation by including the means by which the expectation can be realised. Such means might

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[4] http://global-off-grid-lighting-association.org/

[5] http://kerea.org/about-us/

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).

Examples in the case of finance for electricity access are international development agendas like the Sustainable Energy for All (SE4All) initiative. A number of other relevant expectation or vision-oriented policies and initiatives exist in the context of SHSs in Kenya. The Kenya 2030 Vision is a development programme that is supposed to transform Kenya into a 'newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment.' (ROK 2007, cited in Hope 2013: 209). It also includes plans for increasing rural electricity access to 20 per cent by 2012 and 40 per cent by 2024 (Lighting Africa 2012). Kerosene Free Kenya is a project aiming to reduce greenhouse gases and improve the health situation by replacing fossil energy for lighting and cooking (MEWNR 2013). All these initiatives and programmes have the potential to support the SHS niche via connecting to global and national agendas which express relevant needs and ways solar technologies might meet them.

2.3.5 Institutions

Institutions include laws, regulations and policies as well as 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. Institution-building (whether formal or non-formal) is therefore an important process that co-evolves with those outlined above as a niche develops. From the perspective of SHSs in Kenya, this would include the co-evolution of governmental regulations, like import taxes or quality standards, and solar technologies. This category also directs analytical focus towards consumer behaviour, socio-cultural practices and the relevant energy services that SHSs might facilitate.

3 Methodology

3.1 Hypothesis and research questions

To reiterate from the Introduction, this project sought to test the following hypothesis:

> *H_1: The success of the market for solar home systems and other off-grid solar electrical services in Kenya was due to a range of capability and innovation system building activities undertaken by key actors over time (activities that could be replicated by policy initiatives such as Climate Innovation Centres)*
>
> This is translated into the following **overarching research question**:
>
> *What factors can explain the success of the off-grid PV market in Kenya?*
>
> … and the following **sub-questions**:

- *What role has hardware financing played in fostering the off-grid PV market in Kenya?*
- *What technological capability and innovation system building activities can be identified?*
- *Can "innovation system builders" (i.e. key actors undertaking the above activities) be identified?*
- *How can this inform policy (especially Climate Innovation Centres)?*

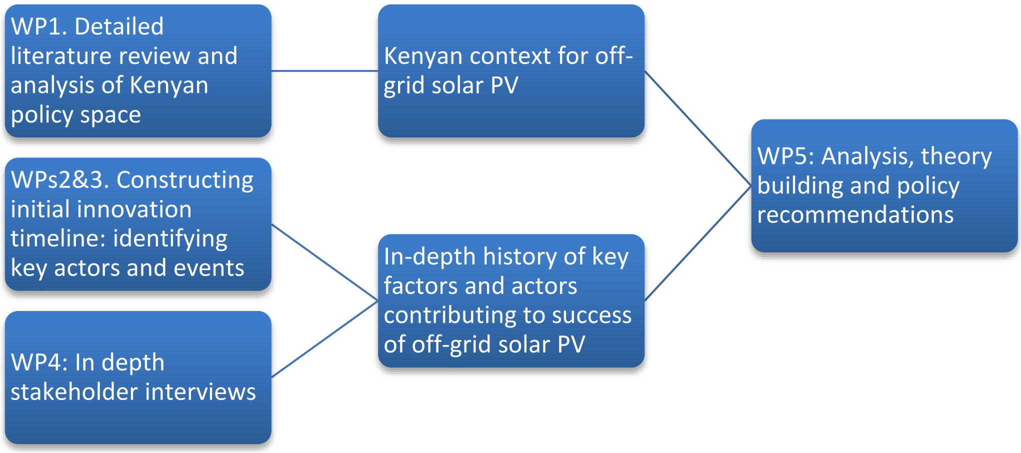
3.2 Overarching approach

A case study based approach was adopted to facilitate in-depth, context-specific analysis of factors that contribute positively and negatively to the uptake of potentially pro-poor low carbon energy technologies within a low income country context. The case study selected was that of off-gird solar electrical services in Kenya. As noted above, this pertains mostly to SHSs but in recent times SPLs have also become significant and were therefore also included in the analysis. The market for off-grid solar electricity in Kenya, particularly SHSs, is one of the most significant in the world. In terms of both annual sales and overall numbers of SHSs installed, Kenya accounts for around 10 per cent of the global market, making it second only to China and therefore number one in the world on a per capita basis (Ondraczek 2013). The significant success of the market for off-grid solar electrical services in Kenya therefore renders this a valuable case study to focus on in terms of understanding the reasons for this success (as well as factors that may have hindered it). Although care is required in generalising from this single technology and country case, it nevertheless provides an important opportunity to conduct in-depth, historical analysis via direct stakeholder consultation in order to explore the extent to which the factors hypothesised above played a role in the relatively high uptake of this technology in Kenya. Kenya also provides a germane context for such analysis from a policy perspective due to current efforts to trial the CIC approach there.

Building on our conceptual framework, we theorise off-grid solar electrical services in Kenya as a socio-technical niche, identified empirically as the set of actors, technologies and institutions associated with the provision of household electrical services using PV. The development of the niche is viewed from a dynamic perspective over time, emphasising a need for historical analysis of niche dynamics identifying key events and directions, or 'trajectories', during niche development (Geels and Raven 2006). The relative global success of the market for SHSs in Kenya and the current boom in uptake of SPLs can thus offer evidence and theoretical insights into how niches might influence dominant socio-technical practices. It also allows us to interrogate the evidence to look at the role of innovation system builders in this process.

The work was conducted via the four work packages described below. Their relationship to the paper's overall analysis is illustrated in Figure 3.1 below.

Figure 3.1: Work packages' context within overall methodology



3.3 Description of work packages

The project is based on empirical analysis via the following work packages conducted between April 2012 and March 2014. The project also benefits from empirical evidence gathered by one of the project team, Rob Byrne, during his doctoral research (see Byrne 2011). See Figure 3.1 above for an illustration of how the various work packages relate to one another and feed into the overall analysis.

3.3.1 <u>WP1: Broader contextual analysis</u>

This Work Package focussed on providing detailed contextual analysis of the institutional and policy spaces of relevance to the adoption of off-grid solar electrical technologies in Kenya, as well as reviewing in detail existing published research in this field. The literature review included analysis of both peer reviewed and grey literature in this field and continued throughout the research as engagement with stakeholders highlighted new literature sources. The analysis of the Kenyan policy space was based on a combination of literature review and interviews with a range of key actors. An analysis of the key policies and policy actors of relevance to the emergence of the market for off-grid solar electrical services in Kenya was conducted. The interview material was based on interviews conducted for a Climat and Development Knowledge Network (CDKN)-funded sister project which also represented a partnership between Sussex University and African Technology Policy Studies Network (ATPS) led by Professor Peter Newell and Jon Phillips. Interviews were conducted on a semi-structured basis with questions aimed at eliciting detail on the political economy of solar energy in Kenya. Interviewees included:

Aisha Abdulaziz, Energy Consultant and member of the Executive Committee of KEREA
Anthony Karembu, KFW – Kreditanstalt für Wiederaufbau
Astrid Lervag, Royal Norwegian Embassy
Bernard Aduda, University of Nairobi
Caroline Nyaboke Ogwang, Sales Manager, Sunny Money Trade
Cathy Owinga, Kenital Solar Ltd
Dickson Khainga, Kenyan Institute for Public Policy Research and Analysis
Enoch Kanyanya, United States Agency for International Development (USAID)

Erastus Wahome, Chief Economist, Ministry of Finance, Treasury
Eustace Muriithi Njeru, Energy Regulatory Commission
Evanson Njenga, Consultant Energy/Higher Education, Japan International Cooperation Agency (JICA)
Henry Watitwa, Chairman of Kenya Solar Training Facility (KESTA) and Managing Director of Bright Home Solar
Jacob Kimuya, Ubbink East Africa Ltd
James Muriithi, Director of Renewable Energy, Rural Electrification Authority
Janakaraj Murali, The Energy and Resources Institute
Joseph Mwangi, Kenya Association of Manufacturers
Kyran O'Sullivan, Senior Energy Specialist, World Bank
Maitene Cancellon, French Development Agency
Margaret Kamau, PWC Kenya and Helen Baker PWC (Global and Africa Technical Assistance)
Michael Omondi, Solar World (EA) Limited
Minori Chitani, Representative Infrastructure/Economy, JICA
Murefu Barasa, Camco Advisory Services
Mwatu J.P. Mbithi, Ministry of Energy
Nicholas Gachie, Kenya Association of Manufacturers
Robert Pavel Omieke, Director of RE, Energy Regulatory Commission
Sanne Willems, European Commission
Stephen Kinguyu, National Climate Change Action Plan Secretariat, Ministry of Environment and Mineral Resources
Timothy Ranja, United Nations Development Programme
Tom Owino, Climate Care
Walter Kipruto, Component Leader (Solar), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

3.3.2 WP2: Adapting Innovation Histories Method for purposes of the project[6]

In order to develop a detailed history of the development of the market for SHSs and other off-grid solar electrical services in Kenya, the project adapted the Innovation Histories Method (Douthwaite and Ashby 2005). As this method was not designed for exactly the same purposes as this project, WP2 necessarily involved work to adapt the method, both to the specific project aims and to fit with the project's conceptual framework, including adaptations to fit within theoretical perspectives informed by the STEPS Centre's Pathways Approach, together with Strategic Niche Management and Innovation Studies.

The Innovation Histories method was developed by Boru Douthwaite and Jacqueline Ashby (2005) as a way of drawing on experience from past innovation processes. The authors base their method within the wider Learning Selection Model developed by Douthwaite (2002). The method comprises a set of flexible guidelines on how to run a workshop with stakeholders involved in an innovation process. A step-by-step summary of the method as conceived by Douthwaite and Ashby (2005), and then as adapted in this project, is provided in Box 3.1.

[6] *Note: A more detailed account and reflection on the project's adaptation and application of the Innovation Histories Method is provided in one of the project's briefing notes which is available via the project webpage* *http://steps-centre.org/project/low_carbon_development/*

Box 3.1: Innovation Histories Method: Key steps suggested by Douthwaite & Ashby (2005) vs. Key steps as applied in this project

Douthwaite & Ashby's suggested key steps:

1. Clarify the objectives and expectations of stakeholders
2. Define the innovation
3. Construct innovation timelines and actor network maps
4. Write up the learning history
5. Use the innovation history as a catalyst for change via a follow up workshop that uses it to discuss shared visions
6. Write up the publishable innovation history to share learning with broader audiences

Key steps as applied in this project:

1. Define and specify the innovation
2. Circulate background information and examples of what participants will be asked to do
3. Clarify aims and expectations of stakeholders via introductory discussion
4. Individual work to construct personal timelines reflecting actors' individual experiences
5. Group work to construct timelines of key events, actors, roles, significance and potential available documentation – here actors are asked to think more broadly about key events of significnace beyond their own personal experiences
6. Group work seeking participatory review of overall timeline from participants
7. Post workshop, write up information into an Innovation History and circulate to participants for further feedback
8. Follow up with detailed, semi-structured interviews with relevant participants
9. Triangulate via interviews with other actors identified during the workshop, or identified during follow up interviews and wider literature review
10. Further triangulation with available published sources
11. Write up and make Innovation History available online and circulate widely throughout its development for feedback and critique
12. Publish innovation history in peer reivewed journal to articulate contribution in the context of existing academic and policy research

The method can be used both as an intervention to improve the innovation process while it is unfolding, or to facilitate an in-depth historical analysis to inform future innovation projects. We adopt a holistic definition of the term innovation, including not only technological innovations, but also social or organisational innovations (for instance car-sharing initiatives), viewing innovation as much more than something 'new to the world'. It is equally innovative if a firm, farmer or person adopts a technology or process for the first time, or is the first in an industry, region or village to adopt a new technology, process or technique. Moreover, incremental and adaptive innovation processes are often observed to be far more important than radical innovations in driving broader processes of change and development. In other words, innovation is not synonymous with invention. The widespread adoption of SHSs in Kenya is therefore an example of innovation across multiple scales. In this sense, the context in which we applied the Innovation Histories method is broader than the focus on the uptake and adaptation of (or to) single technologies that forms the basis of Douthwaite's work.

Douthwaite and his co-authors emphasise the method is a reflection tool to learn from any experience, whether it be positive or negative. For instance, perceived 'failures' are often not reported, although they are critical to the learning process. The Innovation History workshop should therefore try to provide an open and trustworthy environment, so participants feel comfortable enough to share information and to reflect critically on their experiences. Furthermore, for participants to be able to voice their opinions, workshop facilitators must be sensitive to power relations between the stakeholders. Ideally the interaction between participants at a workshop will elicit dynamic discussions, with participants prompting and reminding each other and negotiating the significance of the events and other factors identified.

The method not only pays attention to events but also to projects, processes, products and actors that influenced the development of an innovation (including technical, financial, social and policy aspects). Douthwaite and colleagues propose the workshop includes stakeholders from all levels and stages of engagement in the innovation process, from the researchers, designers and manufacturers to the end-users (and in the context of our work, policy makers, donors and other significant actors). This way the context of the innovation process is more likely to be taken into account, as well as enabling feedback from the users' perspective. Another benefit of this method is its participatory nature. It enables different stakeholders to tell their stories and voice their opinions. It is a way of drawing on their unique knowledge and experience as well as engaging them in the research process.

Notably Douthwaite and colleagues emphasise there is no fixed recipe on how to organise and structure the workshop or the write-up of the innovation history, but that it can be adapted flexibly according to the needs of each project. For instance, they suggest the workshop could include the drawing of timelines and actor network maps. These can first be constructed individually and then shared in groups to discuss, compare and integrate where possible. The discussions and results recorded during the workshop can be used to write up an innovation history, which provides room to narrate various perspectives and controversies. Before it is published the innovation history should be read and commented on by the participants, in order to double-check the researchers' interpretation.

The Innovation Histories method was chosen to inform the analysis of SHS uptake in Kenya in order to ensure the participation of key stakeholders in the research process. It is hoped this form of engagement will help the stakeholders to feel some ownership of the research, to understand its arguments and thereby increase the impact it is likely to have. If stakeholders are actively involved in the analysis and feel that their opinions are being heard, they are able to direct the research to be useful to them, at the same time as making a substantive contribution to the research itself. In this way, stakeholders active at different levels are able to influence policy through their contribution to the workshop and the research's subsequent engagement with policy makers in Kenya and internationally. The participatory nature of the method therefore assists in adhering to the research team's normative commitment of achieving impact via an approach based on three key principles: (1) engagement between researchers and other groups across society can improve the quality and substance of the research as well as ensuring that research contributes to learning; (2) interaction with a diverse set of other actors can provide not only useful inputs into research but can also protect against undue influences by any one group; (3) independent researchers can provide the setting in which to bring together diverse groups from across society to discuss difficult challenges, or they can provide intermediary functions.

3.3.3 WP3: Constructing initial innovation timeline: identifying key actors and events

In line with the Innovation Histories Method, empirical data collection began with a one day stakeholder workshop held in Nairobi in June 2013.[7]

A briefing, timetable, background information on the method and an example innovation history timeline (see below) were sent to the 20 participants who registered for the one-day workshop in response to invitations. Prior to the workshop we intended to familiarise participants with the ideas

[7] : A detailed report of this workshop (circulated to participants after the event) is available via the project website

behind the method and to encourage them to start thinking about and completing their personal innovation history timelines. The timeline consisted of a table with five columns, asking for: the event date; description of the process or project; others involved (actors); significance; and for any documentation (see Table 3.1). A professional facilitator was invited to help plan and guide the workshop, assisted by the researchers.

Table 3.1: Snapshot of personal innovation timeline participants were asked to complete

Date	Description	Others involved	Significance	Documents	Elaborations
1978 (Henry Watitwa)	Brother used dry cell with wires to light a spot light bulb in our room	Friends and other brothers	For fun – *indicates interest in, and awareness of, electricity (power was only in selected houses in town, institutions and Government buildings)*	*Personal memory* *motivation*	There was no solar.
August 1982 (Enos Orongo)	Failed Coup	*Contextual event*	*Stimulated* Government directive to increase TV network country wide	*Possible press reports?*	

According to the workshop plan, the day was to begin with a brief introduction to the research project, the method and the aims of the day. An hour was allocated for participants to complete their personal innovation history timeline (see example in Table 3.1), with tables on A4 paper provided. Next, a group work session, with participants split into two groups, was scheduled to combine personal timelines into one broader national timeline, For this session flip chart-sized tables would be hung on the walls allowing participants to complete their rows with the dates and other information on paper strips. These could then be stuck on the flip chart columns and moved around by using sticky Blu-Tack. This session was also intended to provide a space for dynamic interaction and discussion between stakeholders.

After lunch, both groups would switch rooms and peer review the other group's timeline. Sticky Post-It notes would allow comments, agreements and contentions to be added to the timeline. It was hoped this would prompt further memories and discussions. Subsequently the two groups come together to share findings and discuss points of contention.

Towards the end of the day there would be time for reflection on the workshop using an evaluation form as well as asking participants how the research might benefit them and what needed further examination. Throughout participants would also be asked to record the name, organisation and contact details of any other stakeholders they thought should be contacted for further information on the evolution of the SHS market. The researchers intended to avoid using jargon, keeping the language inclusive to participants who were unfamiliar with the literature and method. Box 3.2 provides some key points for consideration during workshop planning.

The start was slightly delayed after the group decided to wait for latecomers. Consequently some spontaneous reorganisation of the day occurred and, rather than splitting participants into two groups, they remained in one group throughout. A lower number of participants was beneficial in that there was time to introduce each participant to the group, and each had more time to share their experience and to interact with the facilitators and each other. The workshop provided a networking opportunity for stakeholders, which may be beneficial to their subsequent interactions and further development of SHS uptake in Kenya.

Box 3.2: Innovation History Workshop planning

In planning the workshop, these are some of the key aspects to prepare and questions that are useful to consider:

- What is the innovation under investigation? (define clearly)
- Who were the stakeholders involved in the innovation process?
- What aspects of the innovation are you trying to understand? What are the objectives of the workshop? (Do you want to focus on events, projects, products, actors?)

Decide which stakeholders are most likely to inform this understanding and able to answer these questions

- Invite stakeholders early and inform them in simple terms of the method and aims of the workshop
- Ask them to think about and possibly prepare the innovation history timeline (provide them with a template and examples to guide them)
- Organise facilitators and people to help record the information gathered during the workshop

Who will be helping to run the workshop on the day and what will their roles be?

Plan the group work: How big do you want the groups to be, how will you synthesise the group work into the bigger group?

- How can you get as many people as possible to be active and to contribute?
- How can you prompt and engage shy or quiet participants?
- Prepare the materials for the timelines or actor network maps (will you be able to read participants' handwriting and will you understand the descriptions they are giving?)
- How will you react to and resolve any conflicts or tensions between stakeholders?
- How will you analyse the data you gather during the workshop?
- How will participants be able to evaluate the workshop and the conclusions drawn from it?
- How can you best channel the data collected to inform policy?
- How will it impact and benefit stakeholders and users?
- How do you intend to follow up the workshop?

The first session went well as participants completed their personal timelines. These were collected and kept for further investigation. In the first group session participants were actively engaged, but rather quiet, with less interaction than had been hoped for. Looking at the completed flip chart timeline, the researchers realized it would be useful for participants to comment briefly on their contributions.

After lunch, participants were asked to give one-minute explanations of the events/projects/processes they had listed. Although this was helpful for understanding their descriptions, the session drew out and some participants became a little disengaged. However, it also meant every participant spoke and some participants asked each other questions. After a short coffee break, Post-It notes were distributed. Rather than asking for comments, participants were invited to rank the three most significant events. This did help to visualise agreement and thereby underline key events, but because participants were getting tired towards the end of the afternoon it was conducted with more haste than would be ideal. It is also possible participants simply ranked their own contributions rather than properly engaging with others' input. At the end of the day, stakeholders were thanked for their participation and asked for feedback on the day and further suggestions for the research.

Overall, it was difficult to pick up on power dynamics between participants in only one day without having met them previously. Overall, the workshop was different from how it had been planned, although the main objectives were still achieved, i.e. gathering the stakeholders' knowledge and experience of key events/processes/projects and actors, facilitating interaction between them and engaging them in the research. The information gained from the workshop will be followed up with more in-depth individual interviews with some of the participants and other identified stakeholders. Efforts will also be made to further triangulate the data gathered via detailed review of available published and grey literature and making the developing timeline publicly available for comment via the project website.

3.3.4 WP4: In depth stakeholder interviews

The data elicited from WP3 was augmented via data from in-depth, semi-structured interviews with a wide range of different stakeholders. Stakeholders were identified via a snowballing technique that built on the significant existing knowledge of the sector in Kenya possessed by ATPS and via Byrne's (2011) prior research. Table 3.2 details the topics covered by the interviews and the number of contributions made to providing data on each. This is based on interviews that provided around 100 hours of recorded interview testimony. Interviewees and others consulted, except those who asked to remain anonymous, are detailed in Appendix A. They cover a range of sectors and interests, including national and international governmental and inter-governmental organisations, donors, Non-governmental Organisations (NGOs), the finance sector, private sector companies across a wide range of relevant parts of the off-grid solar PV industry and organisations representing the interests of end-users.

The key aim of the interviews was to use the SNM conceptual framework as a basis to gather further, detailed information on the key actors, events and themes in the development and uptake of SHSs in Kenya and why they were important. These data were used to further develop the timeline started in WP3.

The interviews were semi-structured, based on questions developed by Byrne (2011) through a process of piloting, where the first few interviews were analysed to determine if the questions were eliciting answers that could be interpreted through the SNM conceptual framework. Following this, a set of generic questions was developed to be used with any interviewee, regardless of the topic being investigated. The generic questionnaire is given in Appendix B. The questions were then tailored to the topic of interest by inserting the appropriate words for the event or process of interest. For example, assuming the topic was 'Market Entry', question 1 would be written:

> Generic form: Please describe the process in general terms: how, when, why, and by whom, was it initiated; and how did it progress through to completion?
>
> Market Entry: Please describe the process of the company entering the PV market in general terms: how, when, why, and by whom, was it initiated; and how did it progress through to the present day?

However, the first question often elicited new and unexpected information and unanticipated lines of enquiry were often followed as a result. The point of the questions was to guide the interview rather than constrain it. Nevertheless, the basic format of capturing the SNM categories was maintained as far as possible and within the constraints of time. As can be seen at the beginning of the questionnaire, interviewees were asked if they were happy for the interview to be recorded and the manner in which they were happy to be cited. Most respondents took a copy of the recording. The majority of interviews were conducted face to face, but some were necessarily conducted by phone or Skype. Some interviewees were interviewed more than once and over two or three meetings, especially where they had extensive experience in a multiple of roles.

Table 3.2: Summary of interview topics and numbers of substantive contributions

Development	Donor	Finance	Govern-ment	NGO	Private	Uni-versity	Total
General				6	9	3	18
UN Conference 1981	1					1	2
Early SHS Period					5		5
Solar Shamba					1		1
Three-schools					1		1
Regional Workshop	1			1	1		3
SolarNet				1			1
KSTF				3	1		4
Pico-Solar	1				10		11
MOE RE Department	1		2				3
PVMTI		1			1		2
PV Standards	1		1	1			3
KEREA				1			1
Policy Making	4	2	8		3	1	18
PV Schools			3		2		5
PV Curriculum			1		2		3
KESTA				1			1
Micro-Finance		3		1	2	1	7
Market Entry					7		7
Lighting Africa		1			4		5
Ubbink EA					2		2

3.3.5 WP5: Analysis, theory building and policy recommendations

Once a detailed history of the key events and actors who contributed to the success of the market for off-grid solar electrical services in Kenya, together with its institutional and policy context had been developed via WPs1-4, the data was then interrogated against the project's hypothesis, research question and sub-questions. This was facilitated via the application of Strategic Niche Management as a conceptual framework to guide the analysis (see Section 2 above). At all points, findings and insights from the empirical evidence were triangulated on the basis of in-depth literature review updated from that presented in Byrne (2011). A focus was maintained throughout on what lessons could be learnt for policy, in particular the emerging Climate Innovation Centre approach, as well as the significance of any new empirical or theoretical insights that could be written up and submitted to peer reviewed academic journals upon project completion.

3.4 Stakeholder engagement, communication and policy impact

In addition to the work packages listed above, an explicit part of the project's methodology focussed on engaging with stakeholders, providing opportunities for them to inform the shape and direction of the project, to learn from its findings and outputs and to achieve policy impact. This began at project inception with development of a Participatory Impact Pathways Analysis (PIPA) which resulted in a map of key stakeholders the project sought to engage with and the routes via which this could be achieved. At multiple points throughout the project, efforts were made to provide opportunities for the actors and organisations identified in the PIPA as well as other stakeholders to engage with the project. This included, amongst other things, the following range of meetings, events and communications:

- Kenyan Radio and TV broadcasts on KBC English Service Radio (Live) and KBC Television (Live), May 2012
- Presentation at The Low Carbon Energy for Development Network's (LCEDN) inaugural conference at the University of Loughborough, July 2012
- Presentation at Sussex Energy Group seminar, University of Sussex, August 2012
- Presentation at STEPS-ODI seminar, hosted by the Institute for Development Studies (IDS), August 2012
- Keynote speach at the second conference of the LCEDN at the University of Sussex, September 2012
- Presentation at IPCC organised pre-event in the run-up to the Africa development Forum VIII held in Addis Ababa, 18 Dec 2012
- Presentation at Rethinking Climate Change, Conflict and Security conference at the University of Sussex, September 2012
- Parallel event on the project at ATPS's annual stakeholder conference in Ethiopia, November 2012
- Invited keynote on 1–2 Nov 2012, in the US organised by the Woodrow Wilson Centre for international Scholars
- Presentation at a meeting on the Green Climate Fund (GCF) organised by the Asian Development Bank in Singapore on March 7–8 2013
- Presentation at the third conference of the LCEDN at Imperial College London, June 2013
- TV broadcast on Good Morning Kenya on the Kenya Broadcasting Corporation, June 2013
- Presentation at the Future of Agriculture and Food and Nutrition Security in Africa Conference 2013, 17–19 September 2013, Pretoria, South Africa
- Presentation at the 2013 Tyndall Assembly held at the University of East Anglia, 12 September 2013
- Presentation to meeting of 25 high level UN officials and policy makers and private sector representatives from Korea in a presentation at a workshop hosted by United Nations Industrial Development Organization (UNIDO) and Korea Energy Economics Institute (KEEI) in Vienna on 7 August 2013, 'Managing the transition to renewable energy and energy efficiency practices: pointers for policy makers'
- Presentation at PEGNet Conference 2013, University of Copenhagen, 17–18 October 2013
- Presentation at seminar on the project at the Durham Energy Institute, University of Durham, 6 November 2013
- Side event showcasing the project at the 19th Conference of the Parties in Warsaw on 22 November 2013
- Presentation at seminar on the project hosted by the Dept of Geography, Kings College London, 25 February 2014

The project was also regularly featured in newsletters and web based news updates by ATPS, the STEPS Centre, the Tyndall Centre for Climate Change Research and the Sussex Energy Group, reaching hundreds of policy makers, researchers and practitioners across the world.

A project web page was created and regularly maintained by the STEPS Impact, Communications and Engagement (ICE) team to act as a first point of contact and information outlet for the project – see http://steps-centre.org/project/low_carbon_development/

4 Key activities in Kenyan SHS market development

4.1 Introduction to the case study

This section forms the core of this research. Here we build on the detailed empirical data gathered through the workshop and interviews, and summarised in Appendix C. We begin by charting the early arrival of PV systems in East Africa via donor-funded community services projects which later fed in to the emergence of a household market in Kenya. Following this, we discuss how the household market potential began to be exploited and how the idea was picked up by other companies. By the time Mark Hankins (who became an important actor in the Kenyan PV niche) did his MSc research in the late 1980s, there was an active market in household PV systems. Hankins set about disseminating this and recruiting others to a broadening network. Eventually, he had the chance to do more substantial projects and started his own company, Energy Alternatives Africa (EAA), to exploit the opportunities. The section goes on to describe and analyse a number of the niche developments that took place as the market grew in Kenya. Eventually, in the early part of the 2000s, niche actors were interacting with the policy regime directly as they attempted to influence Kenya's new energy policy. This had mixed results and reflects an uneasy relationship between niche actors and some influential figures in the policy regime, an uneasy relationship that continues. More recently, a market for pico-solar has emerged in parallel with that for SHSs, drawing in new actors and offering new hope for addressing the needs of poorer groups.

The history of the development of both these markets challenges the widely-held claim that the Kenyan solar market phenomenon is an example of private sector led development. As the detailed activities examined in this section demonstrate, this 'unsubsidised free market' narrative has been a powerful tool to attract resources from donors to, paradoxically, subsidise important learning and capability-building in the PV niche that has supported the activities of private sector actors. Without these subsidies, it is highly unlikely that such learning and capability-building would have happened. It is therefore debatable whether there would have been a Kenyan solar market phenomenon. But the market, for SHSs and for pico-solar, has indeed grown and this has recently attracted investment in a solar module assembly plant, the first in Kenya. It is too soon to know whether this plant will be a success but it does raise interesting questions and speculations about the directions of development that the PV pathways will take in Kenya.

4.2 PV for community and commercial services

During the late 1970s or early 1980s, it seems that PV was already in use in Kenya for some limited applications, although it is difficult to establish exactly what these applications were, and when and by whom the systems were installed. According to Hankins and Bess (1994: 2), and Duke *et al*. (2002: 481), these early systems were for powering telecommunications, although it is not clear whether they were commercial, funded by donors, or whether the Kenyan Government was involved in some way. The Kenyan National Paper for the 1981 UN Conference on New and Renewable Sources of Energy (held in Nairobi) simply states that PV had, 'barely been tried in Kenya' (Mugalo 1981: 10). Whatever the precise details, it seems that supply and installation in the Kenyan PV sector, to the extent that they existed, were dominated by international telecommunications companies and that, 'all the PV components used including the wiring accessories were imported' (Masakhwe 1993: 66).

The initial experiments with systems in Kenya, for which specific information is available, were with clinic and vaccine refrigerator systems (Roberts and Ratajczak 1989; McNelis *et al*. 1988). The first two of these systems (clinics) were installed in Kenya in May 1983, one each in the villages Ikutha and Kibwezi (Roberts and Ratajczak 1989: 15, Table II). In September 1984 and January 1985, a total of three vaccine refrigerator systems were installed (McNelis *et al*. 1988: 43, Table 4.3), although no locations are given. The two clinic systems were funded by USAID, used equipment manufactured by Solarex (a US company), and were designed and installed by staff from the NASA Lewis Research Center (NASA-LeRC) (Roberts and Ratajczak 1989). The three vaccine refrigerator systems were funded through the World Health Organization Expanded Programme on Immunization (WHO-EPI) effort and used BP Solar-LEC equipment (McNelis *et al*. 1988). The objective of the USAID clinic project was:

> [….] to increase health services in rural areas by demonstrating applicability of PV power systems for rural clinics by providing electricity for vaccine storage, lighting and other discretionary uses; e.g., dental equipment, communications, staff residential lighting and water pumping.
>
> Roberts and Ratajczak 1989: 16, Table III

These projects were part of much larger programmes of experimentation with PV systems in developing countries. During the period January 1983 to October 1984, systems of various kinds were installed by NASA-LeRC in nine sub-Saharan African countries: Burkina Faso, Gabon, The Gambia, Ivory Coast, Kenya, Liberia, Mali, Zaire and Zimbabwe (Roberts and Ratajczak 1989: 15, Table II). The types of systems installed were: rural clinics, vaccine refrigerators, school lighting and TV/VCR, water pumping, and outdoor lighting (Roberts and Ratajczak 1989: 14, Table I). A further six vaccine refrigerators in total were installed in three countries (Ghana, Kenya and Tanzania) through WHO-EPI between May 1984 and January 1985 (McNelis *et al*. 1988: 43, Table 4.3). And, prior to these, OXFAM had supplied 52 PV-powered pumping systems to Somali refugee camps in 1980 (Hankins and Bess 1994: 2). The WHO Expanded Programme on Immunization had the highly ambitious goal of immunising[8], 'all children of the world by 1990' (Henderson 1989: 46). Part of this effort was to strengthen the cold chain, hence the interest in PV-powered vaccine refrigerators. Field tests suggested they were more reliable than kerosene-fuelled types and were cheaper under certain conditions (McNelis *et al*. 1988: 45-47). By the mid 1980s, the programme included a commitment 'to adopt PV-powered refrigerators wherever they were economically and technically justified.' (Foley 1995: 12)

Perhaps as a direct response to this donor-funded activity, and in anticipation of the future PV markets in developing countries, a few companies set up offices or agents in Kenya (and elsewhere) during the early 1980s. Certainly, some of the market projections at the time would excite significant business interest. For example, a study for the European Commission reported estimates of market potential of different PV applications in developing countries at 50 million small solar water pumps, 5000 vaccine refrigerators per year, and a total village power potential of 3.75 TWp (Starr and Palz 1983: 121). Animatics, an agricultural equipment supplier in Kenya, started supplying ARCO modules as early as 1981, selling a reported 420 modules that year (Hankins 1990: 62, Table 4.1). BP Solar set up an office in Nairobi, or possibly established Securicor as their agent, in 1983 (EAA 1998: 23). Total Solar entered the market in late 1985 (Hankins 1990: 67), although they may have been concentrating on establishing a network of dealers for the first year (Interview, Rioba); indeed, EAA (1998: 25) state that Total became 'active' in 1987. Telesales, a retailer, may have entered the market in 1985 as well (EAA 1998: 24), although Abdulla (Interview) claims that they had been stocking modules since the late 1970s and Alpa Nguvu entered the market around 1986 (Hankins 1990: 60).

[8] The programme provides vaccines against BCG, DPT (diphtheria, pertussis, or whooping cough, and tetanus), polio and measles (Henderson 1989: 46, Figure 1).

It is unclear the extent to which the Kenyan ministry responsible for energy was aware of these various developments, although Kenya did have a Ministry of Energy (MOE) by 1979 (Goodman 1984: i). We know that, around the mid 1980s, the Italian Government donated some PV equipment to Kenya, including a water pumping system and energy research laboratory (Interview, Rioba). The MOE created a biomass department around 1984 (Interview, Arungu-Olende), which eventually became a renewable energy department in 1998. The first Kenyan Energy Policy was written in 1987 but it remained an internal document (ROK 1987). While the MOE was engaged in renewable energy projects, and the 1987 policy at least mentioned PV, there is no evidence that it was particularly active with the technology (Interview, Rioba). For the most part, the MOE and donors were more concerned with finding solutions to the problems around biomass energy.

It can be seen therefore, that in the early 1980s, there was no significant market in Kenya for household PV systems. Projects for commercial and community services systems continued and so a market developed around these. Indeed, these kinds of projects have continued up to the present, and they account for a large part of the installed capacity of PV systems in the region (ESD 2003).

4.3 An emergent market trajectory for household PV

This section describes and analyses the very early period of the household market in Kenya; how it emerged and how it was initially developed. These activities attracted others and, as we will see in subsequent sections, the initial work had a lasting effect on the PV niche in Kenya.

4.3.1 Discovery of a household market

The private market in household PV systems is said to have started during 1984 and its beginning is attributed to the activities of Harold Burris, an ex-Peace Corps volunteer, after he set up the company Solar Shamba[9] in a coffee growing region south of Mount Kenya (Acker and Kammen 1996: 87; Duke *et al*. 2002: 481). Burris was an engineer by profession and, according to one obituary, had worked in the nascent US solar industry (SolarNet 2001: 8), particularly with Texas Instruments (Interview, Hankins), before coming to Kenya with the Peace Corps in 1977 (Perlin 1999: 132). He was, according to Hankins (Interview), politically radical and fiercely independent, and so found it difficult to work within the constraints of traditional organisational hierarchies. As a result, he tended not to keep a job for very long before either resigning or being dismissed. Indeed, according to Hankins, he was dismissed from his Peace Corps assignment, following which he returned to the US where he did some, 'early computer-circuit work and helped to develop a health device for a friend', which made him enough money to return to Kenya, around 1979, with his own resources (Interview, Hankins). After spending some time in Mombasa with his wife, Stella, the couple moved to Yata (Stella's home town) in Machakos where Burris began working with appropriate technologies (ATs) and became 'well-connected with AT people' there (Interview, Hankins). He attended the UN conference in 1981 where it is likely, according to Hankins, that he used the opportunity to network extensively. In 1982, Burris set up Kidogo[10] Systems (Jacobson 2004: 125, n160) and tried, unsuccessfully, to market a PV-powered sewing machine through the Singer Company (Hankins 1993: 31; Perlin 1999: 133). He had developed the idea for his wife, a seamstress, powering her sewing machine by PV 'from day one (Interview, Hankins). While Hankins (1993: 31) seemed to attribute the failure of this project to an abortive coup in Kenya in 1982, he now says it failed because the machine was far too expensive for the Kenyan market (Interview, Hankins). Nevertheless, the episode indicates that Burris was searching for a means

[9] "Shamba" is a Swahili word that can be translated to mean "farm", although it can be used for anything from a plantation to a small plot of cultivated land; and it also has connotations of "rural" (Johnson 1939: 416).

[10] "Kidogo" is a Swahili word that can be translated as "small" (Johnson 1939: 76, see the entry -*dogo*).

to earn a living in Kenya, that he was able to source PV equipment, and that he was experimenting with PV systems.

Some time around the middle of 1983, Burris met Mark Hankins by chance at a café in Nairobi (Interview, Hankins). Hankins was a Peace Corps volunteer teaching science at Karamugi Harambee[11] Secondary School, which was in the process of considering electrification with a 'used 5 kVA diesel generator' (Hankins 1993: 31). The generator was chosen because the cost of connecting to the grid, some four miles away, would have been about USD21,000 (Perlin 1999: 133). When Hankins mentioned this in their conversation, Burris suggested that he could install a PV system instead. Hankins was unconvinced, 'I didn't trust Harry at all; the guy didn't look serious' (Interview, Hankins), but he nevertheless put together a comparative cost analysis for the board of governors showing that PV would be cheaper than the diesel generator (Perlin 1999: 133). The board was also un-persuaded but agreed to visit Burris' home system, after which they were impressed enough to postpone purchase of the diesel generator and to trial the use of PV in four classrooms and the headmaster's office (Hankins 1993: 31-32; Perlin 1999: 133; Interview, Hankins). The lighting system Burris designed cost the school USD2,000, which 'was less than the first cost of (the second-hand) generator' (Hankins 1993: 32). Hankins (Interview) recalls that Burris was struggling financially at this time and that 'he was very desperate, he was broke'. The modules he used for the Karamugi installation were left over from his failed sewing machine project. Once the school had given the go-ahead for the installation, Burris went to work on the balance-of-system (BOS) components: charge regulator[12], 24 VDC lights from a local manufacturer, local car batteries, module mount, and battery boxes (Interview, Hankins). Hankins (2001: 2) elaborates on which of the BOS components Burris put together himself and which he sourced locally:

> He [Burris] found that ballasts for 12VDC lamps were being manufactured for local buses by Nairobi company, Sound Communications. Further, he designed and assembled basic charge regulators and DC-DC converters (which allowed use of radios and cassette players) in his own shop. Further, he coaxed the local battery company to improve the design of their automotive battery to make it more suitable for PV systems. He designed module mounting systems and other balance of system components that could be made cheaply and by cottage industry groups.
> Hankins (2001:2)

During the Karamugi installation, which took place sometime during the first to third quarter of 1984 (Interview, Hankins), 'Burris used the services of an electrician based in the town near Karamugi and he trained the school's lab technician to monitor and maintain the system' (Hankins 1993: 32). The results of this monitoring were 'fed back to the installers' (Kimani and Hankins 1993: 93).

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[11] 'Harambee' is used in Kenya to mean 'self-help', and is the national motto (Barkan 1994: 19).'[….] Harambee, or self-help, is a pervasive movement that has become a major arena of rural politics and has shaped the structure of peasant-state relations in that country. With its fifteen to twenty thousand community development organizations scattered across rural Kenya, this self-help movement engages just about all rural dwellers, most politicians, and many state personnel. The primary activity of these organizations is the construction of social-service infrastructure by the residents of rural communities in order to meet their locally defined needs. [….] nursery, primary, and secondary schools, village polytechnics, cattle dips, health centres, water projects, etc.' (Barkan and Holmquist 1989: 359-360)

[12] Although Hankins describes this as a charge *regulator*, it is likely that the device was actually a change *indicator*, as Burris used such self-designed indicators in later installations (Hankins 1990; Hankins 1993: 35).

According to Hankins (1993: 32), and Kimani and Hankins (1993: 93), the headmaster, some of the teachers and others in the community bought systems for their own homes 'within six months of the school's installation'. This was a clear signal to both Burris and Hankins that there could be a market for household PV systems. Burris 'saw that there was a lot of business and there was a coffee boom[13] going on too so there was a lot of cash' (Interview, Hankins).

A major factor in the demand for electricity is the desire to watch television, and portable DC TVs began to appear on the market in about 1981, with the TV signal being broadcast to more and more rural areas during the 1980s (Jacobson 2004: 150-157, and Figures 24 and 26; Interview, Hankins). In response to these developments, Burris moved to Embu where he renamed his business Solar Shamba (Jacobson 2004: 125, n160). Hankins, for his part, was already applying to Peace Corps by the second quarter of 1984 for an independent placement[14] in which he would work with Burris on a project to install PV systems in three more schools, and include in the package the training of local technicians (Interview, Hankins). According to Hankins (1999: 6), he and Burris believed the training element would be critical to the growth of PV applications in Kenya and that rural electricians would need to be able to 'sell, install and maintain PV systems'.

In Embu, as he had done in Meru, Burris powered his home and workshop with PV (Perlin 1999: 133). 'He was in town but off-grid. [….] a kind of in-town appropriate technology demonstration' (Interview, Hankins). He now began 'to get heavily into the marketing' (Interview, Hankins). Dickson Muchiri, who worked as a sales technician for Burris from about 1986 until moving to the company Alpa Nguvu in 1987/1988, elaborates on the marketing strategies that Burris had developed by that time. These were:

- Writing proposals for organisations looking to get a PV system funded by a donor: if the proposal were successful then Burris would most likely get the job

- Placing some kind of 'working sample' in a strategic location such as a small shop: customers could see it, know that it is working, ask questions, etc.

- Sometimes advertising in local newsletters (although not really in newspapers): there was one that went around in Embu town, for example

- Participating in dissemination events organised by aid organisations where he could explain solar and its potential applications

[13] The "coffee boom" is actually said to have occurred during the period 1975/1976 to 1978/1979 (Bevan *et al*. 1990: 359; Akiyama 1987: 6 and 8). There was a peak in the value of coffee exports in 1977 following which the value fell back below USD300 million as of 1980, remained quite steady, and then peaked at a similar level to the 1977 value in 1986. Bevan *et al*. (1990: 359, citing an earlier study of theirs: Bevan *et al.* 1987) state that coffee producers in Kenya, unlike those in other coffee-exporting countries at the time, received significant earnings from the boom because 'export taxes were negligible'.

[14] It is not clear what an independent placement is exactly. It may be that Peace Corps volunteers were placed in organisations to help build capacity in those organisations. In the case of Hankins' work with Burris, this would not be the arrangement and so it may have been considered 'independent'.

- Attending district shows. One example was a show in Embu in 1986 that Muchiri believes achieved wide publicity for Burris. Indeed, van der Plas and Hankins (1998: 301) note that 'agricultural fairs were an important information channel in the late 1980s and early 1990s'

- Using his technicians to cold-call. He employed six permanent and two casual technicians and whenever they were installing a system in a house they were instructed to go around the area looking for potential customers. For example, if they saw someone was building a new house then that person could be a customer. And Hankins (2001: 2) reports that Burris 'encouraged these technicians to seek customers among the high-income households on the southern and eastern sides of Mt Kenya'.

  (Interview, Muchiri)

Hankins (Interview) adds that Burris produced one-page mimeographs, although he does not describe the content of these. We might reasonably assume that these would, at the very least, explain what PV could power and how to contact Solar Shamba in order to buy a system.

By the third quarter of 1984, Peace Corps had given approval for Hankins' independent placement, providing he concentrate solely on the solar project with Burris (Interview, Hankins). Although Hankins says that he had to convince the Peace Corps to approve the independent placement, it seems this was helped by them visiting the Karamugi installation:

> The Karamugi installation was a coup: it involved some Peace Corps leaders coming to the school and talking about how this was a great thing. So there was definitely a sense that this was a great idea and so let's talk to the people in USAID about it.
>
> (Interview, Hankins)

USAID could be expected to be favourable to the idea as they had already funded a 'very successful' energy project in Kenya in 1984, the Kenya Renewable Energy Development Project, which saw the creation of the Kenya ceramic jiko, an improved small stove[15] consisting of a metal case with a ceramic lining (Interview, Hankins). Still, Hankins says:

> I had to write a proposal and design the training and get Harry to go in on this … . Harry was the guy who was dealing with the American companies so Harry was going to get paid to bring that equipment in. … I had to locate three schools. I did a survey of twelve schools; riding around on a bicycle on the eastern side of Mount Kenya convincing schools to put in 50 per cent of the cost. … I did energy audits of the schools; looked at how much wood they were using and tried to come up with a case.
>
> Harry was intimately involved in the process: we would meet in Nairobi in a cheap hotel and we would work on Harry's World War Two typewriter and we would do cut and paste as we designed manuals. We also had to identify twelve solar technicians. One was a relative of Harry's wife, Daniel Kithokoi. We got the equipment, identified the schools and we did the installations one after the other [during 1985 and into 1986]. … When we trained the twelve guys, he [Burris] immediately went to all the twelve guys and said be my agent.
>
> (Interview, Hankins)

[15] The payback time was about two months and there were an estimated 125,000 stoves sold by the middle of 1985 (Jones 1986: 18).

As mentioned above (Interview, Muchiri), Burris did employ some of the technicians: six permanent and two casual. By this time, according to EAA (1998: 24-26), Telesales, Alpa Nguvu Solar Systems, and ABM (Chloride) had all entered the PV market, ABM (Associated Battery Manufacturers) being the 'local battery manufacturer' that Burris had 'coaxed' into improving their automotive battery (Hankins 2001: 2), getting the product on the market in 1985 (Hankins 1990: 74; Acker and Kammen 1996: 88). At the end of the USAID-supported schools project, Hankins and Burris organised a cocktail party in Nairobi so that the technicians could meet these PV and equipment suppliers, resulting in some of the technicians either being employed immediately (Hankins 1993: 32) or striking deals with the companies, independently of Burris (Interview, Hankins).

4.3.2 Socio-technical analysis of the discovery of a household market

The Karamugi School Project

The evidence suggests that, prior to the Karamugi school installation, Burris had not considered PV systems for households as a viable business opportunity. This was despite his using PV for his own home. However, it is clear that he was considering ways to make use of his knowledge of PV to develop a business and had tried to market at least one product, the PV-powered sewing machine. This had failed because it was too expensive compared with the foot-powered device that was already widely available and in use. Even the process of securing the Karamugi installation was a protracted episode. He had failed to convince Hankins, who in turn had failed to convince the Board of Governors, despite having provided a favourable cost comparison with the proposed diesel generator. It was only after the Board had seen the system at Burris' home and workshop that they accepted PV as a possibility.

We can interpret this slow acceptance by the Karamugi Board quite straightforwardly. PV was a new technology and so it is unlikely that any of the Board members would have seen it in operation before the visit to Burris' home. The other ways of getting electricity, the grid or diesel generator, were already familiar. This would have made PV seem highly risky or, at least, unproven. Indeed, they may not have had any conception of PV. Seeing a system in operation would have demonstrated its functionality and may have instilled some confidence that Burris was someone who could perform the installation competently. Certainly, the Governors were now willing enough to take the risk. From an SNM perspective, if second-order learning is characterised by changed assumptions then we could say that the Governors experienced such learning because they now included PV as a possible source of electrical services, alongside the grid and diesel generators. Whether this was a change of assumptions or not, we can certainly claim that they were able to form a detailed socio-technical vision: a well articulated cognitive schema of PV-generated electricity services. Moreover, that vision was now grounded in a physical reality that was close to their personal experiences.

Once the system was in use in Karamugi, further learning occurred that we can most likely categorise as first-order. Obviously, there would have been much learning about the operation, maintenance and monitoring of the system, clearly learning of a first-order quality. But there would also have been the issue of confidence in the technology. For some, this confidence grew quickly and was strong enough that they were willing to buy systems for their own homes.

From the point of view of Burris, witnessing the impact his home system had on the decision making of the Board may have been an important experience that contributed to his later marketing strategies. Despite his having supplied the Board with a quantitative assessment of the costs of a PV system compared with a diesel generator (assuming that he had at least some hand in this as Hankins would have had to get information about a PV system from someone), the decision to buy a system was not made until the Board had actually seen one in operation. Of course, the visit to Burris' system suggests that the cost-comparison had raised their interest to some extent. But the 'deal-maker' seems to have been the system visit. This deal-making quality of demonstrations was reinforced by the Karamugi installation itself, when the headmaster and others ordered systems for their homes, and other schools became interested. Hankins, if it had not happened already, was also convinced by the Karamugi installation[16] and was inspired to work with Burris on another project, this time much larger. Further, it was now clear that a household market in PV systems was a realistic possibility.

We can infer from these events that learning of various kinds occurred. Burris was certainly engaged in first-order learning in terms of the technical details of the systems: he had spent effort putting together the BOS components, and he was receiving information on the performance of the Karamugi system. But we can also infer some second-order learning for Burris regarding the possibility of a household market. He had not tried to market household systems, as far as we know, even though he knew from personal experience that they were technically feasible. One explanation of this is that he assumed there was no market. However, once a demand was demonstrated to him, 'he mobilised very quickly' (Interview, Hankins). He already had a well-articulated technical vision of PV (most likely an economic on), a social dimension (in that he used the technology in his own home), and now he was able to add a business or market aspect. He was yet to develop the detail of this market aspect and how to sell to it, but he had a beginning. There were wealthy enough customers in rural areas who, if they saw the technology in operation, would buy systems for their homes.

Hankins was also recruited to this vision, albeit with his own dimension to it, having now learned that PV was viable and that there was a potential market for PV systems. He could also now see that Burris was 'serious'. Hankins' version of a socio-technical vision included a training aspect. Between them, they had constructed a basic strategy to capitalise on this nascent market: Burris would address the technical aspects while developing his business; Hankins would address the training. This would be more straightforward for Burris in that he could concentrate on finding customers, some of whom were already coming to him. It would have been more problematic for Hankins as he would be unable to sell training in the private sector. So, the notion of implementing a donor-funded project that included training would have seemed sensible. Such a project could be expected to replicate the experience of Karamugi: demonstrate the technology to generate interest and then hope customers would emerge.

Hankins was able to recruit relevant people within the Peace Corps to this vision, themselves having been influenced by seeing the system at Karamugi. Again, the demonstration effect was evident. However, the proposed three-schools project was also in line with existing Peace Corps interests. They had been working since 1979, with financial support from USAID, on developing a rural energy survey methodology, which was 'one component of a Renewable Energy Program [….] to assist developing countries in identifying energy needs in rural areas and in implementing alternative, renewable energy projects at the community level. (Peace Corps 1984: vii) So, from the Peace Corps perspective, the Karamugi installation was exemplary and it is easy to see that they would support similar projects, assuming some due process such as a project proposal, and so on. Indeed, the proposed project would be strengthened, in the Peace Corps view, by a much larger and more systematic training element. This training aspect was also in line with the development regime's interest of building capacity in the private sector.

We can see network-building happening during the Karamugi episode. Burris was already involved in an appropriate technology network in Kenya and knew the PV suppliers, while Hankins was involved in the Peace Corps network and was working in Karamugi School. Karamugi was deeply embedded in its community, especially considering it was a Harambee school, and there would have been some

[16] Hankins was not present when the Governors visited Burris' system (Interview, Hankins).

connections to other schools at least because of the education system. Both the school and the Peace Corps, of course, had access to financial resources: the school directly from the community; the Peace Corps from USAID.

The Three-Schools Project
The processes associated with the three-schools project were sites of further learning, and forming and refining of socio-technical visions. There was also network-building, institutional innovation, and the mobilising of resources. For Hankins, the three-schools project was significant because it resulted in a model of PV market development that he would later use in other countries, as well as much of the material he would use to write what became a textbook of PV system installation tailored to an African context. For Burris, apart from the immediate benefits of paid work and the potential of more to come, the project was important because he was able to train his own agents (as many of them became) at no cost to himself. For the technicians who were trained, the project provided an opportunity to develop new skills and knowledge, to get work and to connect with the PV suppliers in Nairobi. The suppliers benefited by gaining access to more trained technicians. The schools, of course, benefited from subsidised PV systems and the electrical services these afforded. And, in terms of a local PV niche, the project was important because it demonstrated that PV could be installed by Kenyan technicians, i.e. that it did not require highly paid foreign specialists.

We can identify important first-order learning in Hankins' energy audits, which he conducted during his survey of twelve schools. These audits would have helped to quantify aspects of the case he was building to persuade schools to come into the project. The learning here involved developing an energy survey methodology and more precise information on the costs (in time and effort as well as money) of using various energy carriers compared with electricity generated using PV systems. The most direct comparisons would have been with kerosene for lighting; and dry cells, fuel-generators or grid connections for electricity. Indeed, Hankins provides cost-comparison examples of all these, except grid connections, in the 1995 edition of his book *Solar Electric Systems for Africa* (Hankins 1995: 109-112). Not only would these cost-comparisons have been useful in persuading schools to come into the USAID-supported project, they would have helped form the basis for future arguments related to the costs of PV elsewhere, as well as further articulating a PV socio-technical vision.

PV systems were further indigenised through the project. In terms of technical artefacts, there were several innovations. Burris was continuing to refine the technology as much as he could, and he persuaded ABM to modify their automotive battery so that it better suited the needs of PV. He worked with others to develop his manually rotatable module mount, which enabled significantly more solar energy to be harvested by a PV system. This was developed with the help of a local NGO. The ballasts for direct current (DC) lamps were available locally, Burris made his own charge regulators and indicators, and reflectors for the lamps were made locally, as were battery boxes. Clearly, the training of technicians was a significant indigenising process. They were trained in the design, installation, operation and maintenance of systems. Those who worked for Burris would also have been trained in making charge regulators and the other components he developed. And, of course, they would have been active in developing the marketing strategies used by Solar Shamba.

Training, by definition, is about developing practice: that is, an important element of institutional embedding. The design of a system begins with understanding the energy needs of the customer. Here, Burris developed various forms for recording information about a householder's electricity needs and these were tailored to the kinds of homes that were most likely to be found in rural Kenya. The evidence of these appears much later but Burris, as has been said elsewhere, was strict about adherence to good technical practice so we can assume that he was using these information gathering methods from the outset. The design itself involves sizing calculations and Burris developed simple processes for this, which would have been part of the training in the project. These sizing procedures certainly appear in Hankins' 1995 book. Installation involves a number of processes that would have been familiar to electricians but there are also procedures that are more specific to PV systems. For example, the commissioning of a battery: filling with electrolyte; its first charge; what to do if there is spillage of the electrolyte; and so on. In operation, a PV system is straightforward but it performs better if a few simple energy-saving habits are cultivated, and the information supplied on the charge regulator is understood and its implications addressed. For example, if the regulator or indicator shows the battery charge to be low then it is better not to use the loads until the charge returns to a high level again. The customer should be aware of these kinds of operational details and so it would have been important to include this in the training. And, finally, maintenance of a system is simple but, again, important: cleaning the module; topping up the battery; checking connections are secure; and so on. All these aspects are present in Hankins' book and they were part of the training courses given elsewhere. So, we can see that the project was also important as an early attempt to set an institutional trajectory. These procedures had to be articulated so that they could be expressed in the training and Hankins acted as translator here between Burris and the technicians. Burris explained the technical details to Hankins who then attempted to write these in a form that the technicians could understand.

The business impact of the three-schools project was similar to the Karamugi experience. Once a system was installed in a school, there was interest stimulated among the local community and orders for systems began to flow. Here was more evidence that demonstrating the technology was a powerful marketing device. Further, as a later study showed, many people learned about PV systems and bought them as a result of seeing an example in a neighbour's house (van der Plas and Hankins 1998). As Hankins (Interview) puts it, 'Once someone had bought a system, he would have four or five friends come over and they would all want one too'. Again, we can identify learning but not necessarily whether it is of a first or second-order quality. There is something of a first-order dimension to it in that learning that PV can supply electricity has an instrumental quality. That is, if someone wants to get access to electricity and then finds a way to do it then that is instrumental learning. Whatever the quality of the learning processes, we can certainly infer that demonstrations helped to articulate socio-technical visions. Those who were working with PV systems were able to conceptualise them in, to a lesser or greater extent, precise terms, communicate these terms and hence collectivise a socio-technical vision. So systems could be described: what they looked like; how much they cost; their functionality; their reliability; who could install them; and so on. Information in this form is much more readily transmitted in conversation enabling personal networks to act as effective communication channels.

In the same way that users and customers were able to describe systems in more precise terms, supply-side actors were able to articulate the market more precisely. By installing systems in homes, Burris, the technicians and others were meeting customers and developing knowledge of who they were and what they wanted. In other words, they were able to begin articulating the market, sort of learning-by-doing market surveys. We can assume the technicians would already have had considerable knowledge of local culture, including energy use, but it may not have been articulated in any detailed sense. Faced with having to explain PV systems to customers and how they would fit into their lives, in the hope of persuading them to buy, they would likely develop this articulation to some degree. Burris, also, is likely to have had some knowledge of local culture, having already lived in Kenya for many years and been married to a Kenyan. Still, we can assume that he would have learned a great deal in his interactions with customers and this will have helped him to refine aspects of the technology as well as understand the market better. These more precise articulations would have informed marketing strategies as well as technical developments and socio-technical visions.

4.4 Development of marketing models in the household PV sector

The market began to grow quickly during 1985 and 1986, although figures for the number of systems installed are only estimates. Hankins (Interview) believes there could have been about a million dollars' worth of installations altogether over the ensuing two years (amounting to a few thousand systems at between USD500 and USD1000 each), with Solar Shamba doing many of these. Other estimates for Solar Shamba range from about 150 systems (Hankins 1990: 72), to 'hundreds of solar home systems' (Hankins 2001: 2), to more than 500 homes (Perlin 1999: 135), although this last figure is taken from Hankins (1987: 107) and seems to be a total for Kenya, as of January 1987, rather than entirely attributable to Solar Shamba. As noted above, Duffy *et al*. (1988: 3-5, Table 3.1) report that there were USD218,000 worth of PV imports from the US to Kenya in 1986. Up to and including 1986, the estimate is 82 kWp. The first year that we have an indication of module sales is 1987, estimated to be 88 kWp.

Prior to June 1986 there had been import duties and VAT on PV modules (Acker and Kammen 1996: 92). Import duties had been at 45 per cent but these were completely removed because of lobbying, by the World Bank (Jacobson 2004: 142, n184) and by the private sector (Acker and Kammen 1996: 92). In fact, according to Hankins and Bess (1994: 7), there was no official duty rate for PV equipment prior to the 1986 'removal'. Any import duties that were applied depended on an arbitrary choice by the customs official at the border. There does seem to have been confusion, at the very least, over whether duties should be applied. Muchiri (Interview) states that modules would be categorised differently depending on whether they had diodes[17] attached or not.

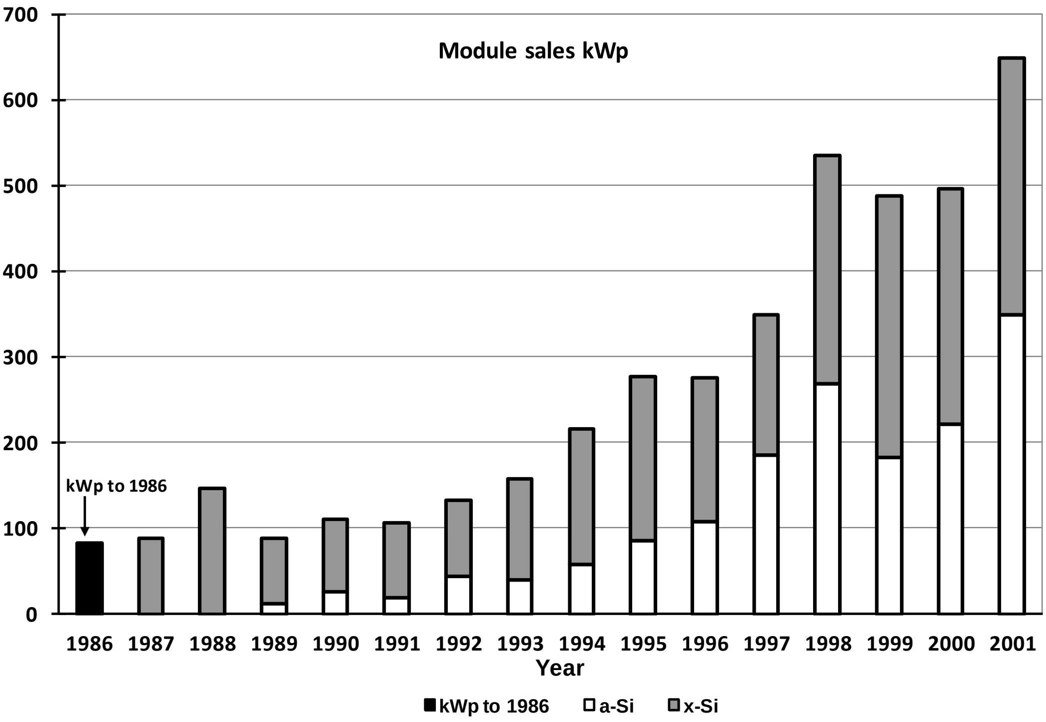
Still, whether the imposition or removal of duties and VAT made any difference to sales is, according to Acker and Kammen (1996: 92), 'subject to debate'. They cite two, apparently opposing, views: that of Hankins and Bess (1994) and that of Karekezi (1994). Hankins and Bess (1994: 7) claim that the sales of modules 'increased dramatically' but Acker and Kammen (1996: 92) state that 'Karekezi found [....] no savings were passed on to the customer'. Judging by the estimates reported in Figure 4.1, we can see that sales did rise very quickly in the period 1986 to 1988 but this could have happened for reasons other than price reductions. First, sales were starting from a low base and, second, this period was the beginning of intense marketing by a number of companies.

4.4.1 The dealer-network approach

At least one other approach was being developed at about the same time as Burris was building his business. Charles Rioba, a chemical engineer who had worked in the Biomass Department at the Ministry of Energy and Regional Development from 1983, had become interested in solar and was looking for a way to develop his own career, the prospects for which he saw as unpromising within the Ministry (Interview, Rioba). He took a year out from the Ministry to do a masters degree in renewable energy at the University of Reading in the UK during 1984/1985. He then returned to the Ministry and registered his own company, Solar World, but did not yet work on it full-time. Instead, he decided that he needed more practical experience and managed to get a job with Total Solar, a subsidiary of the French petroleum company Total which had a network of outlets across Kenya.

Figure 4.1: Estimated module sales (kWp) 1986 to 2001

[17] A diode is connected in series between the module and battery to prevent discharge from the battery when the module voltage is lower than the battery voltage, as would happen in darkness. Muchiri (Interview) says that modules with attached diodes attracted duties while those without did not. In order to avoid duties, the international suppliers would be asked to send diodes separately.



(a-Si: amorphous silicon modules; x-Si: crystalline silicon modules)
Source: Hankins *et al*. (1997) and BCEOM et al (2001)

Total were interested in selling PV in Kenya[18] and were looking to develop a business model. Rioba became their Dealer Development Manager in late 1985 (Interview, Rioba). Total Solar were mainly involved in solar thermal systems but, according to Hankins (1990: 67), they began to include PV in late 1985, around the time that Rioba joined them. Rioba spent his time setting up dealerships around Kenya, 'trying to identify risk-takers' (Interview, Rioba). Two of the marketing techniques he developed were installing subsidised demonstration systems in homes, and setting up demonstration kits in the dealership outlets. These demonstrations, according to Rioba, were the most effective for persuading people to buy systems, especially the demonstrations in homes. Total Solar were not, initially, interested in installing systems in households, they were more interested in larger systems ,but household installations became a more significant part of the business over time. According to Hankins (1990: 68) they installed about 50 household systems in 1986 and had installed about 550 systems by May 1990, by which time 'they [preferred] to install the kit themselves using the company's trained technicians' (Hankins 1990: 67). According to Rioba (Interview) and Masakhwe (1993: 67), Total trained their own technicians as part of the dealership package. These were short courses. about three or four days, and covered both solar thermal and electric systems (Interview, Rioba). Altogether, Rioba estimates that about 80 technicians were trained in this way, including Rioba himself, some of them working in the dealerships and others directly for Total Solar in Nairobi.

[18] Although Total were interested in selling solar equipment in Kenya (and perhaps elsewhere), Rioba characterised their motivation as a public relations exercise. That is, it was more of an attempt to look environmentally responsible than a serious attempt to develop sustainable technology markets (Interview, Rioba). Nevertheless, before they started selling PV, they had about 70 per cent of the solar water heater systems market in Kenya (Hankins 1990: 67).

Masakhwe (1993: 67) acknowledges the importance of Total Solar and their training, as well as their pioneering of the dealer-network approach to marketing PV. By the time Hankins' conducted research on the sector for an MSc in 1990, Total Solar had about twelve dealerships in Kenya: Kitale, Embu, Mombasa, Kisii (the dealer here being Solar World, Rioba's own company), Nanyuki, Malindi, Eldoret, Kisumu, Nyeri, Meru, Nakuru and Nairobi (Hankins 1990: 67; Interview, Rioba). And, by 1990, other companies had embraced the dealer approach 'as most companies [could not] afford to competitively operate from Nairobi without local agents or dealers' (Hankins 1990: 69). Competition in the market had been increasing and, from about 1987, the companies had begun 'intensive marketing campaigns employing both the commercial media (newspapers, magazines and radio) and district agricultural fairs to advertise and demonstrate their products' (Hankins and Bess 1994: 3). There were various kinds of interactions between companies. Some of these were commercial such as buying modules from each other, occasionally in quite large quantities (Hankins 1990: 62, 66, 78; Interview, Rioba). Other interactions were more indirect such as the movement of technicians between companies (Interview, Muchiri). Muchiri, himself, is an example. He trained and worked with Burris, moved to Alpa Nguvu, spent some time freelance, and now works with Rioba at Solar World. And it is well-documented that many of Burris' other technicians went on to work with other companies or start their own businesses (Hankins 1990: 72; Hankins 1993: 33; Acker and Kammen 1996: 87; Perlin 1999: 135). Judging by the speed with which companies moved into the household market initially, and then used similar marketing and distribution methods, it is reasonable to assume that information and knowledge flowed quite freely between them.

This was a serious issue for Solar Shamba. Burris was known to make enemies of those he considered to be less technically conscientious than he was or, at least, those who did not practise to minimum technical standards (Interview, Hankins; Interview, Kithokoi). With the rapid growth of the PV market and increasing competition, many were finding ways to cut costs and this was most easily done by omitting the charge regulator, using thinner wires, installing batteries of inadequate capacity or quality, including incandescent lamps instead of fluorescents, and choosing modules of insufficient power output for the needs of the system. Burris tended to openly criticise those technicians, or others, who made use of any of these practices. As a result, Hankins (Interview) observes that:

> [Although] Harry [Burris] had put a business model in place … he wasn't the type of person to attract business from an investor – that is, investors would not find him an attractive proposition. He was so adamantly independent. The business community in Nairobi steered clear of him and wouldn't invest in him and the technicians, except for the ones he worked closely with, didn't bring him business. They just started doing business on their own, the companies set up their own marketing channels, and left Harry out. Gradually, Harry was becoming isolated.
>
> Hankins (Interview)

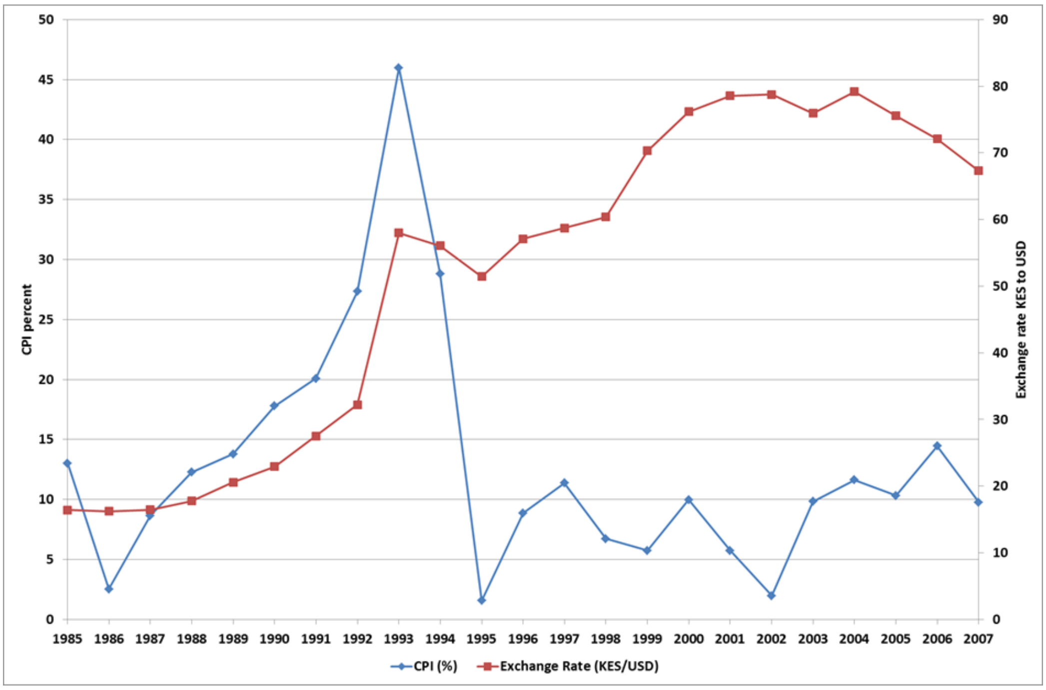
Burris left Kenya towards the end of 1987 or in early 1988 (Hankins 1990: 70; Interview). Although Solar Shamba stopped doing business, Daniel Kithokoi, who had been working closely with Burris, started his own company, Solar Energy Installations, and continued to work in Meru, the area he had been covering while with Burris (Hankins 1990: 70; Interview; Interview, Kithokoi).

4.4.2 PV as consumer product

Two interesting developments occurred in the market during 1989. First, amorphous modules became available in Kenya (van der Plas and Hankins 1998: 298). Second, it seems that Chintu Engineering was given the license to assemble kits using these amorphous (Chronar) modules and began supplying them separately, and as part of the complete solar lighting kits, from May 1989 (Hankins 1990: 63). Chintu supplied the modules and kits through its own three branches, a dealer network and, most notably, through Argos Furnishers, a very large company with over 30 branches in Kenya (Hankins 1990: 64, 69). Argos offered the kits on a cash or hire-purchase basis, 'in the same way that they provide credit terms for bicycles, televisions and sewing machines' (Hankins 1993: 39), the first time PV was available on any credit terms to the consumer (Hankins 1990: 64). It was already widely recognised, of course, that the initial cost of a PV system was high and that this could be a problem for the adoption of the technology, even if the life-time cost could be competitive with other technologies. However, those supplying the household market in Kenya did not have the cash flow necessary to introduce hire-purchase, or other credit schemes, into their selling strategies. Hankins (1993: 39) notes:

A shortage of credit for potential system buyers is the greatest impediment to expansion of PV sales. Many potential customers have steady incomes but are unable to amass the initial capital required to purchase systems. Local dealers cannot profitably offer credit because their own cash flow is limited and because of the problems associated with collection of debt.

Figure 4.2: Consumer Price Index and Exchange Rate of KES to the USD 1985-2007



Source: African Development Indicators (2009)

It appears that Chintu was doing well on the basis of supplying these kits and selling them through Argos, as well as others. According to Hankins (1990: 64), the company sold 1200 modules in less than one year after introducing the kits (500 of them to Argos) and had assembled another 1000 kits by May 1990. However, the hire-purchase offering ended when Argos closed many of its rural outlets 'due to economic reasons' (Hankins and Bess 1994: 14). Those reasons are not given but the period following the introduction of the kits was a difficult one in the Kenyan economy, a period that Acker and Kammen (1996: 90) describe as a 'two-year tailspin', particularly after the suspension of quick disbursing aid by donors starting in early 1992. Figure 4.2 shows the rapid increase in the CPI (consumer price index) and fall in the value of the Kenyan Shilling against the US Dollar, the CPI only really coming under control in 1995 even if the Shilling has never recovered.

4.4.3 Socio-technical analysis of marketing model development

Total Solar and the dealer network

It is not entirely clear why Total moved into the PV market. According to Rioba (Interview) they were only doing this for 'greenwashing', perhaps a response to the growing environmental awareness worldwide. Nevertheless, they had most of the solar water heater market (70 per cent) and may have thought there was a sizeable donor market in PV worth pursuing. In time, however, it was the household market that became more important to their business. Whatever the explanation for Total Solar's involvement, the evidence does suggest that they were the first to develop the dealer-network approach. And, over the next few years, other companies embraced this approach as the competitive pressures in the market intensified.

For Rioba this was an important period of learning. He had gone to Total Solar purposefully to learn and he certainly gained technical training as well the experience of setting up the dealer network. While doing this he also gained useful experience of the market and how to sell to it, although this may have been more indirectly through dealers than directly through interactions with customers. He also saw the effectiveness of demonstration systems for generating business. Indeed, the dealers would have seen the importance of this strategy themselves.

It is difficult to identify whether Rioba's learning was of a first or second-order quality. He may have experienced both kinds. We can be reasonably certain, however, that he had some form of expectation that guided his decision to join Total Solar. The source of this is likely to be a combination of the experiences he gained working in the Ministry of Energy and Regional Deveopkent (MERD) and studying renewable energies for his masters degree. Out of these experiences we could suppose that he formed a somewhat vague socio-technical expectation that incorporated renewable energies and business in Kenya. Given that his first degree was in chemical engineering we can think of his forming of a personal socio-technical expectation as the result of second-order learning, he had changed his assumptions and was attempting to achieve a new goal. The learning that followed was concerned more with the detail of this expectation, technical details of PV, how to establish a dealer network, how to stimulate local markets, and so on. His activities, then, began to articulate some of the detail and so helped him to form a socio-technical vision, in the Berkhout (2006) sense, but on a personal level. Some of this was collectivised by interactions with dealers and the installation of demonstration systems.

For other companies, the existence of a dealer network and demonstration systems were observable and, therefore, possible to imitate. Moreover, Total Solar appeared to be doing quite well in terms of business and this would have served to demonstrate a market demand in more of the rural areas. We can see here a possible method by which Total Solar's business and distribution model could be copied, and a possible reason for companies wanting to copy it. However, apart from the fact that other companies adopted a dealer-network approach, we do not have the evidence to conclude that they actually copied from Total Solar.

The dealer network that Total Solar developed was important for generating more business, of course, but it was also important for raising awareness of PV among more Kenyans. Likewise, the networks developed later by other companies had this effect. Further, the technical training that Total Solar conducted within its own network helped to establish at least some PV-specific skills around the country. While it is likely that this training was not as comprehensive as that given by Burris and Hankins (Rioba talks of three or four days to cover both solar thermal and electric systems), it was an attempt to institutionalise professional practice of a kind.

Chintu, Argos and hire purchase

For market growth, the introduction of amorphous modules was important because they were significantly cheaper than the crystalline variety, even though the poor quality of the modules caused many problems (see section 4.7.1). From the customer's perspective, however, a lower price was not the only benefit. The modules were rated at 12 to 14 Wp, a good match for a PV system that could power a portable TV. The modules began selling quickly, although it is difficult to know to what extent this was because of their size-price characteristic and to what extent it was because of the hire-purchase offering through Argos. But, clearly, the development was a significant articulation of market demand and, in terms of units sold rather than watts-peak, soon became the most popular PV module in the Kenyan market (van der Plas and Hankins 1998).

We would expect that, once the hire purchase option was demonstrated to be effective for generating business, the other companies would have introduced their own hire purchase schemes. But this was a difficult process to manage. Argos already had plenty of experience with other products and so was able to include the kits relatively easily. For the other companies in the PV market, this would have been a risky venture that would have required setting up hire purchase schemes, or some other form of credit facility, from nothing: no existing procedures and no prior experience. Therefore, while we can suppose that learning would have occurred about consumer-credit among other players in the market, and perhaps created a desire to imitate such a facility, we can see that this was not enough to stimulate its widespread diffusion. Significantly more information, knowledge and experience were necessary, not all of which were observable, before other actors could adopt this approach. Moreover, the Kenyan economy went into a difficult period soon after this, causing Argos to close many of its outlets. It is reasonable to assume that, even if others were considering the introduction of hire purchase at this point, the difficulties were too complex and the economy too weak to risk such a move.

4.5 Broadcasting the news – disseminating knowledge beyond Kenya

This section focuses on dissemination of knowledge of the Kenya PV phenomenon beyond the actors directly involved in the market in Kenya. The first attempt at this is in Hankins (1987). It was his first book and covers renewable energy in Kenya in general. While there is a chapter on solar energy, there is only about half a page on the PV market specifically. In this, he could point to just a few hundred systems installed and so it would be difficult to persuade anyone that there actually was a phenomenon. Still, there are some other aspects of this first attempt to disseminate that might be important in terms of the development of a PV niche in Kenya. First, Hankins had to do the research. That meant travelling around Kenya to various projects and so he would have been able to network far more extensively than he had done before this. The book was paid for by USAID and, latterly, the Canadians. Hankins was building a reputation among some of the donors that would be helpful to him later.

4.5.1 Dissemination and recruitment

Hankins left Kenya towards the end of 1987 and returned to the US. He struggled to find a way back to Kenya but he was certainly trying to do so. Eventually, he went to do his MSc at Reading (the same as Rioba's) in 1989. For this, he went to Kenya to do his fieldwork in 1990. He then discovered that the market had flourished since he had left. He did a survey of a number of PV systems and wrote this up for his dissertation. The 'message' in this was 'picked up by the World Bank' (Interview, Hankins). This time, although it may still have been a modest phenomenon, Hankins had very detailed descriptions of the uses of PV systems in rural areas of Kenya, some of which were for 'productive uses'. He had also captured some of the local practices, good and bad.

Hankins did other research including a trip around eastern and southern Africa during which he met many involved in PV. He also did research for another book, this time funded by SELF. In late 1991 or early 1992 he teamed up with the NGO Kenya Environmental Non-Governmental Organizations (KENGO) in order to organise a regional workshop on PV, an idea that Hankins and Burris had conceived. He had put a proposal into the African Development Foundation (ADF) in the US (having been encouraged by a contact there who was ex-Peace Corps). Hankins invited many of the contacts he had made during his trip around eastern and southern Africa to attend the workshop.

The workshop was held in Nairobi during March 1992 and was attended by people from across East and Southern Africa, including some from the MOE in Kenya. (In fact, there was a broad selection of participants: private sector, NGOs, government, universities, donors, individuals.) The format of the workshop included formal presentations, training content, and practical work to install a PV system in a rural area (Meru, where Burris had been working). For Hankins, it was highly successful. He had two or three immediate possibilities for projects that came out of the workshop. In order to get the funding for these, he had to work through a legally registered organisation and so started Energy Alternatives Africa (EAA) with Daniel Kithokoi. Hankins also claims that this was the time when SolarNet was started, although it was an unofficial organisation at this point and had no funding. One of the projects was to set up a solar training centre at Karagwe Development Association (KARADEA), located in the north-west of Tanzania (an area that is very difficult to access). KARADEA was being run by Oswald Kasaizi, who had attended the Nairobi training and discussed the project idea with Hankins.

The KARADEA project proposal was developed during a visit by Burris and his wife late in 1992. Hankins did not attend at this time. However, this was also when the Global Environment Facility (GEF) was about to start its PV project in Zimbabwe and Burris was appointed chief technical advisor to that. He was, therefore, unable to pursue the KARADEA project and Peter de Groot of the Commonwealth Science Council brought Hankins in instead. Kasaizi and Hankins then put the proposal together for what became the KARADEA Solar Training Facility (KSTF), which the Commonwealth Science Council (CSC) funded. It involved a building that included a classroom, PV equipment and other facilities for training PV technicians.

Hankins also wrote a textbook on PV design and installation and got this published in 1991. He then updated it and published in 1995. These were used in the training courses run at KSTF and elsewhere, thereby becoming important for institutionalising best-practice for PV design and installation. He also wrote a book in 1993, funded by Solar Electric Light Fund (SELF), covering four country case studies (see Hankins 1993), and teamed up with Mike Bess to write the Energy Sector Management Assistance Programme (ESMAP) paper (cited above: Hankins and Bess 1994). These two, in particular, helped to articulate the Kenya PV phenomenon more widely than Kenya.

4.5.2 Socio-technical analysis of dissemination and recruitment

This was a highly active period for building networks and disseminating experiences. Hankins' primary immediate objective was 'to get published and to write a book' (Interview, Hankins). He used his experience of working on PV installations as a basis to further this objective. He formed something of a personal expectation or vision, where the goal was to get published and the means included writing about PV. His first opportunity to realise this came with the 1987 book on renewable energy in Kenya for which he had to conduct extensive research around the country. He included a short section in the book on the current state of the PV sector but this was a straightforward list of the numbers and types of systems installed in Kenya.

His research enabled him to network much more than he would have done prior to the book. The book covered most renewable energies and so could not treat any one of them too deeply. Even so, Hankins was able to learn a great deal about the extent of the PV sector in Kenya and to establish contacts in addition to those he already had through his work with Burris. Hankins had already formed a personal socio-technical expectation about PV in Kenya and now he was able to start refining this into a vision through the learning he was doing in his research. This learning would most likely have been of a first-order quality: the kinds of systems in operation and their locations; who was working with the technology; the extent and nature of successes and failures; and so on. Some of these details were included in the book but it was, for the most part, a catalogue of the state of renewable energy in Kenya. As such, it was a useful means for wider dissemination.

More significant, however, was Hankins' MSc dissertation. This was focused exclusively on PV in Kenya, and included considerable detail of both the supply and demand sides of the market. He documented how the supply chains were working and how people in rural areas were actually using the technology, sometimes for productive purposes but mainly to improve the immediate quality of their lives. He learned about some of the problems in the market, some of which were technical issues and some to do with user-practices. Here was an opportunity for him to persuade donors that there was a phenomenon worth encouraging, one that aligned with their institutional interests, but one that needed support and, therefore, it was an opportunity for Hankins to find work in Kenya.

In his 1987 book, Hankins had already started expressing a socio-technical expectation of PV in Kenya. Using his MSc dissertation (Hankins 1990) he was able to strengthen his 'bid' by referring to 'thousands of systems installed through a private market' rather than the 'hundreds' that were in place during the period of the research for his first book. This private sector phenomenon allowed him to connect with the increasingly dominant free-market paradigm that framed much of development thinking. He could point to the 'success' of the Kenyan PV market in diffusing an environmentally benign technology, which also supported development goals, while highlighting ways that it could be improved, in terms of scale and quality, through donor intervention. Whether these arguments, this socio-technical vision, formed the basis of his early proposals is not possible to say but he certainly framed his later descriptions in this way.

Hankins was certainly successful at attracting funding, and much of this enabled him to develop networks, both inside and outside Kenya, through which he could disseminate and develop a PV socio-technical vision. The money he received from the Canadians helped him to make contacts across east and southern Africa, many of whom participated in the Regional Workshop in Nairobi in 1992. That event was, of course, both a networking and learning opportunity for the participants but it was also during this time that Hankins was able to mobilise resources for projects in the region. In order to make use of these opportunities, he started EAA together with Daniel Kithokoi and their work helped the company to become the most important PV actor in the region.

One of those early projects was with KARADEA to help establish KSTF, the first specialised PV training centre in East Africa. The relationship between EAA and KSTF persisted for about ten years during which 175 PV technicians, mostly from East Africa, were trained at the facility (KSTF 2009). Over that period, at least five donors supported the work: CSC, Swedish International Development Cooperation Agency (Sida), Agency for Personal Service Overseas (APSO), Hivos, and Ashden Trust. This shows that network-building has been extensive through the KSTF project. The project also maintained a space in which the basic PV training course could be developed and refined. Indeed, the KSTF course was something of a model for other courses conducted later in the region and informed later national PV curriculum development (see section 4.7.3). So the KSTF collaboration was important for institutionalising PV practices in East Africa, developing networks, and collectivising PV socio-technical visions.

We can see that this period was important for network-building and dissemination. While these have continued, it appears that it was here that the dominant form of the Kenyan socio-technical vision of private sector led PV development was refined and collectivised. Hankins was influential throughout this process and has expressed this vision in his papers, books, proposals and reports, as well as in training courses and other networking events. It has been a persuasive vision because of the fact of the rapid growth of the Kenyan PV market. Hankins, and others who followed, have accentuated the private sector aspect of PV market growth in Kenya and downplayed any donor influence. The somewhat paradoxical effect of this has been to convince a wide range of donors to fund interventions and other activities. These resources facilitated the early network-building, dissemination and training that have been important for the learning, collectivising of visions and embedding of practices that helped to stimulate and sustain the growth of the PV market.

4.6 Articulating the market

This section investigates a number of product design and development and market research activities that occurred in Kenya from 1994. These activities can be categorised into two broad themes, product design and development, and market surveys. A third category, PV cell research and manufacture, has been the focus of activity in the Physics Department of the University of Nairobi. It has been largely disconnected from the local commercial sector while being networked with international academic research. There is little to say other than the core interest of this work is in 'wet cell' research, something that is not yet commercial, and does not seem to have had any appreciable impact on the Kenyan PV niche. The former two categories of activity have been conducted by commercial actors and have helped to articulate the Kenyan PV market in their own ways, in sometimes fine detail. Due to space constaints, the research and development activities investigated here do not constitute all those that have occurred in Kenya. Instead, they constitute a sample (see Table 4.1) that serves to highlight the co-evolutionary dynamics that SNM theory focuses on, as well as being of relevance to the development of the socio-technical niche.

Table 4.1: Activities analysed here

Activity or Project	**Years**
Product Design and Development	
Solar Lantern test marketing	1995 to 1996
Micro Solar	1996 to present
Jua Tosha battery	1997 to 1998
Battery Pack	1997 to 1999
BOS components	1999 to 2001
Market Surveys	
Survey of 410 SHSs	1996 to 1997
STEP (Solar Technician Evaluation Project)	2000 to 2001
Survey of East African PV markets	2002 to 2003

4.6.1 Controlled experiments

As we have seen, soon after EAA were formed they began to implement projects in the region. One of the earliest projects was conducted in Tanzania (the KARADEA Solar Training Facility) but, in 1995, they began a solar lantern project in Kenya and there followed a long period during which they managed many other PV-related projects in the country. This section describes four technology projects they implemented, but also includes some description of the activities of Leo Blyth, who came to Kenya from the UK searching for a way to disseminate, what were called at the time, micro-solar kits, a variant of PV product that has come to be called pico-solar.

It is clear that as early as 1990 Hankins was interested in the market possibilities of solar lanterns, although he considered them to be too expensive, too constrained in functionality, and difficult to repair locally (Hankins 1990: 80). Even so, he saw their potential to bring electrical services to a poorer segment of the population, and to do so as engineered systems rather than the *ad hoc* 'systems' that were becoming commonplace in the market[19] (Hankins 1996: 8-9). Through EAA, and funded by SELF, he had already worked in northern Tanzania to supply a few batches of lanterns (OSEP 1998; Byrne 1999: 13; Interview, Hankins; SELF[20] website). The Kenyan project, however, differed from the Tanzania experiment in that the lanterns were placed in a sample of rural shops rather than being supplied through an NGO. This was a more market-friendly approach than the first lantern project and marked the beginning of a method that EAA used in many subsequent projects.

From those already available on the market, six models of lantern were selected for test-marketing and a seventh, prototyped by EAA themselves, was added (Hankins 1996: 11). These were supplied to six dealers, five in rural areas around Mount Kenya and one in Nairobi (Hankins 1996: 14). EAA tested a sample of the lanterns in-house and later questioned 65 per cent of those who bought lanterns, as well as asking the dealers for their opinions. There was a range of findings related to technical issues, functionality, consumer practices and preferences, the impact of taxes on price, supplier needs, and some suggestions for ways to strengthen the marketing of lanterns.

The technical issues concerned the quality of the designs and how these might be improved. Functionality included recommendations for powering a radio as well as a light. Consumers were found to be conservative in their purchasing, especially the lower income groups. The best selling lantern had a shape similar to a pressure lamp. Middle-income groups tended to buy the lanterns first, lower-income groups were less likely to take risks, and consumers did not like the monochrome light of LEDs. Taxes were seen to add about 30 per cent to the price of lanterns because they were categorised as lamps rather than PV systems (PV modules were taxed at either 10 per cent or 0 per cent). The needs of suppliers included access to a small range of standardised spares, which was also seen as a way to overcome some of the risk-averse behaviour of customers who would not buy a lantern unless spares were available. Three marketing methods were suggested: (1)lanterns could be supplied in two stages, the customer would buy the lantern first, and then pay for it to be charged until the cost of the module had been collected, upon which the customer would then receive the module; or (2) a new product could be introduced that consisted of a battery and charge regulator combined into a single unit. The battery could then be recharged using a battery charging service and the customer could get access to electricity while saving to expand their 'system' to include a PV module and better lamps later; or (3) hire purchase or other financing schemes could be used to help customers buy solar lanterns (Hankins 1996: 31-36).

EAA managed to secure funding for projects to pursue two product ideas they had suggested in the solar lantern report. One of these was for a small locally manufactured 'solar' battery, or 'Jua Tosha' as it became known. The other was for a 'BatPack', the battery and charge regulator unit mentioned above (Hankins 1996: 36). Both projects got underway in 1997. For the BatPack, Ashden Trust funded

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[19] These 'systems' consisted of low quality PV components bought piecemeal and connected together without any design considerations.

[20] http://self.org/archive-tanzania/

EAA and ApproTEC to develop a prototype and this was ready in 1998 (EAA 2001: 5). The Jua Tosha project, supported by ESMAP, began in June 1997 and the first of a total of 800 batteries manufactured by AIBM were being shipped to up-country retailers by November (Ochieng *et al*. 1999: 9). Production of the BatPack, this second phase of the project being funded by ESMAP, did not get underway until April 1999, and test-marketing started in November (EAA 2001: 13).

The Jua Tosha project was largely successful. The battery was well received by the market and dealers, who had not considered a 20 Ah battery[21] necessary, now wanted to see continued production (Ochieng *et al*. 1999: 27). By the time of the report (August 1999) more than 200 units per month were being sold (Ochieng *et al*. 1999: 2). Also, one of the other battery manufacturers, ABM, who had first introduced a 50 Ah solar battery in 1985, started production of a 40 Ah solar battery[22] (Ochieng *et al*. 1999: 27; EAA 2001: 4).

The BatPack project was considered unsuccessful in terms of its original objectives (EAA 2001). The product was unattractive to its target market, few units were sold, and there were unresolved technical problems with the charge control unit. Eventually, EAA decided to import a similar product, the Sundaya Battery Pack from Indonesia, and test-marketed this instead, beginning January 2000 (EAA 2001: 8, 14). Apart from the technical problems with the Rodson controller, it was discovered that an investment of around USD 15,000 for a mould would be required if the BatPack casing were to be made from plastic, a large risk for a small Kenyan company considering that thousands of units would have to be sold to recoup the investment (EAA 2001: 8, n6).

While the BatPack report states the project was unsuccessful, other aspects were highlighted in an effort to suggest that the project achieved some positive outcomes. One of these outcomes was an identified demand for this type of product, albeit among a higher income group than anticipated and for a higher specification unit than the one tested, unless the price could be reduced sufficiently. Evidence to support this claim included the observation that other suppliers, who were not involved in the project, began sourcing similar but higher-specification products from outside Kenya (EAA 2001). Another success claimed in the report was that Rodson, who had designed the charge controller, were said to have introduced two new products to the market as a result of their involvement in the project, a charge controller and a battery monitor (EAA 2001). While it was probably fair to say the BatPack project inspired these product ideas, the work to design and develop the products appears to have been through a project funded by MESP and begun about September 1999 (Osawa 2000). Osawa (Interview) remembers that there was a period during the early 2000s, up to about 2006, when local manufacture of BOS components was very successful. Indeed, World Bank (2001: 2) report that Rodson were selling 'several hundred' battery monitors and charge controllers per month. However, local manufacturing of BOS components has almost disappeared as a result of Chinese-made products coming into the Kenyan market (Interview, Osawa).

For all these projects, EAA used a similar methodology. They persuaded up-country dealers to stock the prototype in their shops, waited for a period and then questioned the dealers and customers about their experiences with the product. They also tested the product themselves, either in-house or with the help of an independent actor, to document the technical specification.

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[21] In practice, the battery was measured to have a 30 Ah capacity (Ochieng *et al* 1999: 22).

[22] World Bank (2001: 4, n5) state that the battery probably had a lower capacity than the manufacturer claimed.

However, in the BOS components project they introduced a new aspect by including focus groups with consumers and, separately, with dealers before the prototypes[23] were manufactured. The results of these focus groups informed the choices of which products to manufacture and refinements to the designs of those chosen. The BOS project had initially proposed six product concepts and the two that appeared to meet the most immediate market demand, battery monitor and charge controller, were the ones developed by Rodson (Osawa 2000).

A number of technical and functional issues were raised during the consultation and test phases of the product development (Osawa 2000). One, Rodson were requested to reduce the value considered a full battery charge so that the full indicator would be illuminated for longer, providing a 'better' customer experience. Two, Rodson were requested to lower the value set for the low voltage disconnect so as to provide electrical services for longer. Three, Rodson were asked to introduce a reset button that would allow a few minutes of electricity supply once the low voltage disconnect had activated, giving the user light while they set up a kerosene lantern, for example. And, four, the charge controller was modified after it was discovered that it could not cope properly with inductive loads such as fluorescent lamps.

Another important feature of the way in which EAA worked throughout these projects was the extent of their networking. Between the four projects discussed here, they interacted with at least 39 different dealers and suppliers in 16 cities, towns and villages around Kenya, and at least five of the dealers were involved in more than one project (Hankins 1996: 14; Ochieng *et al*. 1999: Osawa 2000; EAA 2001: 31). These numbers do not include the manufacturers, donors and other organisations with whom EAA worked: Automotiv and Indusrial Battery Manufacturers (AIBM), Chloride Exide and Rodson; ESMAP, Ashden Trust and Micro-Enterprises Support Programme (MESP) and ApproTEC, Intermediate Technology Developmnet Group (ITDG), SolarNet and the University of Nairobi Physics Department.

Finally, it is interesting to say something about the activities of Leo Blyth. After his first visit to Kenya in 1996, Blyth spent a number of years moving back and forth between Kenya and the UK, trying to disseminate Do-it-yourself (DIY) Solar[24] kits when in Kenya, and finish a development studies degree in the UK. His dissemination efforts included training people to make the solar kits, conducting dozens of such courses in Kenya and other countries in the region, and with various groups including Trans World Radio, SolarNet and the Peace Corps (Interview, Blyth). One such course was conducted in the Nairobi slum Kibera in June 2004 (Keane 2005: 7) and it may have been here that Fred Migai, who has so far been the only Kenyan to try to commercialise the idea (Interview, Blyth), learned to assemble the kits.

However, Blyth himself tried to commercialise a product idea around 2002 with funding from the Shell Foundation, developing the idea out of his experiences in the region with these 'pico-solar' kits and other products he had seen. He had also shown a few of the Chinese pico-solar products that appeared on the local market to Hankins who liked the ideas but was concerned about the quality (Interview, Blyth). For the Shell Foundation project, he worked with EAA and used the BOS project methodology as a template. Following focus groups with consumers, a product to charge a mobile phone and power

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[23] The information provided to the focus groups was in the form of pictures of the product concepts, and proposed functional and technical specifications (Osawa 2000).

[24] DIY Solar was an idea developed by Graham Knight in Ashford, Kent in the UK. He made use of 'discarded' amorphous PV modules from Intersolar, which he cut into smaller pieces and fixed wires directly to the back in order to power devices such as radios (Interview, Blyth).

a radio was chosen and the project was to get 1000 units manufactured in China. However, the manufacturer 'ate the money' and the project collapsed (Interview, Blyth). Migai went on to assemble a simple kit that could charge a mobile phone and power a radio, although it had no charge controller or battery, and to sell the kits up-country himself and through a network of agents (Interview, Migai). Before he learned how to assemble the pico-solar kits, Migai had been a marketing agent for Swiss Guard, selling a healthcare product in Kenya through a pyramid marketing scheme (Interview, Blyth). It appears that the methods he uses to sell the pico-solar kits were similar to those he practised while working for Swiss Guard, and he claimed to be selling around 100 solar kits per month (Interview, Migai).

While Blyth continued for some time to try to commercialise pico-solar products in Kenya, he later considered local manufacture to be the wrong direction. It takes large amounts of investment and needs large volumes to be viable, otherwise the transaction costs are too high (Interview, Blyth). Indeed, Osawa (Interview) came to the same conclusion regarding manufacture in Kenya. It is interesting to note that no actors, other than Blyth and Migai, were interested in pico-solar products at the time. Indeed, apart from Hankins' general interest, many were deeply sceptical.

4.6.2 Market surveys

There have been several surveys of the Kenyan PV market and, as we would expect, they have served to articulate and codify many aspects of it. We have already considered two of these in relation to the dissemination of the PV phenomenon in Kenya. Both of these were conducted by Hankins (1987; 1990). The 1987 survey was more of a cataloguing project, while the 1990 survey investigated some of the detail of the demand and supply sides of the market. Since then, there have been perhaps eight surveys that have focused on the PV niche in Kenya. Numerous other studies have been conducted but they have either incorporated PV into a larger survey or they have not been surveys. Of the eight that are focused on the PV niche, one is unavailable[25] (Musinga *et al*. 1997). Consequently, the discussion here is based on the other seven surveys: Hankins and Bess (1994), Acker and Kammen (1996), Hankins *et al*. (1997), Jacobson (2002a; 2002b; 2004) and ESD (2003).

The Acker and Kammen survey was conducted in July and August of 1994 and included, among other aspects, interviews with 40 owners of PV systems sized between 10 Wp and 100 Wp (Acker and Kammen 1996: 93). It asked similar questions to Hankins' 1990 research and found similar benefits and problems. In this sense, it supported Hankins' work and further elaborated his initial articulation of the market. It asked questions such as, who was buying systems, what kinds of systems were being used, how they were being used, how consumers learned of PV, consumer expenditures, performance of systems, typical benefits and problems, and (an addition to the information gained by Hankins) the distance to the grid.

Some of the more surprising findings of the survey included the discovery that PV systems were being bought by people who could not be considered affluent, and some appeared to have struggled to acquire their systems (Acker and Kammen 1996: 95):

> Many of the households whose annual incomes are less than the survey average of US$2800 are spending over 75 per cent of their income for their systems, with some homes spending almost 200 per cent.

[25] In fact, this Musinga *et al*. (1997) survey of 1000 households may not be focussed on the PV niche; it may have focussed on non-PV households.

Indeed, a visual inspection of one of the graphs in the document suggests that up to a quarter of the systems investigated in the survey were bought by people who had an annual income of less than USD 1000, and a few of these systems cost more than USD 1000 (Acker and Kammen 1996: 96, Figure 23). The understanding up to this point was that reasonably well paid consumers, or cash crop farmers and other business people, were buying systems (Hankins 1990: 3; Hankins and Bess 1994). Another interesting finding was that a quarter of the systems were in homes within 1 km of the grid, in partial support of an estimate of 40 per cent given in Hankins and Bess (1994: 5, cited in Acker and Kammen 1996: 96), even though the 'break-even distance beyond which PV would be cheaper' was estimated to be 8.8 km, and that one of the systems was in a home actually connected to the grid (Acker and Kammen 1996: 96).

One of the questions not asked was whether, and how much, savings were sustained as a result of using PV systems. The next survey of household systems investigated this question, along with many of the same dimensions addressed by the Acker and Kammen study. The survey, funded by ESMAP, was conducted through EAA from December 1996 to March 1997 and covered 410 household systems in 12 districts across Kenya (Hankins *et al*. 1997: 2). It formed the basis of an *Energy Policy* paper written by Robert van der Plas of the World Bank and Mark Hankins (van der Plas and Hankins 1998). The savings the survey found were most significant for smaller systems and, overall, the majority of savings were on kerosene and dry cells, equally shared (Hankins *et al*. 1997: 37-38). The significance of the savings enjoyed by those with smaller systems was heightened because there appeared to be a trend in the market toward smaller systems, already indicated to some extent in the Acker and Kammen study (Acker and Kammen 1996: 97, Figure 26), facilitated by the availability of 12 Wp amorphous modules. The average savings were about USD 10 per month and, for those with systems smaller than 15 Wp, USD 8.55 (mostly on dry cells but also on kerosene and battery charging) (Hankins *et al*. 1997: 36-38).

Other than these findings, the survey was generally in line with the findings of the previous studies but, of course, the number of systems investigated made it an important articulation of the market. And this enabled Hankins *et al*. to present detailed recommendations assigned to all types of actors with an interest in the market: government, donors, industry, financial institutions, NGOs, and research organisations (Hankins *et al*. 1997: 47-53). There were also recommendations made from the Acker and Kammen survey. The Hankins *et al.* study overlapped with these in a number of ways: the need for supportive policy, both national and international; the need for capacity building; that finance schemes should be introduced; standards and codes of practice should be developed to overcome the quality problems; there was a need for better and impartial information; and, there should be smaller engineered systems, such as solar lanterns, and more modular provision of system components in the market (Acker and Kammen 1996: 105-108; Hankins *et al*. 1997: 47-53). It is interesting to note that the Hankins *et al.* recommendations made a point of insisting that subsidies were not to be used to promote PV (Hankins *et al*. 1997: 48) saying, ''Project' (public sector) funds should be channeled in ways which will grow the market, without subsidizing systems or Government institutions'.

This was in line with the report's general assessment of the PV market in Kenya being a private sector phenomenon. In the introduction to the report, it states that there had been an 'absence of Government, finance or donor support, or any project intervention effort' in the Kenyan PV market. It acknowledged only that '[s]everal independent volunteer initiatives were instrumental in catalyzing the existing market, but these were neither expensive nor large scale' (Hankins et al 1997: 9, n2). This is interesting because there were later changes to this position, at least on the part of ESD who began talking of 'smart subsidies' (ESD 2003).

Jacobson, with the help of others and working through EAA/ESD, conducted a number of surveys between 2000 and 2004 (sample size in brackets): Solar Technicians (366); Solar Vendors (312); Solar

Households (76); and Energy Allocation (15 households) (Jacobson 2004: 302-309). For the solar technician (Solar Technician Evaluation Project (STEP)) and vendor surveys, Jacobson employed two local technicians to conduct the majority of the field work: Maina Mumbi and Henry Watitwa (Jacobson 2002a: 7). For the household study, Jacobson employed the same two technicians to conduct many of the interviews (Jacobson 2004: 304). The energy allocation survey involved using data logging equipment to measure appliance use over a period of four to six months for each system, and was supplemented with ethnographic observations (Jacobson 2004: 306-307).

The technician and vendor surveys were important because they characterised the supply side of the market more thoroughly than had been achieved up to that time. The main findings from the technician survey were that most technicians (90 per cent) operating in the PV market were not solar specialists, and only 5 per cent of solar technicians had regular employment in PV services (Jacobson 2002a: 9, 11). Similarly, the vendor survey discovered that only 5 per cent of shops stocking PV equipment were specialists, and 41 per cent were hire purchase shops (Jacobson 2002b: 31).

The most important conclusion that Jacobson drew from these findings was that PV training courses needed to be re-designed to be shorter, delivered in up-country locations, and targeted to the needs of non-specialists who were, nonetheless, working in the PV market (Jacobson 2002a: 8). This was a departure from the form in which EAA had been conducting their training courses for many years, developed from the three-schools project in 1985 and the work at KSTF since 1993. Whether it was a result of the study or not, the training courses supported through the Photovoltaic Market Transformation Initiative[26] (PVMTI) from 2006 seem to be arranged according to Jacobson's recommendations to some extent, particularly the delivery of courses up-country and the targeting of non-specialists (Interview, Nyaga; PVMTI 2009). And an interesting impact of having employed two local technicians to conduct the majority of the interviews was that their interactions with so many other technicians stimulated discussions of forming their own association, Kenya Solar Technician Association (KESTA) (Interview, Watitwa). Although KESTA was officially registered in 2005 (SolarNet 2005: 28), it did not attract funding or manage to collect subscription fees and so has been unable to achieve much for technicians (Interview, Watitwa).

The two other surveys conducted by Jacobson during 2003 and 2004 provided insights into the dynamics of electricity-use within the household. Although the sample was very small in the energy allocation survey, just 15 systems, the detailed information of appliance use, combined with observational material and interviews, provided evidence of a more complex reality of electricity consumption patterns in the home than was previously available. It was assumed that electric light benefited women and children, reducing their exposure to kerosene fumes in the kitchen and improving conditions for studying at home. Or, at least, this was the rhetoric within the development regime in regard to connections between electricity and development. Jacobson's survey discovered that this was not necessarily the case, particularly in households with small systems. He found that TV dominated electricity consumption in homes that had a small system (less than 25 Wp), using 54 per cent of the energy available, and that the kitchen often had a low priority when deciding where to install lights; while with larger systems the majority of energy consumption was for lights (61 per cent),

[26] PVMTI was an International Finance Corporation project that made USD 5 million available for finance in the Kenyan PV market, responding to a perceived finance barrier that was preventing the market from expanding. Beginning in 1998, it intended to lend to both suppliers and MFIs to help reduce the price of PV modules to consumers, thereby releasing pent-up demand and transforming the market. We analyse the PVMTI intervention, and more recent developments in micro-finance for PV, in a separate working paper "Financing sustainable energy for all: A socio-technical analysis of the pro-poor potential of new, pay as you go solar finance approaches in Kenya", available at http://steps-centre.org/project/low_carbon_development/

TV accounting for one third of consumption (Jacobson 2004: 204-232; Jacobson 2007: 153-155). It is unclear whether these findings have had any impact on the rhetoric around PV and development; it may be too soon to be able to notice any effect.

The most geographically wide ranging survey of the PV market to this point was conducted for the World Bank through ESD in 2003, covering seven countries in eastern Africa. One of the stated aims of the study was to be able to describe the development of PV markets in the region. The results showed quite different kinds of markets across the countries studied, with Kenya clearly the largest and most developed, described as 'mature' (ESD 2003). It updated some of the fundamental information about the market such as installed capacity, but also provided statistics on numbers of companies and technicians operating, described increasing complexity in the supply chains and marketing strategies, and gave figures for awareness of PV among the population. Above all, however, it gave a detailed and highly prescriptive set of recommendations on how to develop PV markets in the region including, for the first time, some support for the use of subsidies in PV promotion, argued on the basis that PV markets had been stimulated to grow rapidly in some of the industrialised countries through the use of subsidies (ESD 2003).

4.6.3 Socio-technical analysis of market articulation: controlled experiments

It is clear that the implementation of these various projects generated deep interactions between actors from different sectors and throughout the PV supply chain within Kenya. Further, the projects provided opportunities to learn a great deal about both the supply and demand sides of the PV market: about user practices and preferences; supply-side practices and assumptions; technical details of product concepts; and formal institutional constraints such as VAT and other taxes. We can also see that there was important system-building work being done by some actors, EAA being perhaps the most significant of these. Hankins, in particular, appears to have developed a proposal model that succeeded in aligning the interests of the development regime and the needs of actors within the Kenyan PV niche, while linking to others such as battery manufacturers and electronics specialists. By deploying a socio-technical vision in which PV diffusion could be achieved through the private sector, he was able to attract resources for experimentation that the private sector would have found too risky to provide, but from which it benefited significantly.

The learning generated by these experiments resulted in better articulation of the rural market in two senses: a clearer description of its characteristics, and a strengthening of interconnections between actors in the supply chain. In turn, this better articulation, in both its senses, helped to enhance and collectivise expectations of market demand. Equipped with a richer understanding, actors changed their behaviours and introduced new products to the market guided by finer-detailed socio-technical visions. This is not to say that the projects were either straightforward, consensual or positive in all their aspects. There were technical problems, negative outcomes and, at least where pico-solar products were concerned, the suggestion of dissensus.

Where technical problems were discovered, their solution was generally the result of first-order learning, for example, the modification to the Rodson charge controller so that it could cope with inductive loads (BOS components project), and the sourcing of a product similar to the battery pack when the Rodson control circuit could not be made to work (BatPack project). It was also through first-order learning that expectations were developed into visions, with more precise detail of various aspects such as consumer demand, consumer practices and preferences, willingness to pay, product functionality and quality, local manufacturing capacity, and the impact on price of taxes. This filling in of details was important for niche actors because it lowered the risk of investments for them. They had better information about the market and their role in it, enabling them to articulate business models.

In regard to negative outcomes, it is interesting to observe that these were a source of second-order learning. For example, the lack of demand for the battery packs challenged assumptions that shifted actors' expectations. The shift, in this case, was from targeting a poorer segment of the population to a wealthier one. At the same time, the challenge to assumptions generated a new understanding of the preferences of the poorer segment, that functionality and price are far more important than convenience. Blyth appeared to adjust his expectations about the means to achieve greater diffusion of pico-solar products based on what we might characterise as the negative outcomes of his experiences working with NGOs and the disappointing adoption rates for the solar kits he demonstrated.

However, unlike the private actors in the other projects we have discussed, it took a long time for Blyth to realise this shift in expectations. The explanation for his persistence could lie partly in his personal expectation that PV was 'not just another product' and therefore could 'win' on its own terms, and partly in the examples of two actors who did not see PV in this way. Instead, at least one of them. Migai, marketed pico-solar in a similar way to other small products and achieved some success. Here, Blyth was presented with an alternative vision, at least in terms of the means by which pico-solar technology diffusion could be realised, and it is one he appears to have assimilated. This suggests that second-order learning can occur as a result of positive outcomes as well as negative. In this case, it occurred through observation of the positive outcome for others, a kind of vicarious second-order learning. Indeed, we can see that something similar occurred with the Jua Tosha battery (the other battery manufacturer in Kenya, who was not involved with the project, introduced its own small solar battery soon after the project finished) and, in some ways, with the Batpack project (another supplier, again not involved with the project, sourced a similar product, even if this did not result in any market penetration).

Second-order learning opportunities may also have existed as a result of the dissensus over pico-solar products. It is not entirely clear from the evidence but we could reasonably argue that the paucity of experiments with pico-solar products, and the consequent lack of assumption-testing, was one source of this dissensus. There was some testing going on but it was not being documented or studied systematically. Chinese companies were trying various products in the market, and Migai was selling units through a network of individuals. The only project that would have provided some documented testing of assumptions was that funded by the Shell Foundation but, as with many projects that are considered failures, documentation is difficult to find and few actors want to discuss it. Nevertheless, the characteristics of pico-solar products appear to be aligned closely with practices and preferences among consumers in Kenya and so we might expect the products to be easily embedded in the market. Further, the movement in the market has been toward smaller systems, and much of the motivation for the projects described above has been to enhance the technical quality of such systems. Moreover, there is growing interest in the 'Bottom of the Pyramid' approach to development, and pico-solar appears well-aligned with this expectation.

Given these conditions, it is difficult to understand why the pico-solar 'market' did not attract much interest from the established PV actors in the region or from donors. On the contrary, many of the established PV actors held negative expectations about pico-solar and only a few actors held positive expectations and used these to guide their activities. These pico-solar 'promoters' were working almost entirely in the private sector with meagre resources and independently of each other. However, having said that, the International Finance Corporation's (IFC) Lighting Africa project that began operation in 2007 may be an indication that the situation is beginning to change, at least as far as lighting products are concerned (World Bank 2007). Blyth became a consultant to the Lighting Africa project (Personal communication, Blyth) and, as we will see in section 4.8.1, the pico-solar market expanded rapidly from 2009.

Finally, it is important to recognise that these projects involved many of the same actors, that there was a consistency or stability in the networks of actors. Certainly new actors joined and not all the actors participated in all the projects. Nevertheless, this relative stability facilitated the building of trust (this has been important for eliciting information for market surveys), and the accumulation of knowledge generated in the projects. Moreover, EAA has been a central actor in these activities, as well as in many other projects not considered here. This has been important for at least two reasons: one, it has enabled EAA to be a cosmopolitan actor in the local PV niche, in the sense used by Deuten (2003) or, what we are calling, an innovation system builder; and two, it has enabled the building of local capabilities at this cosmopolitan level.

We can see then that these projects were important for niche building in Kenya. They were initiated primarily to test technologies but generated significant effects beyond the first-order learning that SNM would expect of such technology-testing experiments, essential though this first-order learning is to creating the detail of visions. The projects also generated second-order learning for actors within and outside the project-networks and this resulted in shifted expectations and changes to behaviour. We cannot be certain that the learning and other effects would not have happened without the projects but we can see that the private sector would have considered such experimentation as risky. Donor-funding gave some protection against these risks and the experiments provided a means to test assumptions as well as technologies.

But the experiments also brought local actors together in a way that enabled rich interactions over many years, thereby facilitating the exchange of information, and the collectivising of expectations and visions. We also saw that EAA were central to much of the activity discussed here (indeed, they have been central to much activity not examined in this section) and this helped them to become an increasingly skilful cosmopolitan actor or innovation system builder. They identified project opportunities, attracted funding, managed projects and networks of actors, accumulated knowledge, and built local capabilities at the cosmopolitan level.

By contrast, the pico-solar experience was one in which the networks were fragmented, expectations were not widely collectivised, indeed, they were contested, and learning was, for the most part, individual rather than collective. Indeed, because learning was poorly articulated, it was difficult to form expectations that could have been collectivised. If expectations were collectivised then it may have increased the chances of attracting other actors and resources to experiments that could generate further learning.

4.6.4 Socio-technical analysis of market articulation: market surveys

As we might expect, the various market surveys provided a large amount of detailed information about both the demand and supply sides of the Kenyan PV market. In SNM terms, we can characterise this as being predominantly first-order learning, i.e. generating finer detail about what is already generally understood. However, it is important to recognise that the surveys occasionally generated information that challenged the assumptions of different actors, i.e. we can identify some second-order learning.

While the Hankins (1990) and Acker and Kammen (1996) surveys provided some useful information that helped to detail both supply and demand side practices, they were based on very small samples. The ESMAP-funded survey of 410 households was much more significant. That generated a great deal of first-order learning that enabled a much finer articulation of the market (in the descriptive sense), particularly the demand side. On the basis of this articulation, it was possible to express a persuasive socio-technical vision of PV in Kenya, the objective of rural-household demand for basic electrical services was being provided through the means of PV systems sold in a private market. Further, the observation that the market was moving to smaller systems suggested an extension to this vision or, in some ways, a new expectation. Access to electrical services could be deepened to include poorer groups among the population by introducing more 'pico-electricity' products into the market and providing finance packages 'to lower the initial cost' (Hankins *et al*. 1997: 52).

Indeed, EAA had already shown an interest in pico-electricity products, having test-marketed solar lanterns. Notwithstanding this experiment with the lanterns, the precise details of these pico-electricity products were not yet defined, neither were the details of the finance packages recommended in the survey report (Hankins *et al*. 1997: 3, 52). Both these aspects of the expectation were the focus of projects that got underway almost immediately. So quickly[27], in fact, that EAA had probably formed the expectation prior to the survey, making use of the results to help them collectivise it. The Jua Tosha and BatPack projects went some way to articulating the details of pico-electricity products, while the process of articulating finance packages was the focus of a project discussed in a companion working paper on consumer finance (see the discussion therein on an EAA-managed ESMAP project that experimented with several different approaches). This expectation persisted over time and was adopted, perhaps adapted in conjunction with experiences from elsewhere, by many actors in the development regime as well as in PV niches in Kenya and other developing countries. And we have seen the development regime fund projects that have served to articulate it (envision it, so to speak), while trying to realise its promise, particularly with regard to consumer credit as micro-finance has emerged as a favoured development tool.

However, Jacobson's research provided a refinement to this expectation, perhaps even a challenge to some aspects of it. His findings concerning intra-household energy allocations refined part of what had become a highly collectivised vision, the benefits in the household of PV-powered light compared to kerosene, especially for women and children. It is perhaps too early to assess whether this will cause any second-order quality change in expectations or visions among actors in the development regime or PV niches, but the dominance of this vision seems to be intact for now. Jacobson's other challenge was that extending credit would not extend access to PV-generated electrical services. As mentioned above, there is currently a great deal of interest in the use of micro-finance for extending services into the lives of poorer groups in developing countries and this continues to be tested together with PV systems. However, there are signs that this is changing. Hankins has begun to talk of 'smart subsidies', arguing that the PV markets have grown quickly in industrialised countries because of generous subsidies. And the GEF has introduced a form of smart subsidy into Tanzania Energy Development and Access Expansion Project (TEDAP), the most recent World Bank electrification project in Tanzania. We are not suggesting that this is because of Jacobson's research; merely that it may have been part of this move away from the rhetoric of 'pure' market forces.

The STEP survey also, to some extent, challenged an aspect of the dominant socio-technical vision of PV in Kenya. Although little work had been done to study solar technicians in the market, there was an assumption that they were earning a living by installing and maintaining systems. Jacobson challenged this by showing that the majority of technicians could only secure an occasional job in the PV sector and so it was just one of many sources of income. The survey also achieved three other things. One, it showed the extent of 'coverage' of technicians in the country and codified these findings. Two, by employing two solar technicians to administer the survey it helped to connect the technicians together in a way that had not been attempted previously. An interesting outcome of this was that the technicians created their own association, KESTA, as a way to promote their interests. In doing so, they created a channel for collectivising an expectation that may express their perspective within the

[27] The Jua Tosha and BatPack projects got underway in 1997, before the household survey report was finalised (Ochieng *et al*. 1999: 9; EAA 2001: 5). The finance project was already in a preparatory phase in December 1996, as the household survey was beginning (Hankins and van der Plas 2000: 25, Box 5-1).

Kenyan PV sector. So, the survey stimulated a network effect. Three, the STEP survey appears to have contributed to developing a different, but standardised, training package for technicians.

Perhaps the most interesting part of the ESD (2003) report, from our perspective, is that it makes a list of detailed recommendations that express an accumulation of knowledge gained by EAA and Energy for Sustainable Development (ESD) over the preceding decade. Moreover, the recommendations can be read altogether as a clear and finely articulated socio-technical vision of how PV-diffusion through eastern African markets can be successfully achieved.

The recommendations also indicate a slight departure from the more full-blooded free-market approach to PV-diffusion of the earlier reports. A notable addition here is the advocacy of smart subsidies, based on the argument that subsidies have been important for the growth of PV markets in industrialised countries. This certainly marks a change of assumptions and we could interpret this change as a vicarious second-order learning effect, as PV markets in industrialised countries provided the source of learning. But it may also reflect the shift in thinking within the development regime, the Post-Washington Consensus, and the 'rediscovery' of the role of government. Whether this was the case or not, a significant part of the explanation for the interest in subsidies may lie in the desire to raise quality in the PV market. In this sense, it recognises a market failure. The Kenyan PV market, applauded for being 'undistorted' by subsidies, has seen a downward spiralling of quality as competitive pressures have caused private actors to cut costs wherever possible. Smart subsidies are seen as a way to add value to better quality systems so that private actors are encouraged to eschew the race to the bottom.

Apart from this shift towards the use of subsidies, however, the document could be seen as a statement of the knowledge of the PV sector in Kenya that had been cultivated by a number of actors over the course of at least a decade, longer in the case of Hankins. It expresses a very clear vision of how to diffuse PV systems and because it came from ESD, a well-recognised cosmopolitan actor in the region at the time (now Camco Advisory Services) it carried authority and could be interpreted as the *dominant* socio-technical vision within the PV niche.

4.7 Policy regime interactions

By the end of the 1990s and beginning of the 2000s, PV niche actors began to interact more significantly with some in the Kenyan policy regime. The results of these interactions were mixed, not least because there was no uniform acceptance of PV amongst policy actors as a means to increase electricity access in rural areas. The following section discusses several of these interactions and reveals how, at this policy level, they generate much more obvious political conflicts than those at the niche level. We begin with the process of formulating PV standards which was the first of these more substantial interactions. This was followed soon after by a concerted effort to directly influence Kenya's second energy policy, which was published in 2004. Whilst there seems to have been some success in influencing this policy, more recent attempts have seen niche actors marginalised. But there has been more success in formulating PV regulations, at least in the minds of some in the PV niche. We discuss this process before finishing the section with a short consideration of the regime of taxes and import duties on PV in Kenya.

4.7.1 PV standards

For many years, the lack of standards for PV in Kenya was a recurrent issue, raised time and again during workshops, seminars, and in the writings about the market (Hankins 1990; Hankins 1993; Hankins and Bess 1994; Acker and Kammen 1996). The donor-funded installations, at least those such as the WHO-EPI systems, had their own standards but there were no Kenyan standards that could be applied in the private market. We have already discussed the attitudes to technical standards of some of the pioneers in the Kenyan PV market and some of the practices on both the supply and demand sides that emerged from the highly competitive environment of the late 1980s. Despite the many calls for technical standards that resulted from the recognition of these practices, it was not until the mid 1990s that there appears to have been any attempt to persuade the Kenya Bureau of Standards (KEBS) to do something about the issue. This initial attempt to get KEBS to formulate technical standards failed (Gisore 2002: 47), possibly because it was attempted only by a single actor (Interview, Loh). However, in 1998 KEBS 'revisited' the development of PV standards following 'increased demands from various quarters' (Gisore 2002: 47). It is not clear what this means but there was mounting evidence that there were serious problems with some of the products and practices in the PV market (Hankins 1990; Hankins and Bess 1994; Acker and Kammen 1996; Hankins *et al*. 1997), and there were international moves to develop PV standards (PVGAP 1996; PVGAP 1998).

In any case, KEBS decided to initiate a standards process for all the renewable energy technologies, starting with PV. This got underway officially on 28 April 1999 and consisted of a committee of about 12 invited stakeholders from the renewable energies sector in Kenya (Gisore 2002: 47-48; Interview, Loh). The process of writing the standards entailed, in essence, monthly meetings for which the committee members reviewed draft standards such as PVGAP, wrote outlines and discussed what should be included, what excluded and what needed work (Interview, Loh).

While this sounds like an essentially technocratic process, there is some evidence that it was not straightforward. Two extracts from a presentation given by Gisore, the KEBS representative on the committee, hint at the sometimes contentious deliberations that unfolded and why they were so:

> As an activity that touches on the social and economic aspects of stakeholders, agreements on the standards and codes of practice have been based on consensus. This has not been easy. Many times members have had to vigorously demonstrate the negative or positive effects which certain requirements in the standards or codes of practice will have on the subject matter. Many times consensus has not been reached in a single sitting, and this accounts for the fact that it has taken almost three years to have most of the standards get approval as Kenya standards.
> (Gisore 2002: 49):

And

> For those components manufactured locally, due considerations were given to ensure that the standards did not serve to push [their manufacturers] against the wall.
> Gisore (2002: 50):

Nevertheless, by the time Gisore gave this presentation in August 2002, much of the standards work for PV was complete, even if not everything had been formally agreed (Gisore 2002).

Sometime during the period 2001 to 2002, the committee members began to discuss the idea of forming an association. The argument was that it would be:

> … better that the association has its rules and governs itself before the Government comes in and puts its hand into saying all these things and getting licenses. Better a well-regulated industry …
> Loh (Interview)

Both KEBS and MOE were 'very keen' on the idea and the Kenya Renewable Energy Association (KEREA) was 'very quickly registered, in August 2002' (Interview, Loh). One of the first efforts of KEREA was to conduct a technical evaluation of the amorphous silicon modules on the market in Kenya.

The 'amorphous question' (Ochieng 1999: 19) was something of a refrain in Kenyan PV circles, and there had been a major study of the performance of the modules available on the local market, conducted in 1999 by EAA, Renewable and Appropriate Energy Laboratory (RAEL) at the University of California and STEP at Princeton University (Duke *et al*. 2000). That study found that one manufacturer's amorphous modules performed very poorly, and the company responded by improving its manufacturing process (Jacobson and Kammen 2005: 1). Despite this success, new low-quality brands of amorphous modules appeared on the market and so Arne Jacobson offered to conduct a fresh set of tests for KEREA (Interview, Loh; Jacobson and Kammen 2005: 1).

There was difficulty in agreeing the terms of this evaluation but, eventually, KEREA members agreed to the methodology, and a sample of modules were shipped to the US in 2004 where Jacobson and colleagues performed the tests over the period from September 2004 to March 2005 (Jacobson and Kammen 2005; Interview, Loh). Two brands of modules were found to be severely over-rated and so, in line with the terms of the evaluation, the importers of these agreed to remove them from the market (Jacobson and Kammen 2005; Interview, Loh). By February 2005, before the results of the module evaluation were ready, KEREA had a code of conduct in place (KEREA 2005). The efficacy of the code of conduct was, therefore, tested almost immediately. According to Loh (Interview), it was the peer pressure that KEREA members could bring to bear, based on the agreed code of conduct, that achieved the removal of the sub-standard modules from the market and 'many people were quite chuffed about it that we [KEREA] managed to do something like that … KEREA became something more credible'.

Despite the apparent success of this initial KEREA effort to remove over-rated modules from the market, there were recurring problems with poor quality products over subsequent years. Even though standards were in place, they were not successful in dealing with these quality issues. This was due partly to weak capacity at KEBS to test equipment (Interview, Mboa), poor product-quality information and many new products entering the market (one interviewee suggested that there has been dumping of products) for which standards did not necessarily exist. As well as the problems with poor quality products, there continued to be issues with over-selling by vendors and poor installation by technicians. The introduction of the capacity-building component in PVMTI was intended to deal with these issues (vendor and technician training, and information for consumers) but it appears that this was insufficient, even if PV actors considered it a step in the right direction. KEBS revisited the standards around 2008, about the same time as the recently-established Energy Regulatory Commission (ERC) (see the next section on energy policy) started to develop PV regulations. By this time, it seems that some PV actors were much more willing to support regulation (not just standards) because they were fearful that the PV market was being seriously undermined by the issue of poor quality products and practices. We pick this story up after the next section, which recounts the development of energy policy beginning in the early 2000s and from which the ERC was created.

4.7.2 <u>Energy policy proposals and politics</u>

Around the middle of 2001, the process of preparing a new energy policy began within the Ministry of Energy, and discussions were initiated involving various Government departments and representatives from parastatals (Interview, Theuri). Except in their individual capacity, no other energy-sector stakeholders were invited to participate at this point. However, there was at least some interaction between the Ministry and others in the renewable energies private sector. Daniel Theuri, the Acting Director of the Department for Renewable Energy, worked with both Mark Hankins and Bernard Osawa of EAA within the Intergovernmental Authority on Development (IGAD) Regional Household Energy Project, writing a handful of papers related to energy in Kenya (Theuri and Hankins 2000; Theuri and Osawa 2001; Osawa and Theuri 2001), possibly the first substantive and formal collaboration between the ministry and actors in the non-commercial renewable energy sector[28] in Kenya.

Soon after this official MOE process got underway, towards the end of 2001, EAA began talking with the UK Department for International Development (DFID) about the possibility of funding an energy policy discussion process. Early in 2002 DFID agreed to fund what became known as the Policy Dialogue and the first session took place on 21 May in Nairobi (Interview, Mutimba; Bess 2002: 1). Another five meetings took place that year: one each in June, August, September, October and December (Mutimba 2002a, b, and c: page 1 in each case).

The MOE policy was 'already taking shape' by December 2001 (Interview, Theuri) but sometime in 2002 the UN Development Programme (UNDP) Country Office was asked to support the process (UNEP 2006). Theuri (Interview) states that the draft policy was ready by April 2004 but Mutimba (Interview) claims that the Policy Dialogue had managed to get hold of a copy of the draft during 2003, following which they drafted an alternative policy and submitted this to the MOE by the end of the year. Whatever the precise details of the drafting timeline, during which there seems to have been some tension and politics between the Policy Dialogue and the MOE processes (Interview, Mutimba), a Sessional Paper was indeed passed towards the end of 2004. However, it took another two years before this became the Energy Act.

During those two years, there were more 'cat and mouse games' between the MOE, Parliamentarians and the Policy Dialogue (represented by ESD[29]), as well as interventions by the 'traditional' energy actors such as the utility and those in the petroleum sector (Interview, Mutimba; Interview, Otieno). In terms of the MOE-Policy Dialogue interactions, one account has it that the MOE 'took the [Policy Dialogue] document and oppressed it a bit' (Interview, Mutimba), but used much of it as the official energy policy, while another account claims that the influence of the Policy Dialogue was only really on the charcoal policy (Interview, Theuri). It is not possible to verify either of these accounts but we do have detailed information from Otieno (Interview) on how the MOE attempted to have its version of the policy endorsed by the parliamentary committee on energy. For reasons that are unclear, Otieno and Mutimba were present as observers[30] at this meeting. According to Otieno, he and Mutimba realised that the policy the MOE was presenting had 'everything to do with renewable energy extracted', and informed the committee of this. There then ensued the 'cat and mouse games' between the Ministry, the Committee and ESD. In essence, the parliamentarians insisted that the MOE reinstate the renewables passages, having been briefed by ESD and German Organisation for Technical Cooperation (GTZ) about the details. Eventually, partly because of the MOE's 'fear' of the parliamentarians[31] (Interview, Mutimba), a compromise was reached whereby the renewables components were, at least, strengthened again (Interview, Otieno). As a result of this experience, Otieno 'realised that the parliamentarians have a critical role in formulating policy and have an upper say when it comes to the ministry'. In response to requests from the parliamentarians, GTZ supported

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[28] There were interactions of some kind before this but they were mainly at seminars and workshops such as the 1992 Regional Training and Awareness Workshop (Kimani 1992).

[29] EAA became connected with ESD, a company in the UK, starting around 1998 and changed its name to ESD sometime in the early 2000s. This then became ESDA sometime later and, around 2007, Camco Advisory Services.

[30] Otieno was invited by the committee to observe (Interview, Otieno).

[31] It is not just fear, of course. The parliamentarians have institutional power to accept or reject policy (Interview, Otieno).

the forming of a network, the Parliamentary Network on Renewable Energy and Climate Chang, in which ESDA and others conducted seminars for the parliamentarians on renewable energies (Interview, Otieno).

The Energy Act of 2006 is not specific about the nature of the various intentions it states for renewables but there were practical implications, including a very large project to install PV systems in schools and health centres (Interview, Onyango). However, the initiation of this Institutional PV Systems Programme was not due to the Energy Act, it actually began before the Sessional Paper on Energy received assent in Parliament, which was a result, it seems, of presidential pressure following an electoral promise to electrify North Eastern Province (Interview, Mutimba). According to Mutimba, the MOE decided to go with PV to electrify schools despite a long-standing resistance within the Ministry to renewable energies because there was no other way to realise quickly the promises that the President had made during his election campaign. Onyango (Interview) tells this slightly differently, claiming that the Permanent Secretary (PS) of the MOE was 'the champion' within the Ministry for the Institutional PV Systems Programme. Judging by the views expressed during interviews with some of the actors in Kenya, the former appears to be more likely. The PS was apparently well known for his objections to renewable energies and is said to have expressed his views publicly (Interview, Mutimba; Interview, Otieno).

Whatever the origins and motivations, the MOE started the programme with some pilot installations in one school (Interview, Onyango). There were technical problems with the system, but these were fixed after the MOE employed a long-standing PV engineer, Kiremu Magambo, to consult on the project. Magambo also ran training sessions on PV systems for others in the MOE in preparation for the expansion of the programme (Interview, Onyango). The money to be spent by the Government on the programme was a significant injection into the PV sector. Up to the end of financial year 2006/7 the expected spend would be almost KES257 million (USD3.7 million approximately, using KES70 = USD1). For the next two years, the budgeted spend was to be KES335 million (USD4.8 million). Altogether, this would add about 514 kWp to the installed capacity in Kenya (Mbithi 2007: slides 12-18, and own calculations). These are additions of the order of 20 per cent to 40 per cent of the value of the household market at the time (Interview, Mutimba; Interview, Onyango; own calculations). Indeed, this appeared to mark the beginning of what might be a more supportive policy environment for renewables in general, as evidenced by the budgets for energy reported in ROK (2007).

Table 4.2: Expected output and outcome for the energy sector to 2010 (KES 1000s)

	Estimate			Projected Estimates					
Programme	2007/08			2008/09			2009/10		
	KES (billion)	USD[a] (million)	%	KES (billion)	USD[a] (million)	%	KES (billion)	USD[a] (million)	%
Energy sector recovery	6.29	89.80	35.72	3.22	46.02	22.30	3.22	45.94	22.36
Energy efficiency	0.04	0.51	0.20	0.04	0.51	0.25	0.04	0.51	0.25
Rural electrification	5.74	81.97	32.61	5.74	81.97	39.71	5.22	74.62	36.31

Renewable development	3.47	49.54	19.71	3.97	56.78	27.51	4.48	63.96	31.13
Fossil fuel development	2.07	29.56	11.76	1.48	21.13	10.24	1.43	20.45	9.95
SUB TOTAL	17.60	251.38	100.00	14.45	206.41	100.00	14.38	205.49	100.00

Source: Adapted from ROK (2007: 26, Table 4-0-0) (Calculated using KES 70 = USD 1)

However, there were mixed feelings about the Institutional PV Systems Programme. While it was being welcomed as a positive move in general, there was some indication that it had raised the price of PV to the consumer and there were suspicions of corruption within the procurement process (Interview, Mutimba). There were also some issues over who could win contracts, despite an aim to include local technicians and companies in the work (Interview, Onyango). In order to get a contract, a tendering company needed to have a 'secure' financial base and this limited participation to a handful of large companies (Interview, Rioba). Still, the programme continued and, according to MOE (2013: 59), 945 institutions, including primary and secondary schools, dispensaries, health and administrative centres, had PV systems installed by the end of 2012.

A further institutional development created by the Energy Act was the establishment of the Energy Regulatory Commission (ERC). This had the mandate to regulate production, distribution, supply and use of renewable and other forms of energy. Under this mandate, it began the process of developing PV regulations, in consultation with the KEBS sub-committee on PV and wind. As with the standards process that preceded it, there were occasional tensions between different actors on the committee over the stringency of the regulations. For example, Mboa (Interview), who was now managing the KEBS committee following the secondment of Gisore to the African Regional Standards Organisation, describes the discussions over warranty periods for various PV[32] components. The Government and consumer representatives on the KEBS committee wanted lengthy warranties but the private sector representatives were unhappy with this, claiming that it could put them out of business. For some of the components, the private sector actors claimed, the warranties demanded in the draft regulations exceeded those given by the manufacturers of those components. Eventually, the chair of the committee Kiremu Magambo offered a compromise that was acceptable and the regulations were eventually gazetted in late 2012. Before discussing some of the other details of these regulations, it is worth noting recent developments in energy policy.

Following the new constitution in Kenya, enacted in 2010, and a confluence of other factors, there was a need to formulate an updated energy policy. Perhaps chief amongst these other factors is pressure to promote much faster economic growth (Kenya has a goal of becoming a middle-income country by 2030), which is being hampered by a combination of high prices and unreliable supply of grid-based electricity (Newell *et al*. 2014). Of less concern to some in the Kenyan Government is the need to promote development that is climate-compatible but there are those who see opportunities in steering Kenya along such a pathway and, in many ways, renewable energy based electricity generation could help deal with the problems of high prices and unreliable supply. Furthermore, many donors, who have some influence over Kenyan energy policy, have been pressing a low carbon development agenda. This agenda has started to pique interest in the Finance Ministry, mainly because of the possible flow of significant resources from climate finance.

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[32] The components listed in the regulations are (with warranty periods): charge controllers and regulators (10 years), inverters (10 years), batteries (1 year), light bulbs and LEDs (1 year), panels (20 years), and light fittings and devices (2 years) (ERC 2012: 18).

In alignment with these drivers, the Kenyan Government began to introduce feed-in tariffs (FITs) in 2008 for a range of renewable energy technologies. Solar did not feature in the early days of the FIT but does so in later iterations, including in the latest update from December 2012. However, the smallest off-grid PV installation project eligible for the FIT subsidy is 500 kW, much larger than any SHS found in Kenya (MOE 2012: 16). So there appears to be a continuing lack of interest from the Kenyan Government in regard to SHSs. This is underscored by the brief (three-page) entry PV has in the latest draft of the new energy policy (MOE 2013: 58-61), an entry that also includes reference to solar water heaters. Whilst there is acknowledgement in the policy that Kenya has one of the most successful off-grid SHS markets in the developing world, there are only vague goals for promoting the systems further. The most specific intentions for PV relate to the institutional programme discussed above and to the conversion of a number of large remote diesel installations to diesel-PV hybrid systems.

It is likely that the form of this new energy policy reflects the continuing exclusion of actors from the small-scale PV sector. According to Newell *et al*. (2014), no such actors were invited to consultations during the drafting of the policy and attempts by KEREA to provide inputs to the process were ignored. Furthermore it seems the former PS of the MOE[33] continues to wield power over the energy sector and it is alleged that he intervened actively to undermine any support for PV. He is said to have ensured the FIT, for example, was set low for solar so as to make it unattractive for investors. It is not yet clear whether the new PS has a more favourable view of PV but it is clear that some renewable energy technologies are seen as attractive. Most notably, geothermal is stimulating enormous interest from many in the energy sector, Government, private sector actors and donors. Amongst the private sector actors are large businesses from a range of sectors including manufacturing. They are, of course, interested in low electricity prices and reliable grid-supply. For them, geothermal offers the possibility of meeting their needs at scale. Donors appear to be interested because geothermal is low carbon and so aligns with their climate compatible development agenda. The Government appears to be interested because geothermal could provide a way to relieve pressure from the powerful manufacturing lobby (on prices and grid-reliability) and from grid-connected consumers. And the large capacity increases that geothermal could realise would underpin the increased economic growth that Kenya needs in order to achieve its goal of becoming a middle-income country.

Although recent policy in favour of low carbon development in Kenya might have been expected to benefit the promotion of SHSs and SPLs, it is clear that the Government has prioritised least-cost economic growth over other development aims such as energy access. Any aspirations for increasing energy access in off-grid areas seem to be resting on a hope that the small-scale PV sector will continue to operate as a private market for which Government simply sets the rules that the regulator enforces. There has certainly been an increased effort to regulate the PV market in recent years as we shall see in the next section. However, there are also dangers in assuming that the market can be successfully regulated even though many of the actors involved are now relatively enthusiastic about this approach. As we shall see, the standards and regulatory infrastructure in Kenya are lagging behind the development of the market in both capabilities and capacity.

4.7.3 PV regulations

As discussed above, the ERC was established in 2006 and subsequently mandated to develop regulations for the PV sector. The Kenyan PV market was suffering persistent problems with poor quality products, and the quality of installations and after-sales service were also low. Although there were PV standards in place, they were not being enforced. Altogether, these quality issues were perceived by the bigger players in the Kenyan market as a problem for them and for the market as a

[33] The Ministry of Energy has recently been renamed the Ministry of Energy and Petroleum.

whole. As a result, they urged the Government to introduce regulations (Interview, Mabonga). The regulations were developed in consultation with PV actors, particularly using the PV standards sub-committee managed by KEBS, and they eventually came into force in September 2012.

Amongst its many regulations, there are requirements for all those involved in some way in PV to be licensed. These include manufacturers, importers, suppliers, vendors, contractors and technicians (ERC 2012). Various classes of license cover these different groups but they all require renewal annually along with, in most cases, payment of a fee. In the case of technicians, for example, there are three levels of competence recognised, T1 (basic), T2 (intermediate) and T3 (advanced). T1 technicians, it appears, do not need to pay for a license but they must have achieved a minimum level of approved training and two years of PV installation experience. Indeed all classes of technician are required to meet approved training and experience criteria. However, T2 and T3 technicians have to pay KES2500 and KES3750 respectively, covering application and first license. Renewal then costs KES750 and KES1000 respectively each year. Considering the numbers of technicians and vendors already active in the PV sector across Kenya, and that it is an offense under the regulations to carry out these activities without a license, there is the potential for an enormous administrative burden on the ERC (the licensing authority) at the very least. And yet the Renewable Energy Department has only four or five staff (Interview, Mboa). The register of licensed technicians as of January 2014 had just 37 names (ERC 2014a) and the contractors register (which includes all other categories) had just three (ERC 2014b).

The requirement for approved training has meant the need to develop a nationally-recognised PV syllabus for the three classes of technician. Initiated by KEREA (Interview, Anonymous), and supported by UNDP, this process got underway in July 2012 with a five-day workshop to begin developing the curricula. A range of actors were present at the workshop where the details of the syllabus and tests for each of the classes of technician were discussed and drafted (KEREA 2012). Jomo Kenyatta University of Agriculture and Technology (JKUAT) led the subsequent development of the curricula, in collaboration with ERC, and funded by the Japanese International Cooperation Agency (JICA) (Interview, Mabonga). Chloride Exide, a battery manufacturer and one of the largest PV distributors in Kenya, was asked to assist with research into appropriate PV system components and to provide sizing of a range of systems as well as to install them at various field locations. The research, syllabus content development, sizing and installations were done in the period up to November 2012. After this, Paul Mabonga of Chloride Exide visited the installations to conduct monitoring of the systems up until February 2013. From March 2013, the curricula were ready to be sold to colleges in Kenya.

The syllabus provides for a one-month course module to be incorporated into a standard electrical technician training course, and was piloted with a group of 100 technicians before offering it for purchase (Interview, Mabonga). Fees for the training are expected to be about KES15,000. Those technicians who have already accumulated experience have the option of taking a test instead of the training and would pay about KES5000. The first formal courses were expected to run from September 2013. The National Industrial Training Authority (NITA) has equipped four training centres for running the module and testing technicians, and KEREA is said to be trying to equip another ten (Interview, Anonymous). However, there seems to be a lack of resources to suitably equip these centres and so it is not clear whether the technician training will be able to meet what could be an overwhelming demand.

In parallel with the development of regulations for the PV sector, there has been a process of developing standards for SPLs. However, this has been led by Lighting Africa rather than KEBS. Again, the process was motivated by the experiences in the market with many poor quality products. In this case the products were solar lanterns, but the wider experience with poor quality SHSs was having an influence on the perception of SPLs too. Indeed, the perception of poor-quality SPLs was well-founded, as Lighting Africa discovered when they tested a range of 14 lights in 2009 and only one passed

(Interview, Anonymous). Following this, Lighting Africa initiated research to find out what minimum standard of quality would be acceptable to lantern-users. They then worked with the global lighting industry, advocating better-quality lanterns and awarding prizes for the best products at conferences in 2010 (LA 2011: 74) and 2012 (LA 2012). When they tested another range of 20 products in May 2010 they found eight passed the minimum standard (Interview, Anonymous).

Lighting Africa further pursued the development of these standards and managed, after two and a half years, to get them adopted by the International Electrotechnical Commission (IEC) (Interview, Anonymous). Once adopted by the IEC they can be adopted at national level and, currently, KEBS are considering this (Interview, Mboa). Alongside this, Lighting Africa has been working with the University of Nairobi (UON) to establish a testing laboratory to help in the enforcement of the standard, if it is adopted, and to provide a place where products can be screened by importers before they commit to buying large stocks (Interview, Anonymous). The test facility could also act as an education and training tool, enabling students to gain experience with solar testing procedures and equipment. However, before the laboratory can enforce the standards it must itself be accredited, which means it has to comply with an ISO standard itself. This, too, is in process with assistance from KEBS (Interview, Mboa).

Whilst there appears to be progress in regard to standards for SPLs, there is also some disquiet about the test procedures, their cost, their value, and their stringency. Some private sector interviewees, for example, were not entirely happy with the quality assurance offered through Lighting Africa and claimed that the programme has been promoting sub-standard products alongside those approved. Other issues related to the number of different types of lanterns available in the market, around 40 to 45 saying that this is too many and just causes confusion amongst customers, that customers are not buying approved products so there is questionable value in paying the USD 6000 to go through the quality assurance test. One interviewee claimed that Lighting Africa is not interested in quality products, suggesting it is actually interested in sales figures and market growth. Whether these contentions are indications of what would be expected in a nascent market or are more fundamental problems remains to be seen. It is clear, however, that the Lighting Africa efforts to develop and enforce standards are in step with the wishes of both the major small-scale PV sector actors and those in the regulatory regime. It is likely, therefore, that KEBS will adopt the testing standard for SPLs and that test facilities will be needed.

4.7.4 Taxes and duties

The issue of VAT and import duties on PV and associated equipment has been an abiding feature of the Kenyan PV niche for decades. We have already discussed the issue in Section 4.4 above, where several observers of the Kenyan PV niche could not agree whether import duty and VAT removal in 1986 had been passed to the consumer. Since then, taxes and duties have been applied and removed many times and at different rates, and on different parts of PV systems. For example, Jacobson (2004: 143, Table 16) shows cumulative tax and duty rates rising steeply on PV modules in 1992 before falling back in steps until they are zero-rated again in 2002. Since 2002, there has tended to be a more favourable duty and VAT climate in Kenya for PV, perhaps explained by the close relationship with some parts of Government enjoyed by members of KEREA while working on standards (Newell *et al*. 2014). While any rises in taxes and duties tend to cause alarm in the PV niche, the market has continued to grow, as shown in Figure 4.1 above. This is not entirely surprising given that most SHSs are bought by the middle class, even if higher prices do hurt them.

More recent moves on tax, however, look likely to be damaging to some in the PV niche. As discussed in section 4.8.1 below, Kenya has seen rapid growth in a pico-solar market since about 2009. The customers in this market are much poorer than those who might buy SHSs. But the Government imposed 16 per cent VAT on solar goods from October 1 2013, and many of the private sector actors in this pico-solar market who we interviewed said they had seen dramatic falls in sales as a result. As

Newell *et al*. (2014) observe, the Kenyan Government is currently in need of raising tax revenue and so those actors who do not wield lobbying power are likely to suffer the burden of this need. With the Government prioritising geothermal in its low carbon development plans, off-grid PV, whether SHSs or pico-solar, appears to be of little relevance.

4.7.5 Socio-technical analysis of policy regime interactions

PV Standards Process
The process of formulating PV standards in Kenya was a site for considerable first-order learning, as actors were focussed on the details of what those standards should be. Clearly, this entailed substantial technical discussions that encompassed draft standards such as those being developed through Photovoltair General Approval Program (PVGAP), the experiences and expertise of the local niche actors, and the requirements of the Kenyan regulatory regime.

But we can identify some second-order learning that was also important in the process. This second-order learning occurred much earlier for some niche actors when they realised that there were quality problems[34] in the market. Based on this realisation, they formed a new expectation, perhaps even vision, in which the solution to these quality problems was to regulate the market using standards. They made repeated attempts to collectivise their understanding by expressing a vision of a PV market that was successful and of high quality, with the enforcement of standards as the means to achieve this objective. In fact, they presented two visions. The other, which was to some extent being realised in the market, was a negative vision in which consumers were losing, and business would fail, because of bad practices. Eventually, KEBS was recruited to this vision and initiated an official standards-making process, although it is not clear why this second-order learning did not occur sooner for them.

The process also contributed to the enhancement of networks within the niche, as was the case with other projects we have already discussed. For some of the actors involved, their only interactions with others in the niche had been an occasional business deal, now they were meeting regularly to discuss issues other than business (Interview, Loh). And it was out of this close interaction that they formed an industry association (KEREA). We could see this as a second-order learning experience in that they formed a new expectation, related to the standards issue, in which one of the objectives was a high-quality PV sector[35] that could be achieved by self-regulation of the factors not covered by the technical standards. This expectation was then envisioned to some extent by the formulation of a code of conduct, and the initial embedding of this when they managed to persuade the 'guilty' KEREA members to remove low-quality modules from the market.

One other aspect of the standards process, for which we have only suggestive evidence, is the contention generated by this kind of action. We can interpret standards as socio-technical visions, they are highly detailed prescriptions for certain aspects of action and so intended to formally institutionalise particular behaviour. In this sense, the niche actors on the committee were negotiating a vision of serious importance to them. Each could be affected in different ways by the outcome of the process, some could be winners and others losers, depending on the constraints imposed by the institution. Gisore (2002: 49-50) hints that this was indeed how some of the committee deliberations unfolded and is more explicit when he states that the process included consideration of the consequences for local actors. Unfortunately, we cannot examine these negotiations because we do

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[34] For Burris, of course, this was an issue from the outset. And Hankins was an early recruit to Burris' vision.

[35] Of course, KEREA covers other renewable energy technologies as well as PV, and the code of conduct is for all its members.

not have the evidence and, therefore, cannot assess to what extent they shaped niche development. But, we can recognise that important niche-shaping action resulted from the process, and that the process was inherently political.

Energy Policy Making Process

Both power and politics had important shaping effects on the niche developments we have discussed in relation to energy policy making. The Institutional PV Systems Programme was the result of *ad hoc* policy-making realised because of the power of the President's Office, and driven by the raised expectation among voters of electrifying their part of the country. And the official process of preparing the 2004 national energy policy became a political struggle with the unofficial process of the Policy Dialogue. The final outcome of that struggle, the Energy Act 2006, was a compromise achieved through the exercise of the power of parliamentarians. Of course, these outcomes were not simply the result of power and politics: expectations, learning, networks and institutions, as SNM posits, were all involved as well.

The Institutional PV Systems Programme was initiated because of the expectation of electrification that the President had, it is claimed, collectivised during his election campaign. The only way that the MOE could realise this quickly was with PV systems. However, following years of neglect of renewables by the Ministry their internal capacity was poor. Thus the MOE had to employ a niche actor to help them envision the expectation, to troubleshoot their first system, design systems, train MOE staff, etc. The impact for the PV niche was significant. While it created some big winners among those who won contracts, it also created some disquiet among other actors. In the case of PVMTI, disquiet stimulated actors to collectivise a new expectation and to seek a shift in policy to more capacity building. This does not seem to have been the case with the institutional PV systems Programme. Perhaps, unlike PVMTI, there were at least some winners in the programme and this might have fragmented any efforts to collectivise an alternative expectation.

The formal process of preparing policy, as we might anticipate, was a highly political activity, more so than the other activities we have studied. The number of interested actors, and the consequences at stake for them, was much higher than for other developments. The number of expectations and visions in play, often conflicting, was also higher. We can consider a policy document to be, as with a standards document, both an envisioning and an institutionalising device. The fact that two policy documents for energy in Kenya, the MOE and the Policy Dialogue versions, were competing served to intensify the political struggles. Of course, the MOE felt that their vision had more legitimacy, being an agent of an elected government, but the Policy Dialogue could also claim legitimacy as it had involved a much wider range of stakeholders than the MOE process. The outcome, as expressed in the Energy Act 2006, was a compromise between these competing visions, whereby PV retained some recognition, as we have said, through the exercise of the power of parliamentarians.

Of course, the parliamentarians did not act spontaneously. Niche actors deployed socio-technical expectations in order to recruit their support and the parliamentarians, having experienced this second-order learning, began to adopt the detailed vision, expressed in the Policy Dialogue document, with the help of actors such as Energy for Sustainable Development Africa (ESDA) and GTZ. And ESDA and GTZ themselves experienced second-order learning as a result of their 'success' in influencing the Energy Act. For Otieno at GTZ, and the parliamentarians concerned, that learning was expressed in the formation of the Parliamentary Network on Renewable Energy and Climate Change, that is, the forming of an expectation that policy outcomes on renewable energies could be influenced through parliamentary actors, partially envisioned by employing ESDA to conduct seminars for those actors.

We can see that the interactions of niche actors with the regulatory and policy regimes were important for niche development in a number of ways. There were the kinds of outputs we might expect (such as technical standards, from interactions with the regulatory regime, and an energy act reflecting some of the interests of the niche) from interactions with the policy regime. But there were other outcomes that were significant for niche development. The work on the standards committee stimulated the formation of KEREA. This has the potential to further articulate the networks within the niche and connect to networks beyond, as well as being an industry voice for interactions with Government. It also created a code of conduct, in addition to the technical standards, which could be important for institutionalising practice among the niche actors. The policy experience was rich in learning for some of the key actors in the PV niche, particularly in terms of how to lobby and influence the policy regime.

However, the more recent developments in energy policy making in Kenya have reversed the fortunes of the PV niche to some extent. Actors in the PV niche do not necessarily share the now dominant expectation of low carbon development with, in particular, geothermal energy. Instead, there is a powerful network of actors who do share, or could easily share, this expectation and they are driving the policy making process, whether because of institutional legitimacy (MOE), control of resources (donors, large industry) or the power to effect political change (grid-connected consumers). Those PV niche actors with expectations and visions centred on SHSs and SPLs are unable to wield any countervailing power against this dominant network. In a sense, they are being forced into accepting an expectation of the private sector led PV market, one that does not incorporate the need for protection and nurturing. Instead, it is one that must accept discipline and taxes. There are probably still enough donors who hold expectations around SHSs and SPLs that further nurturing of the niche is likely but the discipline imposed by the expectation embedded in the new regulations is stark for some actors. It begs a question as to whether the niche networks will now fragment as the poorer actors find they are unable to pay for training and licenses, or whether the market is vibrant enough for them to continue making a living from PV installations. The new markets, discussed below, might offer these livelihoods.

4.8 New markets: pico-solar and module assembly

We have already mentioned Lighting Africa several times, and discussed their efforts to introduce minimum standards for SPLs. But the programme did much more than try to address the issue of quality in the pico-solar market. Here, we discuss the other interventions Lighting Africa implemented in Kenya and attempt to demonstrate that these together could be considered a systemic approach to market creation and development. Alongside these interventions, the market for pico-solar products in Kenya has grown rapidly and has seen the entry of a large number of new private sector actors and products. Whilst it would be problematic to attribute this market-growth entirely to the Lighting Africa interventions, there is certainly a strong correlation. Nevertheless, as we will see in the discussion below, without Lighting Africa's advocacy, it could be argued that the variety of new pico-solar products now available would not have been developed and so it is unlikely that such a market would have emerged. Indeed, the evidence discussed below suggests that in-depth research focussed on the Lighting Africa programme, or similar interventions, could yield important insights for pro-poor low carbon development.

This section also briefly discusses the establishment of Kenya's first PV module assembly plant. This is an interesting development in that it suggests the Kenyan PV sector is moving on a trajectory that could see it capture more of the PV value chain. It is still too early to assess the extent to which this is likely but several PV actors consider the plant to be successful to date and it appears to be employing a careful strategy to build confidence in its products in the East African region.

4.8.1 Targeting the bottom of the pyramid: the pico-solar market

In September 2007, the IFC launched the Lighting Africa programme. This was a collaboration between the IFC and World Bank, with a range of donors in support, intended to build on previous market development interventions such as the Lighting the Bottom of the Pyramid (IFC 2007) GEF-supported programme (Lighting Africa 2009: 2; Interview, Anonymous). The first phase involved a global call for project proposals aimed at developing new lighting products and delivery models for Africa's large un-electrified rural off-grid lighting market (DM 2007). The call was launched in partnership with the World Bank's Development Marketplace initiative, which had already been in operation since 1998. In Kenya, as we have discussed in section 0, there had already been several (unsuccessful) attempts to bring PV-powered lighting technologies to the poor, and recent attempts to develop pico-solar products (e.g. the radio and phone-charger marketed by Fred Migai). The hope with Lighting Africa was that recent advances in performance of key technologies, especially LED, could be harnessed to provide cheaper and better lighting for the bottom of the income pyramid (BOP).

Grants of up to USD200,000 were available for each successful proposal, and 16 were selected from the more than 400 proposals received, four of them to be implemented in Kenya (Lighting Africa 2008c: 7). Three of these involved PV (winning company in brackets): consumer finance scheme for SHSs (ESDA); transfer of LED lantern assembly from India to Kenya (Thrive); and a rent-a-light scheme (Solar World). The grants were awarded at a ceremony during the first Lighting Africa conference held in Accra from 6–8 May 2008 (Lighting Africa 2008c: 6). Since then, Lighting Africa conferences were held in Nairobi (2010) and Dakar (2012) during which awards were given for a selection of 'outstanding' lighting products already on the market rather than from a competition such as the Development Marketplace (Lighting Africa 2011: 74; web page[36] for the Lighting Africa 3rd Conference).

By the time of Lighting Africa's second-year progress report in 2009, the programme had begun activities on many fronts, including: 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 (Lighting Africa 2009). For Kenya, by the end of 2008, there were already highly detailed qualitative and quantitative market assessments (Lighting Africa 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[37] for these reports).

In 2009, Lighting Africa began its market development interventions in Kenya (the other pilot country being Ghana). In section 4.7.3, we discussed its quality-assurance activities in which the programme developed minimum performance standards for SPLs and a testing methodology. This also fed into one of its other activities which was to influence policy at the national level. Also at the national policy level, and through the World Bank relationship with Kenyan policy makers, it hoped to address the issue of import duties and taxes on PV products. As we have seen in section 4.7.4, this has been an uneven and unpredictable experience, with taxes being levied and then removed and then levied once more. For many of the private sector interviewees, the issue of taxes and duties has been particularly vexed. According to their testimony, the reintroduction of 16 per cent VAT in October 2013, for example, has severely reduced sales of their products, in some cases by as much as 30 per cent. Others point to 'perverse' incentives created by import duties, where complete PV systems are duty-free whilst components are not. This, they claim, forces local companies to import systems rather than components for assembly in Kenya. That is, the duties are not helping to develop local value chains. In

[36] http://www.lightingafrica.org/2012conference/

[37] http://www.lightingafrica.org/

the opinion of some interviewees, the role of actors such as Lighting Africa should be to lobby for the removal of such policies rather than to create a market.

Nevertheless, many of our private sector interviewees noted that Lighting Africa had been helpful in its market development activities, and some actors in the market were beneficiaries of the initial grants to help get products and delivery models started. This brings us to the other three aspects of the Lighting Africa programme. These are: business support and access to finance; access to finance across the supply chain; and consumer education (Interview, Anonymous).

In short, business support includes identifying potential dealers in rural areas and connecting them with suppliers and organising trade fairs to bring suppliers and buyers together (the conferences mentioned above). Access to finance for business includes enabling credit so that companies can increase their stock of products. Lighting Africa did not itself provide finance and it is unclear whether the programme was able to deal successfully with this aspect of the intervention.

However, when considering access to finance across the entire supply chain, there seems to have been more success. In some ways, this intervention was similar to PVMTI in that it was concerned with finance on both the supply and demand sides of the market. But, it differed from PVMTI in important ways. First, Lighting Africa was not lending any money. Instead, it helped to develop two models of finance. One, the bulk-buyer or corporate outreach model, began with Unilever, which had over 10,000 employees in the tea sector who could be customers. Unilever experimented with a 'check-off' system of payments whereby each employee who is buying a light has a certain amount of money deducted from their salary each month. In essence, this was a hire-purchase model except that Unilever was acting as the loan-agent rather than a third party. The other model was for Unilever to lend money to its associated Savings and Credit Cooperative (SACCO), which could then lend to its members. Again, the basic model is familiar in Kenya except that Unilever could charge a lower interest rate than a bank would do and so the SACCO could pass the saving onto the customers. Whereas PVMTI was constrained to lending a minimum of USD500,000 to a Micro-Finance Institution (MFI), these experiments could lend much smaller amounts which were more appropriate in the context of rural Kenya. It is claimed that both these models have been successful and have been adopted by other large companies and SACCOs (Interview, Anonymous).

The last aspect of the Lighting Africa intervention was consumer education. This was considered the most challenging of the interventions and expensive to implement. It required understanding of what the consumer does and does not know, and involved running forums, road shows, meetings, and more. This was also an aspect in which Lighting Africa learned by doing, evolving its approach with experience. For example, it became clear that just raising awareness could mean disappointment for potential customers. Once they were interested in the idea of SPLs, many wanted to purchase immediately. If there were no dealer to sell the products then the customer is likely to become dissatisfied. To avoid this, it is claimed, Lighting Africa combined awareness-raising activities with its retail outreach in the current target area. It also often had an MFI with it. For those who could not afford to buy immediately, Lighting Africa developed a text-message service whereby the customer could send a blank message to the number some time later and receive a list of approved products. This was available in the relevant local language. Whilst this appears to have been a successful service, it is not clear whether it will be continued now that Lighting Africa has finished its interventions in Kenya.

The programme innovated its marketing campaign in a number of other ways too, although there is no space to detail everything it did. The point to make here is that it did so in response to its greater and evolving understanding of each context into which it moved. In 2012, it was awarded a prize by the Marketing Society of Kenya for the 'best experiential campaign in the NGO/Government category'

(Lighting Africa 2013a: 1). According to the same report, by the end of 2012, Lighting Africa had run over 1100 forums and 190 road shows in Kenya, reaching an estimated 260,000 people.

Up to the official completion of its Kenya pilot phase in July 2013, the programme continued to engage in the combination of interventions described. These were an aggressive and roaming awareness-raising campaign, quality-assurance of products, the 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. Whilst it is difficult to determine the extent to which outcomes can be attributed directly to these efforts, the programme does make a series of claims (see Figure 4.3). One of these is that the annual market for good-quality pico-solar, alone, had grown to sales of over 100,000 products (Interview, Anonymous). And a recent updated survey in three towns in Kenya tends to support the notion that the market for small off-grid lighting products has expanded rapidly in the past four years (Harper *et al*. 2013).

Not all private sector actors have entered the pico-solar market because of Lighting Africa, as can be seen from the discussion in in this section. However, it is unlikely that these interventions have been completely ineffectual and it is clear that many actors would not be aware of the products or where to buy them (both dealers and customers) if Lighting Africa had not intervened. Still, it is remarkable that, as with the rest of the long history of PV described in this case study and the persistent involvement of many donors over this time period, the PV market in Kenya continues to be described by most observers as 'unsubsidised'. The Lighting Africa programme in Kenya alone cost USD5 million (Interview, Anonymous). The whole pilot programme, inclusive of other countries, is in excess of USD12 million.

Figure 4.3: Lighting Africa claimed impacts and outcomes up to end of December 2012

Overall impact	
6,900,000[1]	**People in Africa now with clean lighting** and better access to energy due to solar lanterns
1,386,000	**Off-grid lighting products** that passed Lighting Global quality standards **sold in Africa**
138,600	**Tons of GHG emission avoided;** CO_2–equivalent of taking 26,000 cars off the road
120%	**Growth in sales of good quality lighting products in 2012** (over 2011)
20	**Number of countries** now selling products that have passed Lighting Global quality tests
Quality assurance	
2	**Test methods,** developed by Lighting Global**, for off-grid lighting products;** tests currently used in four laboratories worldwide: Kenya, Germany, and two in the USA
150+	**Lighting products tested** using the Lighting Global Quality Test Methodology (LG-QTM)
49	**Products passed the Lighting Global minimum quality standards**. Most of them have also met the recommended performance targets
12	**Technical Briefing Notes published**, providing manufacturers with information to help them design and improve their lighting products
2	**Eco Design Briefing Notes published**, focusing on health and safety issues for consumers, distributors and manufacturers
Market intelligence	
16	**In-depth market insight reports** that the industry has used to develop products, enter the markets, or mobilize investors
Consumer education	
22,000,000	**People reached** by the consumer education campaigns in Kenya and Ghana
1,500+	**Village forums** in Kenya and Ghana organized to educate rural families about the benefits of solar lighting over kerosene
Access to finance	
7	**MFIs providing micro-loans for consumers** to purchase quality-assured modern off-grid lighting products
Business development support	
30	**Manufacturers whose products** have passed Lighting Global minimum quality standards
15	**Manufacturers/Distributors** receiving advisory services from Lighting Africa **(Associates)**
Policy	
1	**Institutions referencing Lighting Africa's test methods**: the UNFCCC harmonized with Lighting Africa Quality Testing Methodology for carbon finance (CDM) compliance
8	**Country studies identifying key policy barriers** to the adoption of modern lighting products and services published. The studies cover Cameroon, Democratic Republic of the Congo (DRC), Ethiopia, Ghana, Kenya, Rwanda, Senegal, and Tanzania.

[1] The access to clean light computation is based on the assumption that one solar lantern serves one household, and that each household has five people. This calculation is currently under review to accommodate new market data.

Source: http://www.lightingafrica.org/resources/annual-reports.html (Accessed 16 October 2013)

4.8.2 Moving on up? Kenya's first module assembly plant

There has been at least one past attempt to establish manufacturing of PV modules in Kenya, although this attempt fell apart following the post-election violence in 2008 (Disenyana 2009). The intention had been for a Chinese company to start a joint venture in Kenya to manufacture amorphous modules in Nairobi. It is possible that other attempts have been made but none appear to be documented. However, Ubbink EA began assembling polycrystalline modules in Naivasha in August 2011 (Oirere

2012), the result of a long process that could bring more value-added to the Kenyan PV niche (Interview, Kimuya).

The process was apparently initiated around 1999 or 2000 by Chloride Exide (Interview, Mabonga). They had already been sourcing modules from a Dutch group of companies (Ubbink BV) for many years. According to Kimuya (Interview), the two companies first tried to establish the plant in Ethiopia but the policy environment was not conducive. Eventually, they decided to open in Kenya. This process took almost a decade and it is not clear what the explanation for this is. Kimuya suggests it may have been a combination of political and bureaucratic difficulties, as well as the task of identifying suitable personnel. In any case, Ubbink East Africa. a joint venture between Largo Investments (who own Chloride) and Ubbink BV (Centrotec Sustainable AG), was officially registered in Kenya in 2009-2010 (Interview, Mabonga). Three technicians were then sent to the Netherlands for one month of training and they trained six more upon their return to Kenya. This continued and now there are 78 Kenyans trained to operate the machines in the assembly plant (Interview, Kimuya). Naivasha was chosen as the location because of the lower cost of land while being on the northern corridor and so offering good transport links for the main markets. The largest market is Western Kenya, and Kenya is the largest country market that Ubbink EA serves.

Half of the investment for the plant (said to be USD3 million: Oirere 2012) was provided by the Dutch Government and the other half shared between Chloride and Ubbink BV (Stuart 2011). The factory first produced 180 kW of modules per month but this has risen to about 250-300 kW as a result of continuous improvements to the production process (Interview, Kimuya). They produce a wide range of sizes, from 13 Wp up to 240 Wp. The most popular module size is 40 Wp, which is considerably larger than the most popular module size in the market in the past. This used to be 12 Wp (van der Plas and Hankins 1998) but Kimuya suggests that the falling price of PV has meant people are able to buy larger modules and so meet more of their demand. The preference in Tanzania is for 50 Wp modules, and it is 80 Wp in Uganda where the subsidy for projects is generous.

Kimuya (Interview) claims that Ubbink EA has built a solid reputation in East Africa by inviting distributors, dealers, retailers and technicians to visit the factory where they also receive basic PV training. During these visits, they are shown around the production process and talk to the staff. This way, it is claimed, they build trust in the company and the product. There does appear to be a general assessment amongst PV niche actors that the company is succeeding (Newell *et al*. 2014) and they are well-connected into the PV actor-networks in the region, not least through the Chloride Exide contact.

Now that Ubbink is established as a strong name in the region, they are considering diversifying the production to include goods with PV embedded, such as solar radios, lanterns, TVs and street lamps. This may make sense as any attempt to move into the manufacture of cells would require much higher investment risk. Still, there are many examples around the world of assembly being the first of many steps in the direction of building more complex manufacturing and innovation capabilities.

4.8.3 Socio-technical analysis of new markets

Lighting in Africa and he pico-solar market

In some ways, the Lighting Africa programme could have been designed on the basis of niche theory. It has made huge efforts to recruit actors to its network by collectivising an expectation, it has evolved through learning, attempted to institutionalise many socio-technical practices, encouraged a diversity of experiments in different contexts, nurtured and protected, and acted as an innovation system builder. Ironically, the vision guiding this behaviour is one of entrepreneurs seeking profit in a free market and thereby providing clean lighting services to the poor. Of course, this same vision, or expectation, has been promoted throughout the history of the SHS market in Kenya. And it has proved to be a successful vision for recruiting public resources to assist this private market. This is not to argue that these resources have been poorly used. Our argument is quite the opposite and the Lighting Africa programme goes some way to demonstrating that the systemic approach it has taken is potentially both faster at delivering energy services to the poor and more sustainable than a light-touch free market approach.

From the early documentation that led up to the implementation of Lighting Africa, it is clear that there was a concerted effort to build a strong network of actors who could adopt an expectation of pico-solar lights for the poor in Africa (IFC 2007: 6). This effort began more than two years before the launch of the Development Marketplace competition and the IFC consulted over 190 actors in the process. This network was further enhanced through the launch competition and new lighting product and service ideas generated. The winning 16 ideas were then given protection with the grant money. Because they were implemented in a wide range of contexts, this could generate valuable learning about these new socio-technical practices in real-world settings.

Further learning was enabled through the market surveys – both quantitative and qualitative – and policy environment studies commissioned by the programme across several African countries. These were all shared on the Lighting Africa website. As we have seen in earlier sections of this case study, this detailed articulation of contexts is essential for the development of socio-technical visions and their further collectivisation. As actors adopt shared expectations and visions, so they focus on solving similar problems when trying to realise those visions. This raises the chances that those problems will be solved or that new expectations will be stimulated. A simple example in the Lighting Africa experience in Kenya was the discovery that many importers did not actually know what constituted a good quality solar lantern. This led to the testing of a range of lights with users and the eventual identification of a minimum acceptable standard. With this standard codified, Lighting Africa was able to go back to the manufacturers and tell them in what ways their lights needed to be improved. The second round of tests then showed that the manufacturers had actually responded to this.

Of course, this codifying of a minimum acceptable quality then led to the further development of related standards and a testing laboratory. Subsequently, Lighting Africa initiated the process of trying to institutionalise these standards globally, forming other actor-networks in the process. And these practices could eventually become institutionalised in Kenya. Not all actors have adopted their expectation of quality but Lighting Africa has started a process from which to generate learning that could lead to others eventually adopting some version of it. In any case, this expectation around quality has stimulated a diversity of innovations in SPLs, more than 40 of which have been accredited.

There have been innovations in other aspects of the niche too. Working with others, Lighting Africa has experimented with micro-finance models and with marketing techniques. Others have entered the niche with their own experimental business models incorporating, as we discuss in our companion paper on consumer finance, ICTs and PV systems. Nurture has been given to some of these actors through provision of marketing and bearing the risks and expense of finding demand, and connecting it with supply. In a country like Kenya, where many live in remote rural areas, such activity is time-consuming and expensive. Whilst not everything has worked for the programme, and not all actors are satisfied, it has done the work of building elements of an innovation system around pico-solar lighting products and business models.

Ubbink module assembly plant

It is too early to say much about the Ubbink EA assembly plant. Clearly, the existing relationship between Chloride Exide and the Dutch module supplier was important in initiating the idea to establish such a plant in East Africa. And, considering the decade this took to realise, this relationship must have been quite strong. We might expect that there were significant amounts of learning during this establishment process but it is impossible to say at this time what the content of such learning was.

We can see that the institutional environment seems to have played a role in attracting Ubbink to Kenya rather than Ethiopia, although we cannot be clear about the detail of this. However, there is suggestive evidence that there may have been close communication, perhaps even lobbying, between the Kenyan Government and the joint venture investors. Mabonga (Interview) hinted that Chloride Exide influenced the Government in terms of policy, and the budget of 2011, announced in June, ahead of the assembly plant opening in August, included the removal of duties on the raw materials for making solar modules (KPMG 2011: 7). Once again, here is evidence of the complicated relationship between the policy regime and the PV niche.

There is also further evidence of subsidy in the PV niche. This time it was in the form of the Dutch Government providing 50 per cent of the investment for the assembly plant. We can speculate that making such an investment in Kenya would have been seen as risky by those in the joint venture and so this subsidy can be understood as some level of protection against this risk. It would also, of course, be of potential interest to the Dutch Government itself, in terms of representing the interests of Dutch industry, depending on whether the market for modules becomes large.

But there have been other benefits for the Kenyan PV niche. At least 78 Kenyans have been trained in the production process for assembling polycrystalline PV modules. And they have developed their skills in-house to improve this production process. This is an instance of what Bell (1990) refers to as the development of production capabilities. The local supply chain has begun to capture more of the value-added available from the PV market, and parts of the regional supply chain have become more inter-connected. Furthermore, if they had not been trained before, those who have visited the plant (at the cost of Ubbink: Interview, Kimuya) have gained at least some basic PV skills. And they have had the opportunity to meet others in the regional PV networks. Finally, there is the prospect of new locally-sourced pico-solar (and other) products being developed.

4.9 Summary of the case study

In our case study we have charted the arrival of PV into Kenya in the late 1970s and early 1980s. The technology was used for community and commercial services at that time but it also made equipment available that was then used by others in the country. Most notable, from our perspective, was that Harold Burris began to use the technology and experiment with business ideas. Then, together with Mark Hankins, he exploited the availability of PV in several school projects that spawned the idea of solar home systems. These SHSs were then taken up by other private sector actors, beginning with those who were already supplying PV equipment in Kenya. Soon, the SHS market began to flourish and Mark Hankins started to seek donor-funding to experiment with many ideas for product development and business models, including many actors in the market in these projects. The result was a strengthening niche and growing market.

Powerful international development actors then started to become interested in this phenomenon and resources began to flow more readily, assisting Hankins and many others to develop the niche further. As the niche developed and the market grew so more actors entered and gradually specialised in particular roles. Then, with the advent of technical and economic improvements in LED technologies, a new market for pico-solar products has developed, fostered by Lighting Africa.

Niche actors have begun to interact with policy regime actors and have scored some successes in terms of influencing policy to encourage further market growth. However, these relationships have been unstable and they appear to be in decline at present as the policy regime turns its attention to exploiting the vast geothermal energy opportunities in Kenya.

Nevertheless, the activities of actors such as Hankins, his company EAA, and others such as KEREA and Lighting Africa, have helped the Kenyan PV niche to accumulate many elements of a nascent innovation system. And the recent establishment of a solar module assembly plant is suggestive that the Kenyan PV niche is opening a trajectory of development that could lead to much more complex capabilities that might result in the emergence of more sophisticated local innovations.

With this history in mind, we now turn to a brief discussion of the policy implications of this research. These are targeted at developing recommendations for the activities that the Kenyan CIC might implement in trying to promote climate technologies, and for policy interventions more generally that seek to promote climate-compatible development that can deliver benefits for poor and marginalised groups throughout the developing world.

5 Conclusions and key policy lessons

5.1 Discussion of the evolution of the Kenyan PV niche

The analysis above clearly demonstrates how the success of the Kenyan market for off-grid solar electrical services can be attributed to a range of targeted interventions by key actors over time. These contributed by building technological capabilities where gaps existed and putting in place vital parts of a functioning innovation system around off-gird solar in Kenya. The analysis firmly rebuts the received wisdom of many people who often comment on the case of solar in Kenya, showing that it most certainly wasn't a simple case of free market forces driving success. Many of the key actors involved were private sector actors. However, these actors, acting both with and without public funding and support, pursued a range of capacity building activities that served to put in place the components of a functioning innovation system that previously didn't exist. These activities were separate and in addition to conventional rent seeking activities and were integral to providing the basis for long-term, sustained development of the market for off-grid solar in Kenya. Below we draw out some of the key points from the analysis in the report before concluding by articulating key policy lessons that can be drawn from the analysis.

Explaining the evolution of the Kenyan SHS and, more recently, the SPL markets is perhaps best begun by examining the use of socio-technical expectations. From the emergence of the SHS market in the mid-1980s up to the mid-2000s, the dominant expectation was of a market for PV systems. This increasingly-shared expectation guided the search and problem-solving activities of a range of actors, public and private, international and local, on the specific issues relevant to market-development. By focussing problem-solving on issues of relevance to all SHS market actors, any lessons generated were widely and readily applicable. Moreover, as many of these problem-solving activities were funded by donors, the lessons tended to be made public through reporting and through discussion in various forums (such as workshops and other meetings, and likely by word-of-mouth through the well-integrated actor-networks in the Kenyan PV niche). Private sector actors were then able to make use of this learning in further-focussed activities of their own that helped to grow the market.

From about the mid-2000s, a variant of this PV market expectation, based on solar lanterns, began to take hold. Solar lanterns had been available for many years, and had been the subject of various experiments in Kenya, but there were several technical and economic characteristics that made adoption by poorer users difficult. The lanterns offered limited functionality and reliability at prices only slightly below those of the smaller SHSs. But technical improvements in lighting technology,– especially LEDs, meant that there was an opportunity to revisit lanterns as a solution to lighting services for the poor. The IFC began work on constructing an expectation that married these technical possibilities with the rhetoric of the bottom of the pyramid, and actively recruited actors globally to this expectation. Bolstered by the large network of actors thus recruited, the Lighting Africa programme began operations in 2007, having persuaded the GEF and others to provide substantial funding. However, at the time, there were few (if any) lighting products designed specifically for poor African users and so Lighting Africa stimulated the design of a range of products through its international competition for grants.

The grant competition recruited more actors to this new expectation and provided protection in the form of the grants awarded for a number of experiments with different products and delivery models in various contexts. Several other niche-development activities, similar to those seen in regard to developments around SHSs, were then implemented when Lighting Africa began direct interventions in Kenya in 2009. These included articulation activities (descriptive of market demand and problems in the market, connective of the actors in the supply chain and with demand), building actor-networks, socio-technical learning and sharing lessons, and institutionalising practices, from the use of pico-solar products through to formalising performance standards and testing. In the meantime, as this expectation was widely deployed and adopted, and as it became increasingly refined in a particular socio-technical vision, other private sector actors have been attracted to the Kenyan pico-solar market where they have experimented with a wider variety of products and business models. Whether this widening variety of actors and business models can be causally attributed to the activities of Lighting Africa is difficult to establish but the rise of the pico-solar market has a striking correlation with these activities.

Another important feature of the use of expectations, visible in the evolution of the PV niche, and both the SHS and SPL markets, is their political nature. That is, when an actor deploys an expectation they are attempting to persuade others to adopt it. This involves the construction and use of a narrative that defines the problem, and identifies an intervention that will solve that problem. In this case, of course, the problem has been the long-standing issue of electricity access, especially for poorer groups in rural areas. For much of the evolution of the PV niche, the intervention suggested in the narrative was to address market failures so that private sector actors could more easily sell good quality SHSs to customers in a promising free market. Hankins (and subsequently EAA) was particularly important in constructing and deploying this narrative, persuading many to adopt the expectation of a PV market in Kenya by emphasising that rural people would benefit from better development outcomes. It is fair to say that hundreds of thousands of rural people have indeed benefited from electricity access via solar, and many others have benefited from the profit and employment associated with the SHS market.

But it became increasingly clear that poorer groups in rural areas were not getting access to electricity from solar and that it was difficult for them to do so. Attempts to solve this problem within the SHS market expectation, by using micro-finance, largely failed (most conspicuously in PVMTI) and it could be argued that this stimulated the second-order learning that created the pico-solar expectation. However, the early experiments with pico-solar products were unsuccessful, especially as the first solar lanterns were too expensive and provided limited and unreliable functionality. It was not until techno-economic advances in LEDs became available that solar lanterns (and subsequent varieties in functionality) could be seen as viable, and a new narrative could be constructed that convincingly included private sector provision of electrical services for the poor. Whilst there were some actors in the Kenyan niche experimenting with pico-solar products, such as Leo Blyth and Fred Migai, they were not politically active. That is, they were not deploying a pico-solar expectation or narrative and so had little support amongst the established SHS actors, who did not take these pico-solar products seriously. It took a powerful actor, the IFC, to create widespread interest[38] in, and adoption of, a pico-solar expectation.

Here we see the operation of power in how narratives influence the direction of development. Actors such as EAA (Mark Hankins' company) were successful in attracting resources to enable development of the SHS niche and growth of the market. However, in the main, these resources were made available in small quantities that enabled only small-scale interventions and experiments. The only exception to this was PVMTI, an intervention that failed (in its primary goal) because it was based on a misunderstanding of the problems in the SHS niche. As a consequence perhaps the SHS niche has taken decades to develop and still faces many problems. Chief among them, according to actors in the niche

[38] It is not clear from this research who, specifically, initiated the idea of what became the Lighting Africa programme and, indeed, why they adopted such an expectation in the first place. Further research into the emergence of this narrative and mobilisation of resources around it could provide valuable lessons for policy.

it would seem, is the issue of poor quality. In contrast, the IFC is a powerful actor and has had a large quantity of money to bring to the development of the pico-solar market. Moreover, as a globally credible actor, they were able to persuade many others to adopt a pico-solar expectation even before the Lighting Africa programme had been awarded funding. But neither the SHS nor pico-solar actors have successfully persuaded those powerful in the Kenyan policy regime that they should adopt any PV expectations. There are some warm words in policy documents but many PV actors claim that, in reality, there is significant resistance to solar amongst a few powerful figures in the energy sector. Some actors attribute this resistance to close relations between these powerful figures and the fossil-fuel interests in Kenya. Others point to a preference for large projects rather than the small and highly distributed projects that are inevitable with SHSs and SPLs. The reasons for the preference for large projects could range from more lucrative corruption opportunities to the need to realise huge increases in electricity capacity to drive economic growth. Whatever the nature of this alleged resistance the solar niche does appear to be suffering material effects. The most recent manifestation of this is the imposition of taxes on PV products and the damaging impact this is having on sales, according to those in the pico-solar market in particular.

The relationship between niche and regime actors has been somewhat ambivalent in practice through much of the history of the PV market in Kenya. This is not to suggest that all policy actors are negative towards solar, there are many who have adopted the expectations that are in play. And there have been policy innovations that might help to support further nurturing of the niche. For example, the development and adoption of a national PV curriculum could have important capability building benefits for the long-term health of the niche. The introduction of PV regulations could also address the long-running issues of poor quality, although there could also be detrimental effects too. For example, those technicians who cannot afford the required training and licenses will be forced to either cease work in the PV niche or risk becoming criminalised. Capacity in the PV niche would then diminish and the niche networks fragment, potentially weakening niche development rather than strengthening it. But, beyond niche-regime interactions, there are also continuing attempts to both understand and improve user-practices following the adoption of either SHSs or SPLs. In sum, there has been a multiplicity of institutional developments throughout the niche-building process, ranging from informal user-practices to the highly codified PV regulations. This work is incomplete and it is likely to be necessary for many years yet, as new products and business models are introduced.

The final conclusion we can draw from the analysis in this research relates to our hypothesis that key actors have undertaken capability-building activities in the Kenyan solar niche and that these activities explain the relative success of the SHS and SPL markets. We have referred to capabilities as skills, knowledge and linkages between actors throughout an economy (and a society, given that we are interested in the provision of electrical services in that society). Here we can see that actors such as EAA not only deployed expectations that recruited resources and other actors, and guided problem-solving activities, they also drew lessons from projects that informed subsequent interventions. They helped devise and deliver training to improve skills, shared knowledge about the market, linked actors together to develop supply chains, raised awareness of PV amongst customers and linked them to these supply chains. They also lobbied the policy regime for a more conducive institutional environment. Taken together, these lines of activity have helped the niche accumulate elements of an innovation system around PV. In the case of the SHS market, EAA (and its subsequent incarnations) was clearly the most important of these innovation system builders for many years. As the niche strengthened, this role has become more distributed (others such as Solarnet, KEREA, KEBS, etc., have taken on more specialised but mostly complementary roles). In the case of pico-solar, Lighting Africa has been the most important actor, although it has benefited from the existing niche networks and those with relevant skills, knowledge and linkages.

Without such capabilities in place, it should be clear that the Kenyan 'free market' in solar would not function. Moreover, the need for capability-building has not diminished. Apart from the capacity-constraints that actors say the market currently faces, new products and business models continue to be the subject of experimentation and these may well require new specific capabilities. Even without new products and business models, the international climate policy instruments, such the CDM, have not yet been exploited in the Kenyan solar niche. If they were to be, along the lines that China, for instance, has exploited the CDM, then there will need to be other specific capability-building efforts if they are to be successful. Given the continuing ambivalence of the Kenyan policy regime to small-scale PV-powered electrical services, there remains considerable political work to do to persuade regime insiders to adopt PV expectations. Alongside these political needs, there is still a tremendous amount of niche-development work to do in relation to both SHSs and pico-solar. The history of the PV niche in Kenya suggests that these kinds of work need to be done by coordinating actors, by actors who are positioned to structure practices and to build innovation systems. The Climate Innovation Centre could be such an actor in Kenya. Where niches already exist to some extent, there might be a need for specialised and complementary roles so that the CIC might better focus on particular aspects of the innovation system. Where there is little or no niche activity, the CIC might need to take on more of the activities necessary to develop the niche, much as Lighting Africa has done in regard to pico-solar. Whatever role the CIC takes, it is clear from the evidence and analysis here that interventions need to be systemic rather than narrow, be patient, and involve a wide diversity of interested actors.

5.2 Key policy recommendations

Drawing on this enhanced understanding of what happened in Kenya, a range of broader conclusions and policy recommendations can be developed. These are summarised below.

5.2.1 Overarching policy goals

The overall goal of policy must be to build functioning innovation systems around low carbon technologies in low-income countries, building technological capabilities through a range of targeted interventions. These must be inclusive in their approach, attending to the self-defined needs of poor people, if low carbon technology uptake is to be widespread and underpin future low carbon development pathways. Our case study provides some clues as to what such an inclusive approach might be. The various projects that have achieved some measure of success were designed and implemented on the basis of careful and context-specific understanding of the needs in the market and of users. Most notable in this regard is Lighting Africa, which conducted highly detailed studies of the lighting practices and needs of poorer users in Kenya (and elsewhere). This suggests that further pro-poor gains might be achieved by including users more actively in the design of hopeful solutions to their energy service needs, rather than merely observing these needs and eliciting users' feedback on products already in the market. The overall result could be to provide protective spaces where niches of low carbon energy technologies, and new low carbon energy practices, can be fostered that could begin to compete with existing energy regimes.

In order to achieve this, our research suggests the following interventions are necessary:

5.2.2 Building actor-networks

Efforts are required to link diverse arrays of stakeholders, from technology importers and suppliers, through to technology users. An emphasis is required on using projects and programmes to establish meaningful links between these different stakeholders, building trust and understanding. As well as linking up different parts of potential innovation systems, this can also help to identify the different technological capabilities that exist within a country or sector, where various gaps exist and how they might be addressed. Simultaneously, by pursuing projects and programmes that proactively link up different stakeholders, new technological capabilities can be built as learning and experimentation is supported within protective spaces. Such networked, stakeholder based approaches also serve to provide spaces where user preferences, needs and energy consumption practices can be articulated. This is critical to developing markets that directly address nascent demand as well as attending to the needs of poor and marginalised people.

5.2.3 Fostering learning

Learning is critical to the development of appropriate technological capabilities and functioning innovation systems and the resulting successful markets for low carbon technologies that these can support. A key role for policy lies in conducting market research and monitoring interventions, making sure the results are publically available. The public availability of such information can play a fundamental role in reducing perceived risks amongst both potential investors and technology users. This facilitates clear and evolving understandings of things like: user needs and preferences; appropriate hardware components; relative performance of different technology brands; approaches that have met with success; issues that contributed to difficulties or failures and how to overcome these. As a result, learning is facilitated that can feedback into future projects and programmes, whether publicly or privately funded.

5.2.4 Expectations and visions

Linked to the need to foster learning, a need exists for initiatives geared towards raising awareness via targeted interaction with existing and potential technology users. This serves to support a range of key requirements. By fostering understandings of what low carbon technologies can and cannot provide, how they work and the ways other users have benefited from them, users' expectations develop around informed understandings of different technological options. This also provides an opportunity for users to provide feedback on both their self-defined energy needs and their experiences (good and bad) with different technologies. As a result, shared visions develop amongst technology users and suppliers relating to what and how low carbon energy technologies can underpin different development pathways. This simultaneously provides vital user-feedback into both technology design and the configurations and brands that vendors and suppliers provide, with attendant implications for potential market size and profitability.

5.2.5 Supporting experimentation

Again, linked to the need for learning, a key role for policy lies in providing funding and protected spaces for experimentation. Stakeholders throughout the supply chain need to gain experience of new low carbon technologies and learn what works and what does not within specific contexts (across different countries, regions, villages, technologies, energy services etc.). Experimentation can target a range of different aspects. It might, for example, include supporting new multi-stakeholder projects that test and develop ideas. These could relate to new technical configurations, new hardware, new practices around existing technologies, new energy consumption practices that could improve the benefits accrued by users, and so on. Experiments might also focus on mutually supportive interventions that link different stakeholders across markets, building supply chains and fostering new market opportunities where previously potential market players lacked awareness of each other and/or potential market opportunities they might target. Interventions could also experiment with working 'upwards' through value chains, building on existing markets to develop progressively higher-value segments, adding value to existing sectors and fostering increasing economic returns from low carbon energy initiatives across low-income countries.

5.2.6 Appropriate institutions

In order to achieve all of the above, appropriate institutional structures are necessary. One way of achieving this is via nested national institutions like Climate Innovation Centres. However, there is a need to ensure that such centre-based approaches are specifically designed to focus on the key considerations articulated above. There is also no specific reason why such institutions need be badged as Climate Innovation Centres, international examples exist (e.g. Innovacion Chile) where similar institutions have been established within developing countries independent of current international efforts. However, there is significant value in linking up such institutional initiatives across different developing countries in order to foster exactly the kind of learning emphasised above, this time across different country and socio-cultural contexts.

5.2.7 Next steps: Moving forward from this study

This in-depth historical analysis of the market for off-grid solar electrical services in Kenya has yielded a range of insights for informing policy and practice around low carbon technologies, particularly within low-income countries. Moving forward from this study there is a clear need for targeted engagement with policy makers and practitioners to communicate and assess these insights within the context of existing policy efforts. The project team is committed to pursuing this, both formally via the various communication and engagement outputs linked to the study, but also informally via the team's continued engagement with policy makers, practitioners and researchers across different countries and low carbon energy sectors.

It is important to note that the findings of this study are based on analysis of a single technology (off-grid solar electricity), providing specific energy services (e.g. light, mobile phone charging, TV etc.) within a specific country (Kenya). Whilst it is likely that the policy recommendations above will prove valuable across different technological and country contexts, there is a critical need for further targeted research to test the extent to which they can be generalised across these different contexts and to learn from comparative analysis.

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Appendix A: Interviewees and others consulted

Aisha Abdulaziz, Energy Consultant and member of the Executive Committee of Kenya Renewable Energy Association, Strathmore University Business School

Alex Mboa, Standards Officer, Kenya Bureau of Standards

Andrew Kilonzo, former Coordinator, Solarnet

Anil Abdulla, Director, Telesales Solar

Anthony Karembu, KfW – Kreditanstalt für Wiederaufbau

Ashington Ngigi, Managing Director, Integral Advisory Ltd

Astrid Lervag, Royal Norwegian Embassy

Bernard Aduda, Principal of the College of Biological and Physical Sciences, University of Nairobi

Bernard Osawa, formerly of Energy Alternatives Africa, now Energy Regulatory Commission

Caroline Nyaboke Ogwang, Sales Manager, Sunny Money Trade

Cathy Owinga, Kenital Solar Ltd

Charles Muchunku, Consultant, Camco Advisory Services, and Chairman, Kenya Renewable Energy Association

Charles Onyango, Senior Inspector (Electrical), Ministry of Energy

Charles Rioba, Managing Director, Solar World (EA) Ltd

Charlie Miller, Sunny Money/SolarAid

Daniel Kithokoi, formerly of Solar Shamba, DAMUKI Enterprises Ltd

Daniel Theuri, former Acting Head, Renewable Energy Department, Ministry of Energy

David Otieno, former Regional Energy Advisor, GTZ, East Africa

Dickson Khainga, Kenyan Institute for Public Policy Research and Analysis

Dickson Muchiri, Projects Manager, Solar World (EA) Ltd

Edward Namasaka, Sales and Marketing Director, Mibawa Suppliers Ltd

Edward Nyaga, formerly Administrative Assistant, Kenya Renewable Energy Association

Enoch Kanyanya, United States Agency for International Development

Enos Orongo, Telesales Solar

Erastus Wahome, Chief Economist, Ministry of Finance

Eustace Muriithi Njeru, Energy Regulatory Commission

Evanson Njenga, Consultant Energy/Higher Education (rural electrification & renewable energy), Japan International Cooperation Agency

Fatuma Hussein, Head of Climate Change Unit, Ministry of Environment and Mineral Resources

Frank Jackson, former Manager, KARADEA Solar Training Facility

Fred Migai, Pico-solar Entrepreneur, Kenya

Gilbert Maeda, former Country Liaison Officer, African Development Foundation

Helen Baker, PWC – Price Waterhouse Coopers (Global and Africa Technical Assistance)

Henry Watitwa, Chairman, KESTA – Kenya Solar Technician Association, and Managing Director, Bright Home Solar

Jacob Kimuya, Sales and Marketing Executive, Ubbink East Africa Ltd

James Muriithi, Director of Renewable Energy, Rural Electrification Authority

Janakaraj Murali, Area Convenor, Rural and Renewable Energy, TERI – The Energy and Resources Institute

Joseph Mwangi, Assistant Executive Officer, Kenya Association of Manufacturers

Joseph Onjala, formerly of Ministry of Energy, now Institute for Development Studies, University of Nairobi

Justus Simiyu, University of Nairobi

Klara Lindner, Project Manager, Mobisol

Koros Kiprotich, Reporter, Science Africa

Kyran O'Sullivan, Senior Energy Specialist, World Bank

Leo Blyth, formerly Engineer/Entrepreneur, Sunpak, and now International Finance Corporation

Maitene Cancellon, AFD – Agence Française de Développement

Margaret Kamau, PWC – Price Waterhouse Coopers, Kenya

Mark Hankins, former Managing Director, Energy Alternatives Africa, now Managing Director of African Solar Designs

Mary Kabatange, former Country Liaison Officer, African Development Foundation

Michael Omondi, Solar World (EA) Limited

Minori Chitani, Representative Infrastructure/Economy, Japan International Cooperation Agency

Murefu Barasa, International Finance Cooperation

Musa Mzumbe, former Manager, KARADEA Solar Training Facility

Mwatu Mbithi, Ministry of Energy

Nicholas Gachie, Executive Officer, Energy Services, Centre for Energy Efficiency & Conservation, Kenya Association of Manufacturers

Nick Hughes, Strategy Director and Founder, M-KOPA

Oswald Kasaizi, former Executive Secretary, KARADEA

Otieno S. Owino, Reporter, Science Africa

Paul Amambia, former Engineer, Energy for Sustainable Development (Africa)

Paul Kere, Director of Policy, Ministry of Environment and Mineral Resources

Paul Mabonga, Sales and Service Engineer, Chloride Exide

Raphael Khazenzi, Director Renewable Energy, Ministry of Energy

Rashid Mohammed, Kenya Pastoralist Consortium on Climate Change

Robert Pavel Omieke, Director of Renewable Energy, Energy Regulatory Commission

Sanne Willems, Infrastructure Programme Manager, European Commission

Shem Arungu-Olende, former Coodinator for UN Conference on New and Renewable Sources of Energy, and now Secretary-General of The African Academy of Sciences and CEO of Queconsult

Simon Bransfield-Garth, Chief Executive, Azuri Technologies, UK

Stephen Kinguyu, National Climate Change Action Plan Secretariat, Ministry of Environment and Mineral Resources

Stephen Mutimba, Managing Director, Camco Advisory Services

Teddy Ongamo, formerly KUSCCO, now Consultant, Camco Advisory Services

Timothy Ranja, Programme Analyst, United Nations Development Programme

Tom Owino, Vice President, JP Morgan ClimateCare

Vincent Loh, former Chairman, Kenya Renewable Energy Association

Walter Kipruto, Component Leader (Solar), GIZ

Plus eight anonymous (4 private sector, 1 university, 1 donor, 2 government)

Appendix B: Semi-structured interview questionnaire

These questions are intended to form the basic structure of the interview such that each question may lead to further questions, which would be for clarification and exploration of the main idea.
You are not obliged to answer any question you do not wish to answer and you are, of course, at liberty to end the interview at any time.

Before the interview begins, we shall ask you whether you are happy to:

- Have the interview recorded (we can provide a copy of the recording)
- Be cited by name and/or organisation/role, or prefer to remain anonymous

Please check the recording at your earliest convenience and contact us with any corrections, or additional comments, as you feel are necessary or appropriate. We can agree a date beyond which we will assume no changes are necessary if we have not had any contact from you.

Questions

General overview

1. Please describe the process in general terms: how, when, why and by who was it initiated; and how did it progress through to completion, particularly in terms of achievements, challenges and unanticipated developments?
2. What was, or is, your role in the process? How and why did you become involved?

Building connections

3. Who else was involved in the process, how and why did they become involved, and what were their roles? In what ways were they important to the process?
4. What efforts and or activities were undertaken to build relationships between those involved?
5. What kinds of relationships continued after the process finished? Did they lead to any further activities?

Building skills and knowledge

6. What skills and knowledge did those involved already have before the process began?
7. What skills and knowledge did the process help to develop, and why were these skills and knowledge seen as important?
8. What were the sources of any new skills and knowledge and how were they accessed?
9. What arguments were used to say that these skills and knowledge were important? What were the alternative or counter-arguments?
10. In what ways have the skills and knowledge that were developed in the process continued to be used or developed, and in what ways have they not been used or developed?
11. What skills and knowledge still need to be developed, and why?

12. What arguments are now being used to say that these are the skills and knowledge that need developing? What are the alternative or counter-arguments?

Developing policies, laws, regulations and practices

13. Before the process began, what were the enabling and constraining policies, laws, regulations and practices (including normal technical, cultural and social practices) relevant to this process?
14. Which of these policies, laws, regulations and practices were targeted in the process, and why were they targeted? In what ways were they important?
15. In what ways was the process helpful or unhelpful for impacting on these policies, laws, regulations and practices?
16. What new policies, laws, regulations and practices emerged from the process?
17. What other enabling and constraining policies, laws, regulations and practices remain after the process?

Resources and resistance

18. What resistance from others was there to the process?
19. What kinds of resources were provided for the process, who provided them, how much did they provide and in what ways were they important?
20. In what ways did the provision of these resources enable and constrain the process?
21. What ability did, or do, those who provided resources have to influence policy making or other aspects of the SHS market in Kenya?
22. In what ways did they use their ability to influence policy making or other aspects of the Kenyan SHS market after their provision of resources to the process?

Further reflections

23. If the process were to be tried again, what do you think should be done differently (both internally and externally to the process), and why?
24. What lessons can the experience of the process give to the operation of the Climate Innovation Centre?

Appendix C: Innovation history timeline

Socio-technical development/innovation
1981 *UN Conference on New and Renewable Sources of Energy held in Nairobi*
1982 *Harold Burris sets up* Kidogo Systems *in Machakos, Kenya*
1982 August *Failed Coup*
1983 *The government directed Voice of Kenya to increase TV network country-wide*
1983 *NASA Lewis Research Center and Solarex design and install two clinic systems in Kenya*
1983 *BP Solar East Africa sets up office in Kenya*
1983 *Burris and Hankins meet in Nairobi cafe*
1983 December *First solar and TV in rural Kisumu*
1984 *US exports of PV cells to Tanzania and Kenya*
1984 *Karamugi Harambee Secondary School PV installation*
1984 *Harold Burris renames his business to* Solar Shamba *and moves to Embu, in the coffee-growing belt around Mt. Kenya*
1985 *USAID-supported PV training course and installations in three schools around Mount Kenya*
1985 *Various firms enter the PV market (Television Sales and Rentals – Telesales; Alpa Nguvu; Associated Battery Manufacturers; Solar World)*
1986 *Import duties and VAT removed from solar modules*
1987 *Various firms enter the PV market (NAPS; Chintu Engineering; Total Solar)*
1987 *Attempt to produce sessional paper on energy – never made public*
1988 *Kenital incorporated*
1988 *Burris returns to the US*
1989 *Introduction to the Kenyan market of amorphous modules*
1989 *Two more PV market entrants (Animatics; Botto Solar)*
1990 *Two more PV market entrants (Hensolex; Marathon Marketing)*
1991 *Two more PV market entrants (Sollatek; Mitha and Company)*
1991 *Hankins publishes* Solar Electric Systems for Africa
1991 *Simon Roberts publishes a detailed guide to designing and installing small PV systems*
1992 *Donors suspend aid to Kenya*
1992 *Government re-introduces duties and VAT on solar equipment*
1992 *Energy Alternatives AFRICA founded (by Hankins and Kithokoi)*
1992 *Two more PV market entrants (Rodson Electronics; Woodventure Kenya)*
1992 *Regional Solar Electric Training and Awareness Workshop in Nairobi – March 15th to 27th*
1993 *Seminar in Nairobi on renewable energy technologies*

1993 *KARADEA Solar Training Facility constructed and runs its first solar training course, Hankins and Kithokoi involved in the training*
1993 *Solagen starts selling solar*
1994 *Automobile and Industrial Battery Manufacturers enter PV market*
1994 *Proposal between University of Nairobi and a private manufacturer to fund a pilot PV foundry*
1995 –2013, 2010 *Training of MSc and PhD students on PV systems – curriculum (MSc) revised to include more course units in solar energy materials*
1995 *Hankins publishes second edition of* Solar Electric Systems for Africa
1995 *Bunyala Wholesalers Ltd. Start selling PV on hire purchase*
1996 *Amorphous solar panel introduced to electrical department at Comboni Polytechnic in Gilgil*
1996 December – March 1997 *Survey conducted through EAA covering 410 SHSs in 12 districts across Kenya*
1997 *SHS pilot project involving three different micro-finance models*
1997 *Electric Power Act*
1998 *Renewable Energy Department created in the Ministry of Energy*
1998 – present *University research on solar energy materials*
1998 *Two more PV market entrants*
1998 *Solarnet officially formed*
1998 *Photovoltaic Market Transformation Initiative (PVMTI) begins*
1999 *Kenya Bureau of Standards initiates development of PV standards*
2001 September *Consultative meetings on energy policy*
2001 *Solar PV installation in all Kenya Wildlife Service posts*
2002 August *Kenya Renewable Energy Association (KEREA) registered*
2003 *Patrick Nyoike becomes the Permanent Secretary at the Ministry of Energy*
2003-2004 *Installation of PVs in 10 Energy Demonstration Centres*
2003 *VAT exemption on solar accessories*
2004 *Draft Energy Policy produced by Ministry of Energy*
2004 *Ministry of Energy Strategic Plan for 2004-2009 includes commitments for the promotion and installation of PV systems*
2004 *Energy Bill introduced into the National Assembly*
2005 *Kenya Solar Technician Association (KESTA) registered*
2005 *Sustainable dissemination network for solar PV*
2005 September *Chesewew Secondary School pilot PV project*
2005 *The Sessional Paper on Energy is enacted*
2006 March – 2009 *KPVCB (Kenya Photovoltaic Capacity Building) Project*
2006 *Energy Act*
2006 *Energy Act signed into law, Saturday December 30th*

2007 *Report (draft) on infrastructure development progress over the period 2002/2003 to 2005/2006*
2007 *Lighting Africa Development Marketplace competition launched*
2007 *Electricity Regulatory Board becomes the Energy Regulatory Commission, July 7th*
2008 *New SACCO Act – Liberalisation of SACCOs*
2009 *Lighting Africa begins active interventions in Kenya*
2010 *MSc curriculum revised to include more course units in solar energy materials*
2010 *Solarnet officially closed*
2010 *Lighting Africa Conference and Trade Fair held in Nairobi*
2011 February *Pay-as-you-go home solar system is introduced in Kenya, starting with trials*
2011 – present *Development of solar panel testing/standardisation laboratory*
2011 August *Ubbink East Africa begins module assembly in Naivasha*
2011 October *Commercial introduction of pay-as-you-go home solar system branded 'Indigo'*
2012 July *Curriculum development workshop for T1 and T2*
2012 September *PV regulations come into force*
2012 October – December *Consultancy and advising in development of a PV training syllabus and material assembly for rural technicians*
2013 February 2nd *MOE engages consultant for training of technicians on PV systems*
2013 April – present *Partnership proposal between Altech Engineering and Equity Bank on power loans*
2013 May *Kenya private sector engagement in development of T3 solar PV curriculum*
2013 July *Kenya low carbon development policy launched*
2013 July *Lighting Africa officially ends Kenya programme*
2013 October *16% VAT introduced on solar systems*