Collaboration for Environmental Evidence
Library

CEE review 11-004

WHAT ARE THE MAJOR BARRIERS TO INCREASED USE OF MODERN ENERGY SERVICES AMONG THE WORLD'S POOREST PEOPLE AND ARE INTERVENTIONS TO OVERCOME THESE EFFECTIVE?

Systematic Review

WATSON, J. [1], BYRNE, R. [1], MORGAN JONES, M.[2], TSANG, F.[2], OPAZO, J. [1], FRY, C.[2] & CASTLE-CLARKE, S.[2]

[i] School of Business, Management and Economics - SPRU – Science and Technology Policy Research - The Freeman Centre - University of Sussex - Brighton BN1 9QE- UK

[2] RAND Europe, Westbrook Centre, Milton Road, Cambridge, CB4 1YG, UK

Corresponding authors: Professor Jim Watson (W.J.Watson@sussex.ac.uk)
and Molly Morgan Jones (mmjones@rand.org)

Draft protocol published on website: 30 May 2011 - Final protocol published on website: 10 August 2011 - Draft review published on website: 7 February 2012 - Final review posted on website: 2nd October 2012

Cite as: Watson, J., Byrne, R., Morgan Jones, M., Tsang, F., Opazo, J., Fry, C. & Castle-Clarke, S. 2012. What are the major barriers to increased use of modern energy services among the world's poorest people and are interventions to overcome these effective? CEE Review 11-004. Collaboration for Environmental Evidence: www.environmentalevidence.org/ SR11004.html.

Abstract

Background: A lack of access to modern energy services among the world's poor is widely recognised to have negative impacts on their health, education and quality of life, as well as a lack of growth of income at a national and individual scale, further deepening and entrenching their poverty. However, despite the long-standing efforts of many national and international organisations to improve the accessibility of the poor to modern energy services, progress has been slow. Given the uneven record of interventions over many years, there is a large body of literature that attempts to identify what is preventing success (i.e. what are the barriers), and what policies might be implemented to realise widespread access to modern energy services for the world's poor.

Methods: The review was performed in order to answer the question: (i) "What are the major barriers to increased use of modern energy services among the world's poorest people", and (ii) "are interventions to overcome these effective?" A structured, systematic review of academic and grey literature focussed on developing economies, including the BRICS (Brazil, Russia, India, China and South Africa) countries, was conducted according to a detailed search protocol. This included five sets of search terms relating to modern energy services, modern energy technologies, barriers, interventions, and effectiveness measures. Semi-structured interviews were also conducted to triangulate the literature searches and findings. Retrieved papers were then systematically reviewed and included in the study according to a detailed set of criteria related to relevance to the topic of barriers to, and interventions for, modern energy services. In particular, papers were included if relevant to barriers, interventions, lessons learned and geographic focus. Furthermore, each paper was assessed in terms of the quality of its evidence base and foundation for conclusions. Papers which met these criteria as well as a rigorous set of quality criteria for methodological robustness were qualitatively analysed and synthesised into a single narrative.

Results: Despite the large body of work analysing barriers to, and interventions for, using modern energy services, there is a highly uneven spread of coverage and a significant lack of high quality research. Much of the literature focuses on financial barriers and interventions, electricity services, a few technologies, and a small number of developing countries. Within the limited high quality research available, there are constraints to the certainty with which conclusions can be drawn about what barriers are the most important, and what is the relative effectiveness of interventions to overcome them. While this is problematic for policy makers seeking to intervene to increase the use of modern energy services amongst the world's poorest people, there are areas where evidence is conclusive. It is also important to note that the particular method of conducting a systematic review may exclude significant amounts of evidence from the practitioner literature, which might be reporting valuable knowledge relevant to the focus of this review.

Conclusions: Most of the evidence on economic and technical barriers to energy access is consistent and strong. Specifically, this evidence relates to high upfront costs of energy conversion technologies and grid-connection charges, cost-recovery difficulties, poor performance of equipment, and technical capacities for operation and maintenance. However, evidence for interventions to overcome these is less robust. The weakest evidence concerns political and cultural barriers and associated interventions, despite frequent references to their importance. Moreover, our review highlights the interactions between different types of barriers and interventions. To understand these interactions, and increase the chances that the poor can gain access to modern energy services, analyses of barriers and implementation of interventions should be more systemic. The review concludes with implications for policy, management and research that flow from these conclusions.

Keywords

Modern energy services, Modern energy technologies, barriers, interventions, developing countries, Sub-Saharan Africa

1. Background

Although there is no simple definition, modern energy services are often identified in terms that contrast them with traditional energy services such as those derived from the burning of biomass in open fires (UN-Energy 2005; Brew-Hammond 2010). As such, the notion tends to combine both energy carriers and associated technologies, together with the benefits to users that these afford: lighting, cooking, heating, transportation, and so forth (UNDP 2005). Examples of modern energy services, therefore, include (among others) electricity from solar home systems (SHSs) for lighting, natural gas burned in modern stoves for cooking and petroleum-based engines for motive power to enable agro-processing (Modi et al. 2005; Practical Action 2010). However, as this review will show, there is not always complete agreement or clarity within the literature about how modern energy services are defined. The overall review strategy therefore aimed to be as broad as possible so as to enable a robust analysis of the concept. However, further comments are made in the results section about refining this definition.

A lack of access to modern energy services among the world's poor is widely recognised to have negative impacts on their health, education and quality of life, as well as a lack of growth of income at a national and individual scale, further deepening and entrenching their poverty (DFID 2002; Modi et al. 2005; UNDP-WHO 2009; Bazilian et al. 2010). However, despite the long-standing efforts of many national and international organisations to improve the accessibility of the poor to modern energy services, progress has been slow (Modi et al. 2005). One notable exception to this pattern is the case of China's electrification programme, which has achieved about a 99% electrification rate (although 1% of the Chinese population is still a large number of people) (Urban 2009). Nevertheless, the record in China is not entirely one of success: there are significant problems with, for example, the reliability of China's electricity supply (Cherni and Kentish 2007). If progress elsewhere continues along current trends, the world's energy-poor will remain so, with the current 1.4 billion without access to electricity only falling to 1.2 billion by 2030 and the 2.7 billion who rely on traditional biomass today rising to 2.8 billion over the same period (OECD-IEA 2010). Some interventions have had limited beneficial impacts, while others have worsened the situation for the energy-poor (Karekezi and Sihag 2004)[1].

Given this uneven record of interventions over many years, there is a large body of literature that attempts to identify what is preventing success, and what policies might be implemented to realise widespread access to modern energy services for the world's poor. One of the abiding concepts in these analyses is that of barriers to access or to the adoption of technologies that can deliver modern energy services. The UK Department for International Development (DFID) commissioned this systematic review in order to "neutrally collect, critically appraise and synthesise" the evidence provided in the literature on barriers to the use of modern energy services among the world's poorest people, and interventions to remove those barriers, as part of its drive for evidence-based policy making (DFID et al. 2010:1). The final review provides an analysis of the evidence base so as to inform DFID's policy and practice. DFID has asked the review team to focus on sub-Saharan Africa, but the team has conducted the searches in as broad a manner as possible in order to capture lessons learned from lower-middle income countries in other parts of the world.

[1] The review focuses on the barriers affecting or interventions targeting poor people in developing countries, particularly those of Sub-Saharan Africa, who lack access to modern energy services. We acknowledge that the terms poor or poorest people are rather simplistic and general. However as poverty levels and thresholds are defined by the particular conditions of every country or territory we have remained cautious in adopting a particular definition or parameter (such as a predefined average income level) to assess inclusion/exclusion of papers. We have nonetheless adopted World Bank categorisation of "developing country" (WDI 2009) as one of the relevance criteria (see section 3 below).

The main body of this report is structured in the following way: Sections 2 and 3 set out the research protocol that was used to collect, analyse and synthesise the available evidence.[2] Section 4 details the findings and analysis. Section 5 discusses limitations of the study and Section 6 presents final conclusions, including implications for policy and knowledge gaps. Sections 7-10 cover final aspects of the review, including a full list of references in Section 9. Appendices A and B list the search terms used for the academic and grey literature, respectively. Appendix C provides the quality review criteria, and appendix D gives any conflicting interests of the authors. The results from pilot testing are given in appendix E, and a list of articles excluded at full text stage is presented in Appendix F. Appendices G and H provide quantitative analysis of the grey literature and appendices I and J give the systematic maps for this grey literature.

2. Objective of the Review

The objective of this review was to address two primary questions: (i) "What are the major barriers to increased use of modern energy services among the world's poorest people", and (ii) "are interventions to overcome these effective?"

The following sub-research questions immediately fall out of the primary, overarching question.

- What are the different types of modern energy services, and associated technologies for their delivery and/or use, which are used, or could be used, by the world's poorest people?
- What are the major economic, technical, political, cultural and social barriers to the use of modern energy services, and associated technologies, amongst the world's poorest people? What criteria are used to define a 'major' barrier?
- What are the different types of interventions that have been used to promote or increase uptake of modern energy services and technologies? What are their characteristics and outcomes?
- What are the different measures of effectiveness which are used to assess the interventions and how do these vary depending on the intervention, the modern energy service and the relevant barriers in different contexts?

DFID requested that the review concentrated on modern energy services other than cooking, as another systematic review has been commissioned to understand the specific issues related to cooking technologies, such as kerosene or gas which are often categorised as modern fuels for cooking. The review did not include these (and other modern cooking fuels) and the associated technologies, nor did it include transport-related technologies. The specific list of terms used to exclude such technologies is given below in section 3.1.1.

3. Methods

3.1 Searches

3.1.1 Search terms and languages

A broad range and combination of search terms were used. An initial list of search terms, divided according to the four sub-questions, is given below. These were continually refined during the

[2] See Watson, J., Byrne, R., Opazo, J., Tsang, F., Morgan-Jones, M. & Diepeveen, S. 2011. What are the major barriers to increased use of modern energy services among the world□s poorest people and are interventions to overcome these effective? CEE protocol 11-004. Collaboration for Environmental Evidence: www.environmentalevidence.org/ SR11004.html

search, and after a pilot search stage (see below) and the list here represents the final search terms which were used. As far as possible, the terms allow for variants of word beginnings and endings. For example, *phone charg* should capture *phone* and *telephone* as well as *charger*, *chargers* and *charging*. The full set of search terms are provided in Appendix A.

The search terms were applied to TITLE-ABSTR-KEY searches in all cases for the academic literature databases. However, this was not possible for all of the grey literature as this depended on the capacity of individual databases. A full set of search terms for each grey literature database is given in Appendix B.

Some of the terms on the above lists have generic meanings in addition to their specific meanings in the field of energy. For example, the pilot test search revealed that the terms "light*" and "illuminat*" resulted in many irrelevant hits which have the terms in their abstracts to mean "to show clearly". Therefore, in order to improve the relevance of the search, it was judged that it would be necessary to ensure that either the terms "energy" or "electricity" were in every search.

To ensure that the search retrieved a manageable number of hits, the parameters of the search were also defined by language and location. Only English language publications were included, given the skills of the research team members and the resource constraints of the current review. In addition, the main emphasis of the review was on studies conducted in low-income countries in Sub-Saharan Africa. For the most part, only these studies were included past the title review stage, although it is recognised that some studies conducted elsewhere will include important comparators with sub-Saharan African contexts. In light of this, a targeted search was done of the retrieved literature covering Brazil, Russia, India, China and South Africa (otherwise known as BRICS) for specific interventions and electrification programmes. Further information about this search and geographic and topical coverage of the review is discussed in sections 3.1.7 and 3.2.

3.1.2 Search strings and/or combinations of searches

The primary review question is comprised of two parts, with the first part focussed on the barriers and the second part focussed on the interventions. It was recognised that papers that are relevant to barriers may not necessarily discuss interventions, but papers that are relevant to interventions should cover the specific barriers which are being addressed. Three searches were therefore undertaken; one each to identify barriers, interventions and effectiveness measures. All three searches included the terms for energy services, technologies and geographic regions. Many of the papers appeared in more than one of the searches and duplicates were removed prior to undertaking the title and abstract review to avoid any duplication in effort.

Search #1 to locate papers that identified the energy services/technologies and barriers in the selected geographic regions:

(energy OR electricity)
AND
(List 1a and List 1b search terms "OR-ed" together)
AND
(List 2 search terms "OR-ed" together)
AND
(List 5 search terms "OR-ed" together)

Search #2 to locate papers that focussed on the energy services/technologies and interventions in the selected geographic regions:

(energy OR electricity)
AND
(List 1a and List 1b search terms "OR-ed" together)
AND

(List 3 search terms "OR-ed" together)
AND
(List 5 search terms "OR-ed" together)

Search #3 to locate papers that focussed on the energy services/technologies and effectiveness measures in the selected geographic regions:

(energy OR electricity)
AND
(List 1a and List 1b search terms "OR-ed" together)
AND
(List 4 search terms "OR-ed" together)
AND
(List 5 search terms "OR-ed" together)

We undertook pilot searches to test the effectiveness of these keywords. Key pilot search results which influenced our search strategy were recorded in Appendix E.

3.1.3 Comprehensiveness and effectiveness of the search

While a systematic review methodology is designed to be comprehensive, it is always possible that relevant articles are missed. In this review, librarians[3] formally trained in conducting comprehensive literature searches using technical search strategies and data retrieval methods were used to help minimise this risk. All of the searches, including pilot testing, were conducted by a RAND librarian with oversight and continued iteration with members of the review team so as to ensure the retrieved articles were relevant to the purposes of the study.

In addition, steps were taken to limit the potential for bias of some geographic locations over others. Though the task was to focus specifically on sub-Saharan Africa, the searches were conducted in as broad a manner as possible and geographic exclusion terms were only applied to the search at the abstract review stage.

In addition, there is a risk that a literature search will not capture relevant findings in books or edited books where individual chapters are not indexed. Additional interviews were undertaken with a selected group of seven experts, identified in consultation with DFID, to minimise this risk and identify relevant literature our search might have missed. The interviews were also used to gain key insights into barriers and interventions and these were triangulated against the findings from the literature analysis.

3.1.4 Publication databases searched

A range of scholarly database sources were searched, such as:

- subscription databases including JSTOR, Web of Science, WorldCat, Business Source Premier, GreenFILE, U.S. Department of Energy (U.S. DOE) Energy Citations Database, and EconLit.
- in particular, individual journals such as Energy Policy, Renewable and Sustainable Energy Reviews, Global Environmental Change, World Development, and Rural

[3] The librarians are trained in providing customised research support by assisting with development of search strategy, literature searches, citation management, cited reference searches and document delivery. In addition, RAND librarians are knowledgeable in locating and retrieving difficult to find and elusive sources for researchers and have expert knowledge in rapid searches of internet sources and stakeholder organisations in order to retrieve grey literature.

Sociology were included in the subscription databases as these journals were particularly relevant to our review.

3.1.5 Specialist search for grey literature

Grey literature was retrieved through searches conducted in the following non-subscription databases and websites of key stakeholder organisations:

- the International Energy Agency, United Nations databases, Organisation for Economic Cooperation and Development, the World Health Organisation, the World Bank, the African Development Bank, the Renewable Energy and Energy Efficiency Partnership, the Global Village Energy Partnership, and the African Energy Policy Network.

Similar search terms to those used in the subscription databases were applied to the internet search, although depending on the database we were often limited in our ability to apply all the search terms. We also applied additional, specific inclusion/exclusion and quality review criteria to the grey literature which are further described in Section 3.2 below.

3.1.6 Literature provided directly by stakeholders, including peer reviewers

We sought advice from DFID on an appropriate list of key stakeholders to contact and conducted interviews with them as discussed above. When literature was provided to us by stakeholders, we included it in the review along with the other articles and evaluated it according to the established study inclusion criteria. Similarly, when expert views were provided to us by stakeholders, we considered it as a single source of evidence and assessed its quality and relevance to the review during the data analysis stage (described below in Sections 3.4-3.6).

3.1.7 Targeted search of BRICS literature

As mentioned above, though the main emphasis of the search was on literature in Sub-Saharan Africa, it was important to capture some lessons learned from interventions in other countries. In consultation with DFID, and after an initial assessment of the academic literature selected for full text review (see sections below for information on this process) for gaps, the team conducted a targeted search of the retrieved literature on the BRICS countries using the EndNote search function. The terms used in these searches are in Annex A, but broadly covered the following topics: rural electrification, poverty alleviation, solar home systems, biogas digesters, and decentralised energy. These terms were selected because they were believed to cover interventions and programmes which were likely to indicate clear lessons learned and messages about 'what works and why' in the BRICS countries. The papers identified in this way were added to the review and evaluated according to the review criteria.

3.2 Study inclusion criteria

Inclusion criteria were defined and used to determine which studies were included for further review out of those retrieved in the searches (see section 4.1 for totals). Inclusion criteria were organised by: relevance to the subject of the review; by the types of intervention; by the types of comparators in the studies; by the types of outcomes discussed (effectiveness); by the types of the study; and by geographical relevance. Further detail about each type of criterion and the review stage (title, abstract or full text) is given below.

Two sources of literature were used: peer-reviewed academic articles and grey literature. The inclusion criteria which were applied were the same for both sources, although we first focussed

on academic literature as this set of papers was more likely to include highly relevant and methodologically good quality articles[4]. The results from the inclusion assessment of academic literature allowed us to gain an initial understanding of the types of barriers present and interventions implemented to increase the use of modern energy services. We then applied the inclusion criteria to the grey literature, focusing in particular on the lessons learnt from interventions implemented to overcome barriers to increased use of modern energy services. We adopted this focus here as we thought the grey literature was likely to have particular relevance to lessons learned about interventions, for example through evaluations of major World Bank programmes. However, it was also introduced due to resource constraints and the need to narrow the scope of the initial body of grey literature which was returned. For this reason, we also introduced two other inclusion criteria for this set of literature: i) studies published after 2005 and ii) studies where the geographic focus was Sub-Saharan Africa. Further information about the quality review criteria for the grey literature are discussed in Section 3.4 below.

The full set of articles was first reviewed by title according to the first two broad categories of inclusion criteria below (relevance by subject and geographic coverage). The criteria were applied in a tiered fashion, that is, if an article passes the first stage of relevance of subject, we then applied the criteria for geographic coverage. However, many papers had ambiguous titles. If there was no direct information about barriers, interventions or geographic coverage in the title, we erred on the side of caution and included the article for further abstract review.

3.2.1 By relevance of the subject(s)

The first inclusion criterion applied was relevance to the main subject of the review. This criterion was applied at the title review stage. If the article did not meet these basic relevance criteria, and there was no ambiguity in the title leading it to be included out of caution, it was immediately excluded from the review. These criteria were:

- Discussion of modern energy services or energy technologies
- Barriers to using energy services (including but not limited to those listed in List 1a and b in Appendix A), or interventions to using energy services (including but not limited to those listed in List 3 in Appendix A)
- Population, or subject of the review, as including 'the world's poorest people'. Only studies which examine the situation in at least one "developing country" as defined by the World Bank (WDI 2009) were included. At the title stage inclusion assessment both low and middle income countries were considered and then the geographic relevance criteria described below were applied.

3.2.2 Geographic coverage

Each article was reviewed at the title stage for geographic relevance. If it was not possible to deduce geographic coverage at the title review stage, the article was included for abstract review, at which point it was feasible to deduce geographic coverage of the article according to the criteria discussed below.

The team recognised it was possible that barriers to uptake of modern energy services, and interventions to overcome them, have been studied in one part of the developing world but not another. Although the review analysis focuses on sub-Saharan Africa, this is not to imply there is not value to be gained by including evidence from Asia and Latin or South America, or even

[4] The authors recognise that publication in an academically peer-reviewed journal is not an automatic indication of relevance or quality, and for this reason the reader will note that a detailed quality review stage was carried out and is described in Section 3.4.

articles looking at pockets of extreme poverty in higher-income countries. However, as discussed above, due to resource constraints a full geographic review which would have allowed for this comparison was not possible. The team did, though, conduct a targeted search of the BRICS literature which enabled some comparative analysis of interventions and lessons learned.

3.2.3 By types of intervention

The intervention had to be a public policy intervention or type of involvement to encourage or address increased uptake of energy services. If at least one of the intervention(s) discussed in the article was a public intervention, then the article was selected for inclusion in the full text review. 'Public intervention' was taken to mean an activity undertaken by an actor (or actors) not working through normal market means. This does not mean that private actors were precluded. Private actors may well be involved, but it was expected that there would be some kind of public dimension to the activity: for example, donor-support, NGO involvement or government role. The rationale for this criterion was that if normal market means are able to deliver modern energy services then there is no need for an intervention to address a 'market failure', and so the study will have little relevance to the needs of this review.

3.2.4 By types of comparator

Each article was reviewed for inclusion of the following comparators. If one of the comparators below was listed, the article was selected for full text review. The comparators used to include studies were:

- *Use of modern energy services before/after an intervention to target barriers to use*: This was the most obvious comparator to select and the presumption here was that the intervention successfully targets the intended barrier (or barriers) and any change in outcome can be attributed to the intervention. However, it may not have captured compounding factors (e.g. changes in the broader context that might have had more impact than the intervention), and it would not have necessarily captured technology substitution (e.g. if the energy service is new to the user).
- *Use (and associated barriers to use) of modern energy services/technologies versus prior use of traditional fuels*: This comparator captured technology substitution.
- *Use of modern energy services versus use of traditional fuels used at the same time within a geographical region/community*: This could have revealed something about other factors such as individual decision making, or revealed something about the relative importance of different barriers/interventions.
- *Analysis of different communities*: This could have revealed something about factors in the contexts of different (localised) cultures.
- *Analysis across different time periods*: Different time periods are likely to consist of more differentiated contextual factors and so could have revealed the relative importance of context versus barriers/interventions.
- *Use of two or more different types of modern energy services/technologies*: There could be two or more modern energy services/technologies being used within the same household; or different modern energy services/technologies used across different households; or the same modern energy service being realised with a range of technologies either within the same household or across different households. In all cases, the relative importance of barriers and interventions could be different across these combinations.

3.2.5 By types of outcomes

Studies were not excluded from the review based on the types of outcomes. The review question was interested in studies looking at barriers to the use of modern energy services, and in the effectiveness of interventions to address barriers. As such the team was interested in two outcomes: first, use of modern energy services, and second, effectiveness of interventions. Thus, the team have looked primarily for studies that included some type of an indicator of the type/level of energy services being used and evidence of increased use. The analysis explored the robustness and variation across different types of indicators and drew conclusions about what and how they are conceived of, how this varies in different contexts, and the implications for judgements about effectiveness.

3.2.6 By types of study

Articles or reports were not excluded from the review on the basis of study type, and both quantitative and qualitative studies were included in the review. For quantitative analysis, only studies that have controlled for time periods and geographic location were selected. For qualitative studies, this control criterion was problematic. In such cases, the review team assessed whether the analysis was appropriately sensitive to contextual factors and the extent to which lessons could be translated to other contexts. These criteria helped ensure that only the highest quality quantitative and qualitative research was selected for inclusion.

3.2.7 Kappa test(s) for consistency of decision regarding inclusion/exclusion, at title, abstract, and full-text level

After the first review of titles, two reviewers reviewed the abstracts of all accepted articles and made decisions about inclusion or exclusion for consideration for full text review. In both stages, reviewers kept a record of whether articles were accepted or rejected on the basis of just the title or both title and abstract. Reasons for acceptance or rejection based on the abstract were recorded in a template.

Prior to the full review of all the articles retrieved, (of which there were 22,957 as shown in Figure 1 below), a Kappa test was performed to ensure consistency between reviewers. This involved two members of the review team making independent decisions on accepting/rejecting a small sample of 500 of the relevant articles. This number was based on the recommended sample size, which is a minimum of 10% of the full list, up to a maximum of 500 references (CEE guidelines, p. 37). The Kappa test was passed with a level of 0.55 which indicated a moderate level of agreement between the reviewers and after discussing and resolving reasons for discrepancy, the team was able to proceed to reviewing all titles and abstracts independently.

3.3 Potential effect modifiers and reasons for heterogeneity

The majority of studies were qualitative in nature and heterogeneity of study type and output prevailed as can been seen in the analysis sections 4.1-4.3 and as discussed in more detail in Section 5. Contextual factors of each study were considered as these may have had an impact on outcomes or findings of the study (see Section 5 below for a discussion). Difficulties that may have arisen were anticipated because of many factors in study design and analytical approach. In quantitative research, these problems are usually discussed in terms of reliability and validity (both internal and external). These terms are less appropriate for qualitative research; instead ‘equivalents’ used were dependability/auditability in place of reliability, credibility/authenticity

in place of internal validity, and transferability/fittingness in place of external validity (Miles and Huberman 1994; Lewis and Ritchie 2003). There were, indeed, many possible ways to attempt to address these difficulties and many of them are covered in more concrete terms in the next section on how study quality was assessed.

3.4 Study quality assessment

In order to determine which papers were given a greater emphasis in the full text analysis and final data synthesis, each of the selected papers was assessed according to their topical and methodological relevance, as well as for their quality and potential risk of bias. This process proceeded in two stages. First a rapid quality assessment was made of the paper for basic quality criteria (listed below). If any of these were not met, the paper was excluded. After this, the paper was then subject to a more detailed quality assessment and data extraction process whereby the information and data in the text was systematically reviewed and summarised in a separate data template. This allowed the reviewer to determine the quality of the different types of data, analysis and conclusions. A full list of the questions the reviewer considered in this process is given in Appendix C.

The same quality criteria were applied to the grey literature, along with additional criteria concerning date of publication (after 2005) and geographic scope (Sub-Saharan Africa only). In addition, we only included papers which had a specific focus on interventions as this would provide information on barriers and would address pragmatic solutions to overcome them. However, it is important to note that the grey literature often omitted methodological information, and therefore it was difficult to assess the quality of such papers. Since methodological information and clarity about data collection is a crucial indicator of quality, particularly for qualitative papers, when this information was not available in a grey literature paper we automatically excluded it. Further comments about the implications of this are made in the discussion section below (Section 5).

Rapid quality assessment

An initial set of criteria was used for a rapid quality assessment of the paper. If any of the criteria were not met, the paper was automatically excluded from the full text review. These criteria were:

- Does the paper describe the study design?
- Does the paper describe the form of original data?
- Does the paper describe the barriers/interventions in the context of at least one country/community?
- Does the paper have a clear methodology, including information/data collection methods, analysis and conclusions?
- Does the paper define the focus of the study/population or community or region?

If the initial, rapid quality assessment was passed, the paper was further assessed for topical and methodological relevance.

Topical relevance

To assess topical relevance, two sets of criteria were used, one for studies focussing on the identification of barriers, and the other for studies examining intervention effectiveness. Some of the papers fell into both categories, in which case both sets of criteria applied. The two sets of criteria are as follows:

- ***For studies which focus on the identification of barriers***

The first half of the primary question was "what are the major barriers to increased use of modern energy services among the world's poorest people?" The keyword here was "major", and the challenge here was to separate the important barriers from the less important ones. While it was difficult to objectively determine what qualifies as 'major', the team did require that in order for a barrier to be identified and included in our synthesis, the barrier needed to be clearly supported by evidence in the paper and, ideally, linked to analysis of an intervention. Studies which simply listed barriers without providing the reasons why they are presented, or how they have been identified, were less useful in contributing to the conclusions on "major barriers" and were not extracted for analysis.

- ***For studies that examine intervention effectiveness***

  The second half of the primary question was "are interventions to overcome these effective?" This was a question about whether the policies, programmes or other interventions have achieved the intended outcomes. A highly relevant study for addressing this question had to include the following elements:

  - a measurable and appropriate indicator of outcome
  - a measurement of how the outcome has changed
  - a baseline/counterfactual against which the change in outcome can be measured

  We exercised our expert judgement on what an appropriate outcome indicator would be, as they are often open to debate. The fact that baselines/counterfactuals are difficult to define with qualitative studies was also taken into account. That they are often contentious anyway, and that many studies in this field are good and rigorous but do not necessarily include counterfactuals was noted. Therefore, the criteria list above was only used as a guide rather than a set of rules.

- ***Methodological relevance***

  To assess methodological relevance, quantitative and qualitative evidence was appraised by looking at methodological quality and relevance and topic relevance, with specific criteria and questions within these broad assessment categories to fit the nature of the evidence. For quantitative studies (which we expect would represent only a small proportion of the relevant papers), their methodological rigour was assessed by considering their study design, including sample size, use of control variables, methods of measuring and assessing different variables, and potential sources of bias.

  For qualitative studies, the factors which contribute to methodological rigour were not so easily identified because of the diversity of disciplinary approaches present in qualitative research. However, the team adapted and refined the recommendations in the Weight of Evidence Framework (Gough 2007) published by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) and used in previously developed RAND frameworks used in rapid evidence reviews[5] to define a list of core quality criteria.

  Once papers were evaluated as having both topical and methodological relevance, the data extraction phase began (described below). During this reading a further set of quality criteria were considered and used to make a final judgement about the quality of the paper. Low quality papers were not included in the final analysis, and medium papers were used where there were particularly well-evidenced points about barriers or interventions, even though the paper as a whole may have been of lesser quality. All high quality papers were included in the final analysis.

[5] These frameworks are not publicly available, but are based on EPPI Centre and Cabinet Office rapid evidence assessment tools.

The full set of quality criteria included several criteria for review and a full list is provided in Appendix C. However, they fell under the main headings of: credibility of findings; breadth and depth of study findings; extent to which the study addresses the original aims and purposes; defensibility of study design; defensibility of sample design and coverage; quality of data collection; quality of the approach and formulation of the analysis; clarity and coherence of reporting; clarity of assumptions that have shaped the form and output of the study.

3.5 Data extraction strategy

Information management software (EndNote) helped ensure transparency and replicability throughout the review. This was used to record bibliographic information for the studies retrieved during the searches. Descriptive information was recorded for each paper in a separate Excel database, the template for which was:

- Full bibliographical reference
- Publication type (peer review journal article, institution working paper, etc.)
- Study design
- Country or region of the study
- Type of energy service or technology analysed
- Type of barriers assessed
- Characteristics of community assessed (including the reason why the community was selected and how the study subjects were recruited)
- Time period
- Sample size and characteristics
- Outcome/s or type of intervention under investigation
- Effectiveness measures (of interventions to overcome barriers) discussed
- Findings (quantitative and qualitative).
- Biases, effect modifiers/confounding variables identified and/or measured by authors (including in their discussion if *a posteriori* to acknowledge any flaws in their results)

3.6 Data synthesis and presentation

The synthesis is presented as a structured empirical narrative alongside several mapping and summary tables (presenting descriptive details of each study included in the review). A statistical meta-analysis was ruled out as it was anticipated that the majority of studies reviewed would be qualitative.

The synthesis is structured according to the sub-research questions that fall out of the main review question, as indicated in section 2. Within this structure, the secondary questions given in section 2 were used to guide the analysis and develop the synthesis. This approach promoted transparency and the possibility for repeatability.

As evidence was reviewed, the strength of the conclusions that could be derived from it based on assessments of the methodologies employed to gather and analyse that evidence were discussed. The range of comparators included supported these assessments further by enabling a discussion

of any effect modifiers, such as contextual factors, and the extent of their influence over outcomes. These were dependent on whether there are sufficient studies to reveal these factors.

Intervention outcomes were kept purposely broad and inclusive in the search stage of the review; the synthesis appraises the scope of outcomes analysed in the evidence, and considers any outcome indicators potentially neglected. To the extent possible, we discuss variability in outcomes and how such variability might be explained according to different barriers, types of modern energy services, or contextual factors. Finally, the synthesis addresses gaps in the evidence base on the systematic review question.

3.6.1 Selection of studies and outcome data for synthesis

Studies were selected for synthesis based on the criteria for study quality and relevance as described in earlier sections. All studies selected are summarised in Section 4.2.

As previously mentioned, the definition of effectiveness was broad, and the potential range of outcomes of primary studies was thus large. However, not all outcome data from primary studies were relevant for analysis in this systematic review. Outcome data synthesised in the review only includes those which specifically address how the interventions increase uptake of modern energy services and technologies. This includes both quantitative and qualitative findings, with qualitative findings including, for example, narrative subject reports of outcome differentials of a given intervention effectiveness indicator.

3.6.2 Process used to combine/synthesise data

The synthesis of data was guided by the following key questions:

- What is the overall evidence on the barriers to uptake of modern energy services in the developing world?
- What is the evidence on different types of intervention providing differential outcomes?

Following from the steer provided by these two questions, the sub-research and secondary research questions were used to focus the analysis, as has been discussed in greater detail in earlier sections. However, it is worth nothing that one hypothesis of the authors was that the evidence on barriers to the use of modern energy services among the world's poorest people, and interventions to increase uptake, has not been gathered or analysed in an integrative way. Therefore, a fully integrative synthesis of the evidence of barriers and their interactions, as well as interventions and their impacts, was problematic since such a synthesis would require different methodological approaches to those used in the studies themselves. Therefore, an integrated synthesis of barriers and interventions was not possible within the limited resource constraints of this review.

3.6.3 Deriving conclusions and implications

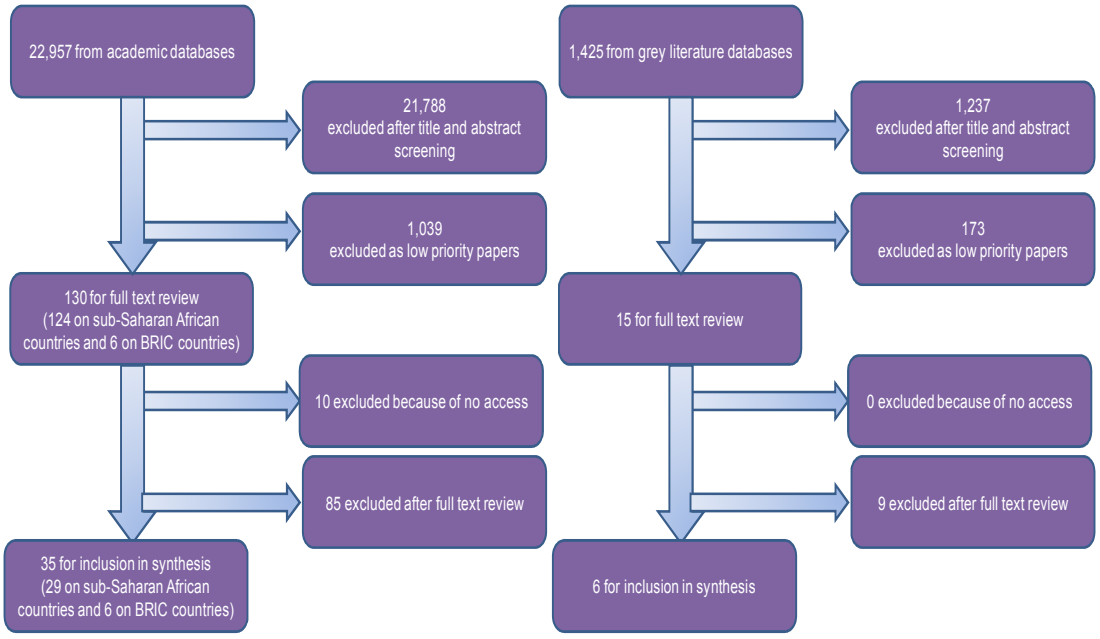
Implications and conclusions were derived from the synthesis of findings from the review. Within the review team, it was considered how the question fits within broader development strategies and the key literature identified through the search strategy on modern energy services access and uptake. In the study design, the team has chosen to include a wide range of barriers and interventions, including evidence on economic, technical, and cultural barriers and their interaction in different local contexts. Necessarily, then, the conclusions and implications are emergent and context-dependent.

4. Results

4.1 Review descriptive statistics, systematic map

A systematic study search was undertaken based on the protocol set out in previous sections. This resulted in 22,957 articles from the academic database and 1,425 articles from the grey literature database. A title and abstract screening and relevance assessment were then undertaken identifying 130 relevant articles from the academic literature and 15 from grey sources for full text review. In addition to these 145, there were 1,039 academic and 173 grey articles identified that were not directly relevant to the review and so were set aside as low priority. The purpose of doing this was to be able to return to these if needed and resources permitted. In the event, these were not examined further and so were finally excluded as a low priority. After a detailed review of quality and relevance of the 145 articles, 41 were included in the final synthesis (29 peer-reviewed academic papers about sub-Saharan Africa, 6 grey literature articles and 6 peer-reviewed academic papers about BRIC countries). The results from each stage of the review are summarised in Figure 1.

Figure 1: Results of each stage of the review (academic literature and grey literature)



The rest of the descriptive statistics focuses on the 41 highly relevant articles that are of high/medium quality. Table 1 shows the different types of modern energy service or technology examined in this set of articles. As shown, electricity/electrification is the most commonly discussed modern energy service, followed by solar or photovoltaic. It is also interesting to note that they are often examined alongside one another in the same paper.

Table 1: Type of energy service or technology analysed

Type of energy service or technology analysed	Number of articles		
	Peer-reviewed academic papers on sub-Saharan Africa	Grey literature on sub-Saharan Africa	Peer-reviewed academic papers on BRIC countries
Electricity or electrification	15	3	4
Battery or battery charging	0	1	
Refrigeration	0		
Heat or thermal comfort	1		
Lighting or illumination	1		1
Mobile phone charging	0		
Hydro power	1		
Biofuel, biogas, bioethanol or waste	3		
Solar or photovoltaic	9	1	3
Wind power	1		
Gas turbine	0		
Nuclear power	0		
Fuel cell	0		
Improving energy efficiency	1		
Sustainable/renewable/modern energy services in general	2	1	

Note: total count would not equal the number of studies reviewed, as some papers look at multiple energy services/technologies.

The barriers described in this set of papers were also examined. Based on a close examination of the data extracted by individual reviewers, five key themes/categories were drawn out: financial/cost, cultural, technical, institutional/regulatory, and capacity (skill). The barrier that is featured most prominently in the articles is financial/cost barrier (see Table 2). These categories will be defined and discussed in greater detail in the section 4.3.

Table 2: Types of barriers assessed

Type of barriers assessed	Number of articles		
	Peer-reviewed academic papers on sub-Saharan Africa	Grey literature on sub-Saharan Africa	Peer-reviewed academic papers on BRIC countries
Financial/cost	15	2	3
Cultural/social	5	2	3
Technical	7	1	4
Institutional/regulatory/managerial/political	4	3	2
Capacity (skill)	2		
Macro socio/demographic factors (geographical dispersal and migration)	2		2

The main types of interventions are: financial (e.g. subsidy, grant or other forms of assistance), technical assistance, and capacity building (see Table 3). Financial interventions are slightly more commonly discussed in articles, but not by much. There are a few other interventions that were not grouped under any of the headings in Table 3, including: voluntary actions by companies, government intervention, ESCO project-a service, 'market oriented' approach, infrastructure provision, and project implementation. Additionally, it should be noted that some papers did not discuss interventions at all (12 out of 28 academic papers).

Table 3: Types of intervention under investigation.

Type of intervention under investigation	Number of articles		
	Peer-reviewed academic papers on sub-Saharan Africa	Grey literature on sub-Saharan Africa	Peer-reviewed academic papers on BRIC countries
Financial subsidy/grant/assistance	6	2	2
Institutional/market reform	1	2	4
Technical assistance	4	1	
Capacity building	2		

Finally, the distribution by country within sub-Saharan Africa was examined (Table 4). There is a high concentration of papers in Kenya, Zimbabwe, and eastern and southern African countries in general.

Table 4: Distribution by country

Country	Count	
	Peer-reviewed academic papers	Grey literature
Botswana	1	
Burkina Faso	1	
Eastern and southern Africa in general	1	
Eritrea	1	
Ethiopia	1	
Kenya	7	1
Lesotho	1	
Malawi	1	
Mali	1	
Mozambique	2	
Nigeria	1	
Senegal	1	
South Africa	3	
Sub-Saharan Africa in general	1	2
Tanzania	2	3
Tunisia	1	
Uganda	3	2
Zambia	2	
Zimbabwe	5	1

4.2 Narrative synthesis including study quality assessment

For each included study a summary of quality and findings along with other key information such as barriers, interventions and effectiveness measures examined is provided. Before the summaries of individual papers, Table 5 below provides the full bibliographical reference, an overall rating of quality and the type of publication. This set covers 41 articles in total, with 35 from academic literature (including the 6 peer-reviewed academic papers about BRIC countries) and 6 from grey literature.

Table 5: Full bibliographical reference of the included papers and their overall quality rating

Full bibliographical reference	Overall rating of quality	Type of publication
Acker RH, Kammen DM: **The Quiet (Energy) Revolution: Analysing the Dissemination of Photovoltaic Power Systems in Kenya.** *Energy Policy* 1996, **24:**81-111.	High	Acad. literature
Adkins E, Eapen S, Kaluwile F, Nair G, Modi V: **Off-grid Energy Services for the Poor: Introducing LED Lighting in the Millennium Villages Project in Malawi.** *Energy Policy* 2010, **38:**1087-1097.	High	Acad. literature
African Development Bank Group: **Tanzania Rural Electrification Project: Project Performance Evaluation Report (PPER).** *Tanzania Rural Electrification Project: Project Performance Evaluation Report (PPER)* African Development Bank Group; 1996.	Medium	Grey literature
Campbell B, Vermeulen S, Mangono J, Mabugu R: **The Energy Transition in Action: Urban Domestic Fuel Choices in a Changing Zimbabwe.** *Energy Policy* 2003, **31:**553-562.	High	Acad. Literature
Clough L: **Marketing Challenges and Strategies for Micro and Small Energy Enterprises in East Africa.** In *Book Marketing Challenges and Strategies for Micro and Small Energy Enterprises in East Africa*, GVEP International; 2011.	Medium	Grey literature
Collings S: **Phone Charging Micro-businesses in Tanzania and Uganda.** *Phone Charging Micro-businesses in Tanzania and Uganda*, GVEP International; 2011.	Medium	Grey literature
D'Agostino AL, Sovacool BK, Bambawale MJ: **And Then What Happened? A Retrospective Appraisal of China's Renewable Energy Development Project (REDP)**. *Renewable Energy*, 2011. **36**(11): 3154-3165.	High	Acad. Literature
Diniz ASAC, Machado Neto LVB, Camara CF, Morais P, Cabral CVT, Oliveira Filho D, Ravinetti RF, Franc ED, Cassini DA, Souza MEM, Santos, JH, Amorim M: **Review of the Photovoltaic Energy Program in the State of Minas Gerais, Brazil.** *Renewable & Sustainable Energy Reviews*, 2011**. 15**(6): 2696-2706.	Medium	Acad. Literature
Dube I: **Impact of Energy Subsidies on Energy Consumption and Supply in Zimbabwe. Do the Urban Poor Really Benefit?** *Energy Policy* 2003, **31:**1635-1645.	High	Acad. Literature
Duke RD, Jacobson A, Kammen DM: **Photovoltaic Module Quality in the Kenyan Solar Home Systems Market.** *Energy Policy* 2002, **30:**477-499.	High	Acad. Literature
Foster V, Steinbuks J: **Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa.** Policy Research Working Paper 4913. World Bank: African Sustainable Development Front Office; 2009	High	Grey literature
Gaunt CT: **Meeting Electrification's Social Objectives in South Africa, and Implications for Developing Countries**. *Energy Policy*, 2005. **33**(10): 1309-1317.	Medium	Acad. Literature
Green JM, Wilson M, Cawood W: **Maphephethe Rural Electrification (Photovoltaic) Programme: The Constraints on the Adoption of Solar Home Systems.** *Development Southern Africa* 2001, **18:**19-30.	High	Acad. literature
Green JM, Erskine SH: **Solar (Photovoltaic) Systems, Energy Use and Business Activities in Maphephethe, KwaZulu-Natal.** *Development Southern Africa* 1999, **16:**221-237.	Medium-high	Acad. literature
Guimarães L, Caracaleanu C, Sy B, N'Dongo A, Sankaré O: **Energy Affordability in the Sahelian Region.** *Applied Energy* 2003, **76:**9-13.	Medium	Acad. literature
Gumbo R, Katsvairo L, Asai K: **State of Photovoltaic Home Systems in Zimbabwe.** *IEEE*; 2003, **2643**:2640-2643	High	Acad. literature
Gustavsson M, Ellegård A: **The Impact of Solar Home Systems on Rural Livelihoods. Experiences from the Nyimba Energy Service Company in Zambia.** *Renewable Energy* 2004, **29:**1059-1072.	High	Acad. literature
Haanyika CM: **Rural Electrification in Zambia: A Policy and Institutional Analysis.** *Energy Policy* 2008, **36:**1044-1058.	Medium-high	Acad. literature
Hofmeyr IM: **Towards Adequate and Equitable Energy Provision for Farmworker Families.** *Development Southern Africa* 1995, **12:**273-279.	Medium	Acad. literature
Ilskog E, Kjellström B, Gullberg M, Katyega M, Chambala W: **Electrification Co-Operatives Bring New Light to Rural Tanzania.** *Energy Policy* 2005, **33:**1299-1307.	Medium-high	Acad. literature

Karekezi S, Kimani J: **Status of Power Sector Reform in Africa: Impact on the Poor.** *Energy Policy* 2002, **30**:923-945.	High	Acad. literature
Karekezi S, Kithyoma W: **Renewable Energy Strategies for Rural Africa: Is a PV-Led Renewable Energy Strategy the Right Approach for Providing Modern Energy to the Rural Poor of Sub-Saharan Africa?** *Energy Policy* 2002, **30:**1071-1086.	Medium	Acad. literature
Ketlogetswe C, Mothudi T: **Solar Home Systems in Botswana--Opportunities and Constraints.** *Renewable and Sustainable Energy Reviews* 2009, **13:**1675-1678.	Medium	Acad. literature
Kirubi C, Jacobson A, Kammen DM, Mills A: **Community-Based Electric Micro-Grids can Contribute to Rural Development: Evidence From Kenya.** *World Development* 2009, **37:**1208-1221.	High	Acad. literature
Lee KS, Anas A, Oh G-T: **Costs of Infrastructure Deficiencies for Manufacturing in Nigerian, Indonesian and Thai Cities**. *Urban Studies*, 1999. **36**(12): 2135-49.	Medium	Acad. literature
Mapako M, Network BU: **Provision of Long-term Maintenance Support for Solar Photovoltaic Systems - Lessons from a Zimbabwean NGO.** *Journal of Energy in Southern Africa* 2005, **16:**21-26.	Medium	Acad. literature
Mulder P, Tembe J: **Rural Electrification in an Imperfect World: A Case Study From Mozambique.** *Energy Policy* 2008, **36:**2785-2794.	Medium-high	Acad. literature
Mulugetta Y, Nhete T, Jackson T: **Photovoltaics in Zimbabwe: Lessons From the GEF Solar Project.** *Energy Policy* 2000, **28:**1069-1080.	High	Acad. literature
Murphy JT: **Making the Energy Transition in Rural East Africa: Is Leapfrogging an Alternative?** *Technological Forecasting and Social Change* 2001, **68:**173-193.	Medium-high	Acad. literature
Nygaard I: **Institutional Options for Rural Energy Access: Exploring The Concept of the Multifunctional Platform In West Africa**. *Energy Policy*, 2010. **38**(2): 1192-1201.	High	Acad. literature
Peng WY. Pan JH: **Rural Electrification in China: History And Institution**. *China & World Economy*, 2006. **14**(1): 71-84.	High	Acad. literature
Pereira MG, Freitas MAV, da Silva NF: **Rural Electrification and Energy Poverty: Empirical Evidences From Brazil.** *Renewable & Sustainable Energy Reviews*, 2010. **14**(4):1229-1240.	Medium	Acad. literature
Rehman IH, Kar A, Raven R, Singh D, Tiwari J, Jha R, Sinha PK, Mirza A: **Rural Energy Transitions In Developing Countries: A Case of the Uttam Urja Initiative In India**. *Environmental Science & Policy*, 2010. **13**(4): 303-311.	Medium-high	Acad. literature
Schut M, Slingerland M, Locke A: **Biofuel Developments in Mozambique. Update and Analysis of Policy, Potential and Reality.** *Energy Policy* 2010, **38:**5151-5165.	High	Acad. literature
Steel K: **Dynamics of Growth and Investment in the Kenyan Electric Power Sector,** *Power Engineering Society General Meeting, 2007. IEEE*,, pp.1-5, 24-28 June 2007 doi: 10.1109/PES.2007.385906	High	Grey literature
Thiam DR: **An Energy Pricing Scheme for the Diffusion of Decentralized Renewable Technology Investment in Developing Countries.** *Energy Policy* 2011: **39**(7). 4284-4297	High	Acad. literature
van der Plas RJ, Hankins M: **Solar Electricity in Africa: A Reality.** *Energy Policy* 1998, **26:**295-305.	High	Acad. literature
Walekhwa PN, Mugisha J, Drake L: **Biogas Energy From Family-Sized Digesters in Uganda: Critical Factors and Policy Implications.** *Energy Policy* 2009, **37:**2754-2762.	High	Acad. literature
Winkler H, Spalding-Fecher R, Tyani L, Matibe K: **Cost-Benefit Analysis of Energy Efficiency in Urban Low-Cost Housing.** *Development Southern Africa* 2002, **19:**593-614.	High	Acad. literature
Wolde-Ghiorgis W: **Renewable Energy for Rural Development in Ethiopia: The Case for New Energy Policies and Institutional Reform.** *Energy Policy* 2002, **30:**1095-1105.	Medium	Acad. literature
The World Bank Independent Evaluation Group: **The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits.** World Bank; 2008	High	Grey literature

The summaries below provide further detail on the papers in Table 5 above. The summaries are structured as follows: full bibliographic reference of the paper; indication of paper quality

assessment; short summary of the paper covering analytical focus or topic, methods used or sources of data, main findings focusing on barriers or interventions and conclusions.

Acker RH, Kammen DM: **The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya.** *Energy Policy* 1996, **24:**81-111.

Quality: high

Summary: This paper analyses the growth of the SHS market in Kenya and the performance of systems in the field. The study focuses on small-scale PV systems ranging from 10 to greater than 100 watt-peak (Wp), within a range of income levels and income sources amongst users. Technical, financial and capacity (skills, knowledge, etc.) aspects of SHSs, the market and potential adopters are investigated using a case-study approach. The approach included interviews with 40 SHS adopters and a few local experts, as well as a set of measurements of the technical performance of the 40 systems investigated. The field research was conducted during July and August 1994, and the systems were clustered around Nakuru, Meru and Bungoma. The paper also provides a detailed contextual discussion of the Kenyan economy, energy profile, energy policy environment and the history of the SHS market. A range of variables is reported in the paper: system size, age, technical condition, cost of system components, appliances used and distance from the grid at time of purchase; dispersion of systems across income groups; system-cost compared with user-income; channel through which the adopter became aware of SHSs; perceived benefits and disbenefits of SHSs.

Based on the empirical analysis, the paper offers many recommendations for policy, which are categorised under small-scale approaches, financing schemes, capacity building (on both supply and demand sides), and domestic production of system components.

Small-scale approaches (promotion of solar lanterns and PV battery-charging stations) would respond to the market demand for small systems and extend services to poorer users. Financing would help overcome the high initial cost barrier, and examples are given from experience elsewhere (Bangladesh, Dominican Republic, Mexico, as well as two Kenyan dealers). Capacity building would include education and training on the supply side, and information and advice for potential adopters. Domestic production could begin with encapsulating solar cells while developing the skills necessary to begin manufacturing the cells, with the hope that this would lower costs to the consumer. Again, examples are given from elsewhere: Dominican Republic, Zimbabwe, China and India.

Adkins E, Eapen S, Kaluwile F, Nair G, Modi V: **Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi.** *Energy Policy* 2010, **38:**1087-1097.

Quality: high

Summary: The study examined a pilot programme which aimed to introduce solar light-emitting diode (LED) lanterns in Malawi. The program was market-based, relying on local vendors and cooperatives to sell lanterns to villagers without subsidy.

The study surveyed lantern buyers as well as non-buyers (54 and 43 households respectively) to investigate the factors underlying households' decisions to buy LED lanterns. It found that cost was a determining reason, based on the following observations:

- Households that purchased the lanterns early on reported significantly higher incomes and greater ownership of assets than those who did not
- Non-buyers reported monthly incomes that were about half of the price of the lantern

- Feedback from non-buyers further confirmed cost was a determining factor (although the number of non-buyers who provided this feedback was not clear from the article).

Additionally, the authors investigated on the impacts of LED use. They found that lantern purchases had a positive effect on households' lighting use and expenditure. Households obtained longer hours of light (from 2.7 hours per day from kerosene in the week before lantern purchase, compared with 4.4 hours per day from the LED lantern in the week after the purchase, i.e. a 63% increase). At the same time, households enjoyed reduced lighting expenditure (an annualised saving of $47.06 on average, i.e. enough to cover the cost of the lantern ($29.87) after the first year).

The study also offers some preliminary results on whether the lanterns had an impact on income generation. When asked "do you see the lantern providing opportunity for economic development", 53 out of 54 respondents replied "yes", with a few (less than 10%) offering the explanation that the lanterns provided extended business opportunities by allowing more time to work at night.

Finally, the paper also identified lessons learned about programme implementation. It is found that community engagement was crucial. Early vendor interviews allowed the programme implementation team to assess vendors' willingness and capacity to sell LED lanterns. Vendors were educated about the benefits of LED lighting and discussed the proposed business models (e.g. single payment vs. instalments). Community interactions informed villagers of the technical features of the LED lanterns, the expected savings, and the business model and process, e.g. contracts.

African Development Bank Group: **Tanzania Rural Electrification Project: Project Performance Evaluation Report (PPER).** *Tanzania Rural Electrification Project: Project Performance Evaluation Report (PPER)* African Development Bank Group; 1996.

Quality: medium

Summary: This paper is a project completion report on an electrification project in the Arusha and Kilimanjaro regions in Tanzania, executed between 1982 and 1989. The project financed the foreign exchange costs of expanding the national high voltage grid to facilitate transmission of cheaper hydroelectricity, medium voltage distribution systems and rural electrification networks in certain regions.

The report follows the Bank Group's guidelines and regulations to assess the effectiveness of project implementation through a number of indicators and measures such as: rate of electrification; institutional performance (electric power sector reform, tariff policy and structure, accounting and budgeting, auditing, billing and collection); management and organisational effectiveness (staff recruitment, training and development); performance of consultants and contractors; economic performance; financial performance; social impact and environmental impact. The review also looked at project sustainability, including the restructuring of TANESCO (Tanzania Electricity Supply Company), increased investment in the power sub-sector, operations and maintenance of the electricity systems and power system losses.

The report highlights several lessons learnt from the project, which are mainly referred to as administrative, procedural and coordination issues: closer co-ordination and synchronisation by the Bank of activities with those of other donors would have reduced the delay in loan effectiveness that occurred on this project; delays during implementation would have been reduced had the Borrower been better appraised of the Bank's procurement rules and procedures; the Bank ought to have ensured that the observed lapses in the audit reports were rectified; more rigorous examination of loan conditions and, where necessary, provision of technical assistance, would ensure appropriateness of the conditions. The report also investigates on the structural

reform processes implemented in the country and recommended that an earlier study and appreciation of the liberalisation process by the Borrower would have minimised the negative impact on TANESCO. Finally, it is recognised that a baseline study on socio-economic profile of the project areas would have provided a benchmark for evaluating the effectiveness of the project after completion.

Campbell B, Vermeulen S, Mangono J, Mabugu R: **The energy transition in action: urban domestic fuel choices in a changing Zimbabwe.** *Energy Policy* 2003, **31:**553-562.

Quality: high

Summary: This paper describes a comparative case study looking at the modern energy transition from wood to kerosene to electricity in urban Zimbabwe. The research is based on 2 surveys of communities carried out in 1994 and 1998 to generate quantitative data. The study investigated the factors determining access to fuel such as income, prices of fuels and appliances changes during that period. Through the use of a logistic chi-square test the study found that electricity use increases with income (pp557), but there were no differences in the rate of change of electricity use over time with income. Access to electricity is a key determinant of whether a household uses electricity, with only 0-3% of households reporting to have a connection to electricity but not use it. The study shows that, amongst those without a connection in 1999, 51% cited the price as a reason, 21% due to non ownership of their home, 18% because they had a preference for kerosene, and 5% because electricity was not available in their area (pp558). The paper concludes that government policy in Zimbabwe of subsidising electricity and liquid fuels has enabled poorest households to use the same fuel, however the policy has failed to keep fuel prices in pace with inflation, and has favoured wealthier households. 'A series of foreign exchange crises and breakdown in law and order have meant that fuel has become far more erratic in both availability and price' (pp561).

Clough L: **Marketing Challenges and Strategies for Micro and Small Energy Enterprises in East Africa.** *Marketing Challenges and Strategies for Micro and Small Energy Enterprises in East Africa*, GVEP International; 2011.

Quality: medium

Summary: This GVEP (Global Village Energy Partnership) report examines the marketing challenges and strategies for micro and small energy enterprises in East Africa. Fieldwork research undertaken in Kenya, Tanzania and Uganda, where 37 entrepreneurs and 22 customers were interviewed was used to inform the report. The study investigates the effectiveness of promotion means and consumer awareness about modern energy products.

The report found that the greatest proportion of the interviewed entrepreneurs (10 out of the 28 responded, i.e. 36%) suggested word of mouth was their most effective promotion technique. This was followed by hawking (14%), product displays (10%) and promoting at community meetings (10%). Only 7% cited linking with a local community based organisation. The reliance on customer referrals to increase their market means that product quality and price are of crucial importance; however entrepreneurs also face competition from sub-standard goods that are under-priced. One highlighted exception is phone and battery charging, in which the price of the service is fairly fixed with little variation. For these businesses location is key and entrepreneurs need to be located within 5 km of their customers.

Concerning consumers' familiarity with certain energy products – namely briquettes, improved cook stoves and solar lanterns – all the 22 consumers interviewed were aware of improved cook stoves, 73% were aware of solar lanterns and only 45% were aware of briquettes. These responses varied across the countries visited – no Tanzanian consumers were aware of briquettes,

while there was awareness among Ugandan consumers. The report implied that the level of awareness correlates with areas where the GVEP International programme Developing Energy Enterprise Project East Africa (DEEP EA) operated.

The report also elaborates on barriers that prevent customers from purchasing these energy products and refers to finance and availability as the most often cited reasons.

Although this study is a publication of GVEP, it is not an evaluation of the success or failure of the GVEP programme; therefore the risk of bias is low.

Collings S: **Phone Charging Micro-businesses in Tanzania and Uganda.** *Phone Charging Micro-businesses in Tanzania and Uganda*, GVEP International; 2011.

Quality: medium

Summary: This GVEP report examines phone charging micro-businesses in Tanzania and Uganda with the aim to understand (i) the market dynamics and the potential for growth and possible diversification into sales of solar lanterns and lighting systems, and (ii) the impact that the Developing Energy Enterprises Project (DEEP) has had on these businesses. The data used in the study were collected through interviews with 15 phone charging businesses (3 in Uganda and 12 in Tanzania) and 14 customers. As the sample size is very small, this report should be viewed as a qualitative study for generating in depth insights rather than a characterisation of the overall phone charging micro-business market. The study's key findings are summarised in the following:

Phone charging businesses have a high potential to grow, based on the author's observations that:

- In all cases there were more customers than could be serviced. Almost all of the entrepreneurs interviewed intended to buy another solar panel to expand their service.
- Some charging businesses had no immediate competitor (nearest service was more than 3km away). The majority had 1-3 competitors offering similar services in the immediate vicinity.
- None of the entrepreneurs expressed major concerns about competition.

Phone users reported significant economic and social benefits from use of their phones, including:

- The benefit of having a service locally, which saves considerable amounts of time and money. While previously they had travelled considerable distances (typically 7-15km) to charge a phone, they now have a provider within 3 km of their home. One customer reported having to spend UGX 6000 (US$2.20) a week on transport in order to charge her phone – she now spends the money on airtime.
- Customers felt that they received higher quality of service (e.g. full charge) and reduced risk of theft or damage.

The author suggested that a major constraint on growth is lack of access to funds for the businesses to purchase additional panels and accessories. Most businesses were considering applying for a loan.

GVEP manages a programme which supports micro-businesses engaged in servicing the energy needs of poor communities in Kenya, Tanzania and Uganda – Developing Energy Enterprises Project (DEEP). Although this study is a publication of GVEP, it is not an evaluation of the success or failure of the GVEP programme; therefore the risk of optimism bias is low.

D'Agostino AL, Sovacool BK, Bambawale MJ: **And then what happened? A retrospective appraisal of China's Renewable Energy Development Project (REDP).** *Renewable Energy*, 2011. **36(**11): 3154-3165.

Quality: high

Summary: The paper is a peer-reviewed, retrospective and qualitative analysis of the long-term impacts of China's Renewable Energy Development Project (REDP) in the areas of Beijing, Xining, and Shanghai. Though the REDP aimed to support wind technology improvement and photovoltaic technologies, this study focuses on evaluating the photovoltaic (PV) component of the programme. The PV component had the priorities of improving product quality (with penalties for noncompliance), reducing production costs and installing a total of 10 MWp of SHS capacity. The REDP was supported by the World Bank and though it had conducted its own evaluation, this is the first independent study to qualitatively understand the long-term implications of the programme for all relevant stakeholder groups. The methodology included a literature review and semi-structured interviews with thirty stakeholders, including project staff, employees at renewable energy companies, retailers in direct contact with end users, and end users.

The REDP set up a sub-grant for each SHS unit sold of $1.5/Wp. The scheme also incorporated a quality assurance component where compliant products were branded with a 'Golden Sun' to indicate high quality. The study found that sales figures for PV companies increased after the REDP and several companies have won additional contracts for similar projects. However, there was a concern that the domestic market was now saturated. SHS retailers claimed sales had increased and that quality was the most important criterion customers used to make decisions. However, this contradicted feedback from consumers which indicated they made their decision on price alone. None of the retailers actively promoted products based on certified quality, such as products which had the 'Golden Sun' branding, so the effects of this aspect of the PV programme were unclear. End-users also reported benefits of SHS ownership which in some cases contradicted those of the World Bank evaluation and cited different reasons for not undertaking repair and maintenance of their systems, including distance to shop, and previous poor experiences with equipment reliability.

Overall, the authors concluded that the following lessons could be learned:

- Rural credit constraints have impeded end user and corporate investments in new SHS stock and the REDP should not have discontinued its credit access programme.
- More robust results are needed to make definitive conclusions about the effects of SHS ownership on poverty and randomised controlled trials are needed.
- Improving the quality of after-sales service at township and provincial level would help to improve user uptake and there is a need for research into which after-sales service models are most pragmatic.
- SHS can be a transition technology while people are waiting for grid connections.
- The REDP had a life cycle approach to quality improvement (starting with manufacturing standards and practices through to product certification and introduced randomised testing regime which penalised non-compliance at production-line and retail stages). This contributed to strengthening the quality of SHS at multiple points in the supply chain.

Diniz ASAC, Machado Neto LVB, Camara CF, Morais P, Cabral CVT, Oliveira Filho D, Ravinetti RF, Franc ED, Cassini DA, Souza MEM, Santos, JH, Amorim M: **Review of the photovoltaic energy program in the state of Minas Gerais, Brazil.** *Renewable & Sustainable Energy Reviews*, 2011. **15**(6): 2696-2706**.**

Quality: medium

Summary: This paper presents a summary review and an ex post policy evaluation of the photovoltaic energy programme which was implemented in the state of Minas Gerais, Brazil, as part of the 'Light for All' government programme, whose main objective was to supply electricity to all communities by 2010. The specific energy programme in Minas Gerais was implemented

by the Energy Company of Minas Gerais (CEMIG) between the 1990s and the late 2000s. The authors give a detailed background of the context of rural electrification in Brazil and provide a summary of many of the political, technical and economic factors which have influenced the development and execution of the Light for All Programme (p. 2696-2700). There were three alternatives which could be pursued: extension of the distribution grid, autonomous off-grid generation using micro-grids, and individual electricity supplies. After local research, a solar rural electrification programme was pursued in Minas Gerais, called the Sunlight Program. It had three components: a SHSs Sub-programme; Rural School and Community Centres Electrification with PV systems; and a PV Solar Energy Training Programme. The paper reports on the following effectiveness measures, which subsequently are presented as key criteria to consider when developing a solar rural electrification programme and its relative merits over other rural electrification technologies. These include:

- Geographic location: Isolated and remote communities, as well as those on environmentally protected land should be considered for use of PV or hybrid systems;
- Cost analysis: When the cost of electrification of the community is at least double that of photovoltaic systems, then PV technology is competitive and can be chosen;
- Market analysis: potential consumers are small rural producer, or rural producer typical, and consumers must be categorised as residential low income, agriculturally based and earn 2 minimum wages per month.

The authors conclude that their experience using these criteria has demonstrated both technological reliability and electrification cost effectiveness, and so future solar electrification projects could benefit from using these criteria in ex-ante policy analysis.

Dube I: **Impact of energy subsidies on energy consumption and supply in Zimbabwe. Do the urban poor really benefit?** *Energy Policy* 2003, **31:**1635-1645.

Quality: high

Summary: This paper discusses subsidy policies for grid connection in Zimbabwe. Data were gathered using a survey of members of the community in major cities in Zimbabwe and data from the Department of Energy on subsidies and energy sources.

The paper examines the effect of subsidies on the affordability of electricity, and the distribution of subsidies among different urban household income categories and other economic sectors, measuring if subsidies were decisive for the affordability of electricity by the urban households.

The study found that different household income categories pay for electricity differently, with the urban poor paying a larger proportion of income than non-poor (pp1639). Furthermore, the author concludes that ‘the energy costs incurred by the poor on non-electrical energy sources could cover the current subsidized electricity costs’ (pp1639).’ It was found that urban households are currently paying much more for kerosene than the stipulated subsidized price. This means that subsidies are not decisive for the affordability of energy by kerosene users (pp1641). The existence of electricity subsidies is also not decisive for the affordability of electricity by the urban household, but the removal of such subsidies will impact more negatively to the more vulnerable groups than the affluent groups (pp1641). Subsidies are not entirely decisive for the affordability of energy due to different household wealth and other factors, such as upfront energy costs (or initial costs) for poor households (pp1642). Finally, regarding factors that create difficulties in access to energy, the study concludes that ‘the upfront electricity costs, could be considered, a significant barrier towards the access to electricity by the poor households, compared to affordability of the recurrent electricity costs even without subsidies’ (pp1642).

Duke RD, Jacobson A, Kammen DM: **Photovoltaic module quality in the Kenyan solar home systems market.** *Energy Policy* 2002, **30:**477-499.

Quality: high

Summary: This paper examines the information failure problem of the solar home systems (SHSs) market in Kenya. The study uses a review of literature to inform the qualitative analysis.

The paper describes PV technology in the country of origin of prevailing brands. Most SHSs purchased in Kenya since the 1990s use small 10-14 Wp amorphous silicon (a-Si) modules. Two of the three main a-Si brands marketed in Kenya performed adequately; however, a third brand with severe quality problems maintained a substantial market share, despite a far higher price per delivered Wp. The problem was that SHS owners are only able to gauge PV module quality after purchase, making PV a classic candidate for quality information failure.

The paper found that Kenyan households suffered major financial losses simply because they have had the misfortune to purchase the wrong brand of PV module. In addition to this direct harm, the inability of consumers to discern the relative quality of different module brands reduces overall confidence in PV and creates an important market failure. "Pooled quality" assessment pushed public perception of module reliability towards the performance level of the worst brand sold, while unfair competition from low quality brands forced to fulfil these pessimistic expectations by pressuring better performers to over-rate their modules as well. The authors conclude that this perverse dynamic constrains the market for SHS below the socially optimal level.

Foster V, Steinbuks J: **Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa.** *Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa*, Policy Research Working Paper 4913. World Bank: African Sustainable Development Front Office; 2009.

Quality: high

Summary: This study investigates the reasons behind electricity generation by private firms in sub-Saharan Africa (SSA) covering the period 1990-2006. It explores factors such as the unreliability of public power supply, regulations of international export markets and firm characteristics in more than 26 countries in SSA utilising original data from two sources: the UDI World Electric Power Plants Data Base (WEPP), containing an inventory for 2,843 operating plants and 941 plants under construction of all sizes and technologies in 47 SSA countries and the World Bank's Enterprise Survey Database, which gathers 8,483 operating firms in 25 North and Sub-Saharan African countries sampled from the universe of registered businesses.

Although the study does not focus on barriers to the use of modern energy services among poor communities or public interventions (it rather covers investment decisions by private firms), the results can be clearly linked to factors hindering the effective use of electricity in poor SSA countries. The paper also estimates costs and benefits of personal electricity generation by private firms, which can be used as a measure to estimate net benefits compared to public power supply. The results of the study show the extent to which personal electricity generation by firms contributes to the national electricity generation mix in the countries studied, which can be used as an effectiveness measure of energy service provision.

Overall, there are at least 4,000 MW of installed capacity owned by firms in SSA, which accounts for about 6% of total generation capacity in SSA. This figure rises in low-income countries, post-conflict countries, and West Africa (from around 12% on average and more than 20% of total generation capacity in a few countries). The conclusions of the report demonstrate that the causes of personal generation are due not only to unreliable public power supply, but also other factors including: firm characteristics, such as size (the probability of own generation doubles in large

firms relative to small ones), sector (agriculture, construction and tourism are highlighted), corporate structure, and export orientation of firms (emergency back-up and export regulations are also crucial factors).

Gaunt CT: **Meeting electrification's social objectives in South Africa, and implications for developing countries.** *Energy Policy*, 2005. **33(**10): 1309-1317**.**

Quality: medium

Summary: This paper presents a literature review and analysis of rural electrification in South Africa during the period from 1994 to 2005. The sources of data are not always clear, but the paper does contain useful insights into how rural electrification can be assessed in relation to how well it meets the social objective of poverty alleviation.

The paper describes interventions to enable rural electrification including funding for grid and non-grid connections to electrify rural areas; subsidies for the rural poor; and technology change to meet demands and differences in costs of different types of technologies, in particular PV. The paper emphasises that effectiveness measures for rural electrification programmes need to address social objectives such as poverty alleviation, health, education, etc. and that the initial objectives of rural electrification were too focussed on economic and socio-economic objectives and so were unable to meet these social objectives. In particular, the author claims that restructuring the electricity industry with clear social objectives in mind can help meet demands of poverty alleviation by enabling electrification programmes to have suitable tariffs for different social classes and can be used to indicate more socially appropriate capital investment decisions. The author concludes that decision-makers need to be aware of the differences between economic, social and socio-economic objectives and how the different understandings of these shape electrification plans and investment decisions.

Green JM, Wilson M, Cawood W: **Maphephethe rural electrification (photovoltaic) programme: the constraints on the adoption of solar home systems.** *Development Southern Africa* 2001, **18:**19-30.

Quality: high

Summary: In this paper the authors examine a pilot programme aiming to investigate and test the process of introducing solar home systems (SHSs) in Maphephethe (a rural community in South Africa). The project has a focus on local capacity building, involving the establishment of a community-based organisation responsible for all aspects of solar energy acquisition in the community. It is found that the rate of SHS dissemination was slow - only 5 percent of the community have adopted the new technology after 3 years of project implementation. In consumer theory terms, the process has not moved beyond the innovators' stage. Various reasons for the slow dissemination were explored through group discussions held in the community and during informal conversation throughout the course of the project. The most pertinent reasons identified were: financial constraints, a lack of experiential knowledge of solar power and a lack of opportunities to try out the system before making a purchase. The project also had limited success in building up the capacity of the local community. Since no accreditation is provided for those who are trained to work with solar technology, and the remuneration for their roles was poor, the author observed that there exists a danger of losing all locally trained people to more lucrative employment in urban areas.

Green JM, Erskine SH: **Solar (photovoltaic) systems, energy use and business activities in Maphephethe, KwaZulu-Natal.** *Development Southern Africa* 1999, **16:**221-237.

Quality: medium-high

Summary: The paper describes the implementation of a PV SHS project in Maphephethe, KwaZulu-Natal, led since 1996 by Solar Engineering Services (SES), which is the South African branch of SELF (a Washington DC-based non-for-profit organisation). Using focus groups as primary data and secondary sources from a survey carried out by an external organisation (EU) the study offers an analysis of the factors explaining the success and difficulties in promoting local participation and a business approach to rural electrification.

The paper elaborates on uptake levels to measure successful diffusion/dissemination of innovations, based on theoretical contributions from consumer studies literature (Schiffman & Kanuk, 1987; Grundy & Grundy, 1999). Under the rationale of these authors, it is concluded that the Maphephethe project has reached very low levels of PV SHS purchase and installations, accounting for 5% of potential market (all rural households in the area).

Barriers to greater technological diffusion are characterised as financial, cultural, technical and organisational.

Financial barriers are characterised by: inability of rural population to access finance and pay upfront capital, dependency on donors' financial support; insufficient working capital for manufacturers and distributors and lack of financing options for investors.

Cultural factors associate the expectations of getting access to grid electrification instead of PV SHS; low awareness levels about PV electrification; increased levels of vandalism and theft and the perceived status of owning a PV SHS.

Technical limitations are explained as low levels of technical capacity in the community to operate and maintain SHS and dependency on donors' technical support.

Organisational barriers refer to the limited capacity to implement local management and maintenance schemes. This is linked to the low uptake of PV systems which leads to financial struggles of local technicians, who prefer to move to more vibrant markets. Another mention is that of payment systems that does not fit local needs (people have to travel long distances to pay monthly bills).

The main findings of the study are:

1. The Maphephethe project aimed at building local capacity for management, maintenance and overall administration of the project. However, the project has not been able to create the necessary conditions for a local business to grow and become independent from donors' support.
2. It is not clear the extent to which marketing and promotional activities have been well designed so rural inhabitants are encouraged to buy PV SHS. It seems that the project has devoted more efforts in technical aspects related to the technology rather than engaging a broad set of actors that can contribute to create the adequate institutional and market structures that can sustain the development of the project.

Guimarães L, Caracaleanu C, Sy B, N'Dongo A, Sankaré O: **Energy affordability in the Sahelian region.** *Applied energy* 2003, **76:**9-13.

Quality: medium

Summary: This review looks at financial interventions to sustainable energy introduction in the Sahel region, covering the period from 1997 to 2001. It is argued that most measures only look at the economic and technological aspects of new energy systems, ignoring acceptability, cultural gaps, education and sustainable implementation. This study focuses on energy affordability and observes that in order to assess population's willingness and ability to switch energy types, it is important to look at their present energy expenses and their willingness and ability to pay more.

The study found that affordability of energy depends on income, spending (surveys have shown that the average household is ready to spend around 10% of its income on energy), indirect costs of energy (such as deforestation, land degradation, time consumed by energy production), and energy subsidies (such as fee-for-service-public sector subsidy per household connected, tax exemptions for renewable energy technologies). The paper concludes that there are measures to achieve more sustainable energy structures that are more affordable for customers: 1) frameworks to promote private actors for electrification: legislative and regulatory framework, public subsidy; 2) framework of organisational issues: village cooperatives to coordinate and combine efforts locally, promotion of productive activities at village level; 3) framework of technical issues: promotion of improved cooking stoves, building local energy-equipment manufacturing companies.

Gumbo R, Katsvairo L, Asai K: **State of photovoltaic home systems in Zimbabwe.** *IEEE;* 2003: 2640-2643 Vol. 2643.

Quality: high

Summary: This conference poster discusses a study looking at various solar delivery strategies in Zimbabwe. The study gathered data using a structured survey questionnaire, a literature review, visual observations, measurements of battery characteristics and some in-depth discussions with owners or users of PV systems. Four different PV implementation projects were compared with regards to technical barriers to their implementation: 1) the hire purchase approach, ('The terms of project involved loan facility from a revolving fund for system purchase at 15% deposit, 15% interest rate; 3 year payback period; accredited companies doing the installation with limited back-up for a year' (pp2641)); 2) the energy service company approach, (low cost and low maintenance systems installed with a user monthly fee); 3) the do it yourself approach; 4) the company approach (cash up front system). Comparing the 4 strategies using effectiveness measures perfectly working, not working, meeting GEF standards, battery failure rate, charge controller failure rate, and light failure rate, it was found that: ESCO has the highest number of perfectly working systems (due to local technicians) while DIY has the lowest number of systems that are functioning without a fault; there are more hire purchase (29%) systems that are not working (due to lack of technical backup) than the other three delivery modes; DIY delivery mode has the lowest number of systems meeting standards (lack of technical knowledge of installer and owner). The highest rate of battery failure (81%) is under the DIY delivery mode, (most systems do not have charge controllers for battery protection monitoring the system) and ESCO had the highest rate of charge controller failure (14%), and light failures (43%) (ESCO system lights are used often).

It has been noted that future projects should have awareness campaigns on the importance of using quality equipment, and it is also important to educate the clients on the importance of each component that constitute the solar home system, to make components affordable to reduce the usage of less efficient components and to have consumables accessible to the users of the technology.

Gustavsson M, Ellegård A: **The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia.** *Renewable energy* 2004, **29:**1059-1072.

Quality: high

Summary: This paper is a study on a solar energy service intervention (i.e. provision of a package providing maintenance and repair as well as solar panels) in Zambia and assesses financial, technical and socio-economic barriers to implementation. A survey of users and interviews of non

users was conducted to gather information about the provision of a service package by a solar energy service company (ESCO) in Nyimba town, Zambia. The ESCO was a government intervention to test a 'market oriented' approach. Amongst the indicators monitored was a change in livelihood as a result of access to electrical services such as light.

The survey results illustrated that ESCO clients were paying substantially more than their neighbours for energy services (paying a monthly sum rather than cost per use) (pp1063). 'The expense on energy services per household was ZMK 28,000 for clients and ZMK 19,000 for neighbours' (pp1063). However, most clients (63%) find the service fee reasonable, but they are found to be the upper middle-class rural society, with most clients (75%) reporting a steady household income over the year. There are reported problems with the systems (61% of clients reporting problems), including blackouts (reported by 55% of users), low capacity of systems (45%) (pp1065), and seasonal variations in solar radiation can be a problem, as in the rainy season the battery may not be fully charged in one day (pp1066). One feature of the programme is that servicing is carried out by the company, with technicians visiting each client monthly. Clients think that this works well, as maintenance, servicing and client contacts are found locally (people know them, know who to ask if there is a problem) (pp1070-1071), but 86% of clients would like to own the systems themselves and not have to pay for servicing (pp1066).

In general, a wide range of benefits was reported from the systems, with half of the respondents reporting benefits for children. Two thirds of client respondents reported changing their daily routine and entertainment (TV, radio etc) (pp1066-1067). The number of hours of light used per household did not change significantly, but there was improved quality of light reported, with 89% reporting that children could study at night without complaints about the light (pp1068).

Haanyika CM: **Rural electrification in Zambia: A policy and institutional analysis.** *Energy Policy* 2008, **36:**1044-1058.

Quality: medium-high

Summary: The paper presents a general analysis of developments in rural electrification policy in Zambia from 1994 to 2005. The study covers grid extension and decentralised micro-hydropower and solar PV, supported by examples. The analysis describes financial, skills related, and institutional difficulties in achieving policy objectives.

The main barriers to increased use of modern energy services are characterised as financial constraints (high cost of the infrastructure due to long distances from existing power stations to targeted rural areas and low population densities and inability of rural users to pay for both capital and service due to high poverty levels). From a technical and institutional perspective, low skills availability is mentioned as one major barrier, as well as the need for less stringent technical standards and service levels that take into account local conditions. In addition, it can be inferred that the institutional developments have faced important pitfalls and drawbacks due to the lack of capacity to fully implement a well intended set of policy objectives. Main reasons are explained as a lack of accountability, monitoring and evaluation. Moreover, a lack of mechanisms to translate central government guidelines and policy directives are apparent, although this is not explicit in the paper.

The main institutional and policy developments are described. Among these, the following are highlighted: creation of a National Energy Policy (1994); enactment of the Electricity and Electricity Regulation Acts (1995); establishment of the Rural Electrification Fund-REF (1995); enactment of the Rural Electrification Act (2003). However, there seems to be a disconnection between policy objectives and measures to implement them. An example of this is that although the Rural Electrification Fund (REF) (to which all electricity consumers contribute with 3% of their billed electricity) is considered a key governmental strategy for rural electrification, the actual available funds are only a small proportion of the estimated annual budget, due to

bureaucracy in the transmission of the levy (in 2000, out of K12 billion budgeted in the fund, only K700 million were available (pp 1054)).

Hofmeyr IM: **Towards adequate and equitable energy provision for farm worker families.** *Development Southern Africa* 1995, **12:**273-279.

Quality: medium

Summary: This paper reports the main findings of a study conducted during the period from 1992 to 1993 of energy access and use by farm-worker households on farms across South Africa. It combines a postal survey of farm owners (575 respondents) in 14 regions, interviews with 36 farm-worker households in the western Cape and secondary sources. The study looks at electrification rates but also reveals energy-use patterns for fuel wood and commercial hydrocarbons, as well as other sources of energy services (candles and dry-cell batteries).

The author finds wide variety in electricity-access rates and consumption levels across the country (11% access in the northern Cape, 71% in the western Cape, only 32% of households on electrified farms across the country have access), and wide variety in fuel wood shortages (8% to 42% of households face shortages in Natal and Transvaal), while farm-owners perceive shortages at much lower levels (9% to 12%). Where farm-worker households have electricity access, the paper reports that consumption is constrained in a range of ways by farm-owners: limits on appliances, restricted hours of connection, limited free units of electricity, rationing of meter cards. Farm-owners, on average, pay 81% of farm-workers' electricity consumption. The analysis of these patterns suggests that barriers to electrification are financial (cost of connections and consumption) and what could be described as political-legal or cultural, depending on how power relations between farmers and farm-workers are conceptualised (noting the still-strong legacy of the Apartheid regime at the time of the study).

The paper proposes a number of recommendations to overcome barriers. With regard to costs of access to electricity, support for connections is recommended for both unconnected households on electrified farms and PV systems in non-electrified farms. Additionally, the paper recommends suitable tariffs to avoid low consumption levels and damage to the viability of the utility. Payment systems should "suit low or intermittent cash incomes" (p277), and delivery systems would need to "place control of electricity use in the hands of the consumer" (p277). Other recommendations include strong central policy development for integrated energy planning, minimum standards, allocation of responsibility for implementation and maintenance, mechanisms for administering funds for service provision and structured roles for cooperation between farm-workers, farmers, government, NGOs and energy suppliers.

Finally, the paper elaborates on democracy and inclusion. Farm-worker families should be viewed as rural residents in their own right and their dependence on farmers lessened: electrification was seen to depend on the goodwill of farmers, and impediments such as trespass laws exist. In addition, any subsidies in effect at the time of the study were controlled by farm-owners not farm-workers. More generally, governance institutions need to be more democratic and efficient to ensure equitable opportunities for disadvantaged communities.

Ilskog E, Kjellström B, Gullberg M, Katyega M, Chambala W: **Electrification co-operatives bring new light to rural Tanzania.** *Energy Policy* 2005, **33:**1299-1307.

Quality: medium-high

Summary: This paper looks at a rural electrification intervention in Urambo village, Tanzania, between 1985 and 2002, with an emphasis on the period from 1993 to 2002. The agriculture

dominated district, in which tobacco is the most important cash crop, has a population of approximately 80,000 inhabitants, from which around 20,000 live in the village.

The paper does not have a clear methodology and design. However, the study provides useful insights about the main barriers faced by, and lessons learned from, the establishment of a local electrification co-operative. This operates a diesel-based generation and isolated mini-grid distribution system providing electricity to 10% of households in Urambo township.

With regard to barriers to the increased use of electricity, the authors elaborate on financial, managerial and technical problems. Financing for capital investment seems to be the main barrier to increased access to electricity in rural areas. However, there seems to be high willingness to pay for electricity services despite high poverty levels, which suggests unnecessary subsidised tariffs in other areas served by the national utility. The case of Urambo co-operative demonstrates that electricity supply can be managed locally when adequate technical, managerial and financial support is provided. This support has involved highly committed international assistance from the Stockholm Environment Institute (SEI) and the Swedish Development Cooperation Agency (Sida) and national technical assistance from TANESCO (para-statal national utility). In order to overcome financial struggles the authors highlight the importance of transparent management, so clients improve their understanding and trust towards the business model (tariffs and cost structures) and thus payment default is reduced.

According to the authors, important reasons for the success in Urambo have been (pp 1307):

1. Strong local leadership and commitment;
2. Training of the co-operative's staff;
3. Utilisation of well proven technical solutions;
4. Initial financial support for investments and covering of initial problems with recovering operational costs;
5. Ability and willingness to pay for at least the full operating cost of the service;
6. Availability of an organisation that is prepared to provide technical support, when needed, without much delay.

Karekezi S, Kimani J: **Status of power sector reform in Africa: Impact on the poor.** Energy *Policy* 2002, **30**:923-945.

Quality: medium

Summary: Based on a regional study by the authors of eastern and southern Africa, and supplemented with experiences from across other countries in sub-Saharan Africa, this paper reviews the status of power sector reforms and their impacts on the poor.

The paper provides a detailed description of the status of power sector reforms. The average electricity consumption per capita in Sub-Saharan Africa is found to be very low with a tradition of a monopolistic hold over national electricity industry in the power sector. For most countries in sub-Saharan Africa, power sector reform was the focus of intense effort during the 1990s, attempting to address the poor performance of electricity services via the grid arising from dissatisfaction over its poor performance. This poor performance was assumed to be the result of inefficient and corrupt government-owned and vertically integrated utilities. Popular options of reform are structural change and privatisation. The hope was that privatisation and unbundling of electricity services would increase their efficiency and reliability, reduce levels of corruption and remove political influence from electrification programmes. It was expected that electrification rates would improve and the power sector would become more economically sustainable. Many countries have attempted this corporatisation and commercialisation and many have introduced contract management to improve efficiency in the power sectors. Independent power projects aim to meet the demand of populations in Sub-Saharan Africa and recently a number of legal and

regulatory changes have occurred in some countries to encourage private participation, minimise government intervention, redefine public utility from welfare agency to commercial entity.

The authors find that the record of power sector reform is patchy, varying at least by country, and has not necessarily resulted in the electrification gains and reduced corruption expected. There has been controversy surrounding the reforms, in particular surrounding the independent power producers with allegations of corruption between government and private sector companies. Even though a number of African countries have implemented independent power projects, the state utilities still remain the only buyers of the power. There has been an observed reluctance to establish independent regulatory bodies, with multi-sector regulation potentially being more effective (as in the example of Ghana). Similarly, the impacts on the poor are context-specific. Many countries have seen dramatic tariff increases as private companies seek full cost recovery. The extent to which these price rises affect access to and use of electricity from the grid by the poor depends on the extent to which the grid reaches poor households. Many of the poor in Africa are not connected to the grid and so tariff increases do not affect them directly. However, some countries do have large numbers of poor households electrified and here there could be serious impacts.

Not least amongst such impacts are the reactions that tariff increases can cause, such as riots in Ghana and protracted political debate in Kenya. With regards to electrification, '[n]otable examples of failed rural electrification programmes can be found in Kenya and Zambia. Several factors contributed to the failure of rural electrification in the two countries. Firstly, poor billing and revenue collection led to non-remittance of rural electrification levies; secondly, reallocation of rural electrification remittances by the utility to the Treasury to other uses. Thirdly, costly undertakings by the utilities and the failure to utilise least-cost electrification options'. On the basis of their wide-ranging and detailed analysis, the authors offer a number of suggestions for ways forward.

Karekezi S, Kithyoma W: **Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?** *Energy Policy* 2002, **30:**1071-1086.

Quality: medium

Summary: This paper examined the role of PV for providing modern energy to the rural poor of sub-Saharan Africa. They drew on data from various sources (including the World Bank, AFREPREN and other academic publications) and found that the cost of a typical low-end PV (i.e. 40-50 Wp) household system is 130% to 360% of the GNP per capita of most sub-Saharan African countries, or 100% to 200% of the annual income of a rural household. Hence, they concluded that high cost was one of the most important barriers to greater dissemination of PV technology to households in sub-Saharan Africa. Additionally, they examined the energy use by small and micro enterprises (i.e. enterprises that rely primarily on family/household members). Many of these small and micro-enterprises are involved in agro-processing. Their activities require equipment with a minimum power output of well above 1000 Wp, but a PV system of this size was too costly for most rural households. Therefore, PV is limited to low-power application, such as lighting, powering radios and black-and-white TVs. The paper argued that rural energy policies that emphasize a broader range of renewable energy and focus more on income-generating activities were likely to yield greater benefits.

Ketlogetswe C, Mothudi T: **Solar home systems in Botswana–Opportunities and constraints.** *Renewable and Sustainable Energy Reviews* 2009, **13:**1675-1678.

Quality: medium

Summary: This paper looks at solar energy in 3 villages in Botswana – Kudumatse, Lorolwana, Motlhabaneng – in a fee-for service project run by the Government of Botswana and the Japanese International Cooperation Agency between 2002 and 2005. With the majority of populations in Sub-Saharan Africa living in rural areas, with low incomes and scattered clusters of households, the development of electricity infrastructure and therefore rural electrification is poor. This paper describes the electrification state in Botswana, and the state of reforms to expand the use of photovoltaic lighting systems in rural communities. It is apparent that this is the ideal market for photovoltaic systems. The authors examine data from monitoring of revenue collected from participants and it is found that reasons for low use of solar home systems by rural communities in Botswana include: 1) low income status of most rural inhabitants, resulting in them being unable to pay for the systems, and being repossessed due to a lack of payments and; 2) migration of house-owners from village status to lands, or cattle posts, having an effect on regular payments. The authors conclude that there is economic variation among rural communities and energy policy should focus on this variation, and also that from observed results of revenue, the fee-for-service model seems unsuitable for rural communities. The authors make several recommendations to stimulate sustainability of solar home systems in rural communities in Botswana.

Kirubi C, Jacobson A, Kammen DM, Mills A: **Community-based electric micro-grids can contribute to rural development: evidence from Kenya.** *World Development* 2009, **37:**1208-1221.

Quality: high

Summary: This paper presents a detailed case study of a community-led, donor supported diesel-based micro-grid electric system in Mpeketoni, Kenya (Mpeketoni Electricity Project -MEP). The study covers the period between 1994 and 2007 and is informed by interviews held with a broad set of actors. It analyses the socio-economic effects of improved access to electricity, highlighting the "mechanisms through which rural electrification can contribute to rural development" (pp. 1208), such as increased productivity per worker and income levels of SMEs, improved public service delivery at schools (lighting and electrically-powered equipment used for educational activities), markets (improved banking and communication services) and agricultural productivity (pumped irrigation and maintenance of tools and tractors). The paper describes general barriers to improve access to modern energy services in rural contexts from a review of literature, highlighting obstacles such as low population densities, limited ability to pay (hence low demand), high capital and operating costs, low levels of cost recovery and political interference. The study also assesses the financial performance of MEP analysing the levels of cost recovery over a period of 12 years. The paper concludes that:

1. Community-led rural electrification has a high potential to reach adequate levels of cost recovery, which is fundamental in the success of such interventions (through cost-reflective tariffs charged and enforced and linked to the promotion of productive uses that can generate revenues and improve the load factor).
2. The provision of capital subsidy (in the form of concessionary interest rates or grants) in rural electrification programmes may be justified.
3. Rural electrification policy must be coordinated with other development efforts (mainly infrastructure).
4. Specialised institutions/agencies in charge of coordinating and developing criteria/ methodologies and rules for the process of rural electrification seem to be vital.
5. Alternative management and ownership models seem to be promising in accelerating rural electrification in SSA given the status of development of electricity systems, but the mechanisms to enhance collective action deserve more detailed research.

Lee KS, Anas A, Oh G-T: **Costs of Infrastructure Deficiencies for Manufacturing in Nigerian, Indonesian and Thai Cities.** *Urban Studies***,** 1999. **36**(12): 2135-49.

Quality: medium

Summary: This paper presents an economic analysis of infrastructure service self provision by private manufacturing firms based in main and secondary cities of Nigeria, Indonesia and Thailand. Based on data collected through a survey implemented in 1988 the study assesses on-site electricity generation and other infrastructure service provision (water supply; transport and communications), which are self managed and generated due to deficiencies in public provision of these services.

With regard to effectiveness measures, the paper highlights that public service provision from the supply side (infrastructure provision) is not a good metric to analyse effectiveness. Demand-side satisfaction of service needs should also be considered when assessing effectiveness of services delivery.

The main findings of the study, in the context of Nigerian firms, can be summarised as follows:

1. There is a high dependence on self provision of electricity generation.
2. As firms grow in size they tend to rely more on self provision of infrastructure services.
3. Costs of service (self) provision decline as firm size grows, due to economies of scale.
4. Regulatory environments influence the extent to which firms are able to produce infrastructure services on-site. Nigeria has a strict regulatory framework inhibiting the development of private infrastructure service delivery, despite the inefficiencies of state infrastructure provision, while in Indonesia and Thailand governments have opened up the market and the incidence of private service delivery is much higher than in Nigeria.

Mapako M, Network BU: **Provision of Long-term Maintenance Support for Solar Photovoltaic Systems - Lessons from a Zimbabwean NGO.** *Journal of Energy in Southern Africa* 2005, **16:**21-26

Quality: medium

Summary: This paper compares two different interventions in Zimbabwe, which both aimed to ensure maintenance of the solar home systems (SHSs) throughout their lifetime. These two interventions were guided by different approaches. One is the facilitator approach, illustrated in the GEF Solar Project implemented between 1993 and 1999. This approach uses an independent, trained, local person who can respond to maintenance issues in the SHS on a case by case basis, with payment from the SHS owner per visit. The other is the fee-for-service approach as exemplified by the Japan International Cooperation Agency Energy Service Company (ESCO) study which ran from 1999 to 2003. In this case, the customer pays a regular fee to the company for installation and maintenance of the SHS.

The authors found that the clustering of installations is important for facilitators as they have access to more business, and also for the ESCO as it is able to have shorter response times, and lower transport costs. The facilitator approach can be viewed as more quality based and competitive, as customers can choose which facilitator to use, and there is an incentive to compete with other facilitators in the area. There is little competition under the ESCO approach, but the user can withhold fee payment if they are unsatisfied. The main problem with the ESCO approach is that it has not been shown to cover operational costs: e.g. fee payments are disrupted, foreign exchange rates are volatile. The facilitator approach does not suffer from an erratic payment problem and so may be more suitable for the developing world. In summary, the facilitator approach shows ways to disseminate SHSs commercially, but the ESCO approach has not shown financial viability.

Mulder P, Tembe J: **Rural electrification in an imperfect world: A case study from Mozambique.** *Energy Policy* 2008, **36:**2785-2794

Quality: medium-high

Summary: This study presents a cost-benefit analysis (CBA) of a rural electrification project, grant-funded by a donor – Sida (Swedish Development Cooperation) – at a cost of USD 4 million in the mainly agricultural Ribáuè district in Nampula province in northern Mozambique. The project included a grid extension of 160 km plus installation of a distribution network providing electricity to households, as well as commercial customers and other organisations.

The CBA is conducted in two parts: an analysis of a period of operation (2000 to 2005) and a set of scenarios (2005 to 2020). A combination of reported and assumed values is used for the CBA together with a sensitivity analysis using different discount rates. These values are derived from electrification rates, consumption patterns, direct and indirect costs and benefits: household energy savings, lower production costs and increased demand (cotton production and maize milling), new businesses (shops, bars and restaurants), education and health gains, more tax revenue and increased access to ICTs. However, some of the benefits and costs are not included because of methodological difficulties.

The paper argues that institutional barriers explain why such projects are difficult to implement. The study finds that rural electrification can be commercially viable if there is at least one major consumer for productive purposes. This leads to the recommendation that projects should look for such productive opportunities so that the positive externalities (many of which are difficult to quantify) are captured – those such as educational and health gains, as well as the development of economic linkages into other parts of the locality. However, complementary developments need to be in place to maximise these externalities – e.g. roads and stronger institutions at the national level. Many of the positive externalities are not appropriable by the private sector and so there is likely to be an underinvestment in such projects even where they might be commercially viable, adding weight to the case for government and donor support.

However, donor support can be a problem because it can introduce complexities into policy development and implementation – donor fads, for example, could mean shifting priorities that undermine the long-term needs of infrastructure development. The paper adds that other institutional changes could be necessary such as utility reform but these are likely to be resisted by vested interests – the Mozambican case illustrates this where reforms have not been funded by the government and so have in effect been blocked.

Mulugetta Y, Nhete T, Jackson T: **Photovoltaics in Zimbabwe: lessons from the GEF Solar project.** *Energy Policy* 2000, **28:**1069-1080.

Quality: high

Summary: The paper critically analyses a GEF-funded PV project implemented in Zimbabwe between 1992 and 1998. It starts by characterising the country-wide intervention to promote the diffusion of PV at the household level and its main objectives. It then analyses the effects that the project had on the PV market in the country. The paper investigates the extent to which a donor-driven rural lighting project achieved its intended goals of promoting the creation of a solar market in the country while reducing poverty and limiting GHG emissions. The main findings can be summarised as follows:

1. Donor-driven technology-push initiatives have little likelihood of long-term sustainability (retention of technological capacity at the local level, adequate operation and maintenance of

PV systems, growth of service and technology markets), so there is a need to generate adequate policy frameworks beyond limited project lifetime;
2. Projects aimed at delivering rural electrification solutions should be conceived in the framework of defined rural electrification strategies and national energy polices;
3. Such strategies should respond to critically assessed demands and needs informed by continuous monitoring, analysis and evaluation from national policy makers in order to ensure donors focus on national priorities;
4. There is a need to improve accountability and transparency of policy interventions, allowing greater participation of a diverse range of stakeholders and defining clear monitoring and evaluation criteria;
5. Donor-driven projects providing market mechanisms and incentives have a tendency to distort already feeble local renewable energy markets. It is not clear the extent to which market creation-based projects are able to target poor populations in low-income rural areas of developing countries.

Murphy JT: **Making the energy transition in rural East Africa: Is leapfrogging an alternative?** *Technological Forecasting and Social Change* 2001, **68:**173-193

Quality: medium-high

Summary: The paper looks at three energy technologies in East African households: electricity grid extension; renewable electrification (solar PV and biogas); and efficient cooking stoves. Using data from financial and technical cooperation projects from international and multilateral donors implemented in the 1980s up to the late 1990s in Kenya, Tanzania and Uganda, the study analyses the potential for leapfrogging to modern energy services. This paper presents an interesting approach, drawing on ideas of technological change, socio-technical transitions, technology transfer, leapfrogging and capabilities. It is argued that the problem of lack of access to modern energy services requires a systemic approach in which the context, characterised by social, economic, cultural and political institutions, is of crucial importance.

Thus, the paper describes several cultural factors hindering the diffusion of energy technologies, such as gender dynamics, local power structures and socio-economic realities of poor rural East Africans. The author argues that most of the barriers arise due to an over-emphasis on techno-economic viability of the technologies being promoted in detriment of an appropriate consideration of socio-cultural and institutional factors.

Although the study refers to economic, social, political, and cultural factors, barriers could be categorised as financial, technical, organisational (or managerial) and cultural.

There is also mention of effectiveness measures. In that regard, the study indicates that most interventions focus on technologies filling a gap in energy services from a top-down approach relying on the automatic creation of markets and provision of supply-side services, '(h)owever, adoption levels tell us little about the sustainability of these technologies or the efficacy with which they are utilized' (pp187).

The paper concludes that "energy transitions in rural areas are incremental processes" (pp 173), therefore leapfrogging is a misconception because there is insufficient attention to the dependence of the accumulations of technological capabilities at the individual and institutional levels in different scales (local, regional), which requires long time-scales for the technology and associated practices to be designed, tested, redesigned or redeveloped and widely disseminated, a rather "hard slog" process (pp 188).

Nygaard I: **Institutional options for rural energy access: Exploring the concept of the multifunctional platform in West Africa.** *Energy Policy* 2010, **38:**1192-1201.

Quality: high

Summary: This paper is the analysis of two case studies to examine the implementation and barriers to implementation of multifunctional platforms (MFP), a small diesel engine turning one or several types of milling machinery and a generator for production of electricity, under the management of women in Mali and Burkina Faso. The study included a literature review, Mali programme internal reviews (1994-2005), informal talks in Mali in 2007-2008, and in Burkina Faso in 2007.

The paper found that installations were subject to a number of technical and organisational problems. Barriers included the hard to install multifunctional nature of the technology, financial losses from sequential running of machines (therefore using the same time as two separate machines), the risk of repair and associated down-time, and reduced flexibility with regards to location (pp1196-1197). About 35% of installations were not in operation by the end of 2005 and, according to the review, 60% of non functioning MFPs were a result of socio-organisational problems, 26% ceased due to technical problems, and 14% due to economic problems (pp1197). It seems that women's organisations faced difficulties in operating and managing the platforms, with a greater share of functional than non functional platforms changing their organisational modality. Specifically, although donors had stipulated that the MFPs were to be controlled by women's groups, 'men are almost systematically present in the women's groups, and in a considerable number of cases operation has been taken over by men' (pp1198). In 43% of cases, the women had handed over the operation of the platform to a concessionaire, illustrating that women's associations faced difficulties in operating and managing platforms, with only 50% of platforms having women responsible for day to day management. While this would suggest that women's groups were poor managers, the argument actually appears to be that any community groups would have faced the same problems. That is, the author appears to argue that community-group management is not a familiar form of business operation and so, in the cases studied, led to social conflicts. Consequently, the argument is further elaborated to say that development aid should build on local structures rather than impose new and complicated institutions.

Peng WY, Pan JH: **Rural electrification in China: History and institution.** *China & World Economy,* 2006. **14**(1): 71-84.

Quality: high

Summary: This paper reviews China's rural electrification program in relation to its three stages of development. The first stage was from 1949-1977 and established a comprehensive management network vertically from the national level. Investment was primarily in rural electrical irrigation and agricultural production, in addition to a small programme of hydropower production. Rural electrification in this stage was slow and 245m people did not have electricity access. Rural power consumption was 13.3%, whereas people in rural areas accounted for 70% of the country's population. Line losses due to inefficiency were 25-30% and there was a total capacity of 6.33 GW.

The second stage was from 1978-1997 and was characterised by central government transferring management of local electricity systems to the local government. Three main investment projects were also undertaken in this stage: i) rural small hydropower investment enabled rural electrification in 653 counties; ii) poverty reduction was the second project and significant investment was put into rural electrification in order to reduce poverty; and iii) hydropower station construction in rural electrified counties was initiated and government subsidies were introduced. At the end of this stage, electricity consumption in rural areas increased to 495.5bn kWh, which was about 40.53% of the national total. Capacity of generating units at county level and below was 44.15 GW and accounted for 26.7% of total electricity consumption. Rate of

access was 99.2% in townships, 98.1% in villages and 96.87% in rural households. However, 8.81 m rural households were still without access.

The third stage of policy for rural electrification was from 1998-2002 and this stage promoted commercial operation of the utility market. This stage saw institutional reform which aimed to facilitate the commercial operation of the utility market and a rural grid renovation programme in order to overcome technical barriers to electrification. All effectiveness measures improved during this stage. Electricity voltage was more than 90 percent; 12% higher than before renovation of the grid. The reliability rate was up by 8 percentage points to 95% and grid losses were down by 25-30% to about 12%. Costs to some rural areas were reduced by over RMB 0.13/kWh, resulting in savings of over RMB 42 billion in electricity costs.

The authors conclude that it is easy to simply attribute the success of China's rural electrification programme to government investment and favourable policies for rural electrification, although this is not the case. Instead, the main driving forces of rural electrification in China are related to a diversity of funding channels, modes and institutional structures. Rural electrification drives development and must be supported by a mix of technical, social and economic factors, within a supportive institutional context.

Pereira MG, Freitas MAV, da Silva NF: **Rural electrification and energy poverty: Empirical evidences from Brazil**. *Renewable & Sustainable Energy Reviews*, 2010. **14(**4): 1229-1240.

Quality: medium

Summary: This paper reports on a large survey which aimed to generate empirical evidence on the impact of rural electrification on energy poverty in rural areas of Brazil between 2000 and 2004. The paper contains a summary of the state of knowledge about rural electrification and energy poverty in Brazil, in addition to a presentation of the findings of a survey and analysis of 23,000 rural households.

The authors argue that although energy poverty is widely discussed as an objective of rural electrification, there are few studies which empirically examine their relationship and the dynamics of energy poverty over time. Two groups were surveyed for the study: those that were in the electrified sample were part of the national rural electrification program, Light for All, and the second group was a control sample (non-electrified) comprised of a set of rural households that were not part of national rural electrification programme. Households were sampled prior to and after access to regular electricity. The control sample was interviewed at similar time periods to detect natural changes in energy consumption/poverty during the time period.

They show that use of energy after electrification indicates a dramatic drop in energy poverty as energy use increased significantly in rural households. A small drop in energy poverty was seen in the non-electrified sample, over the same time period, but it was not as significant. The authors conclude that the fact that there was a statistically significant change in energy usage indicates that there was a change in behaviour in families which had access to electricity, though this level of usage is still far from that indicated as necessary in the literature in order for a significant improvement in life quality to be observed.

Rehman IH, Kar A, Raven R, Singh D, Tiwari J, Jha R, Sinha PK, Mirza A: **Rural energy transitions in developing countries: a case of the Uttam Urja initiative in India.** *Environmental Science & Policy,* 2010. **13**(4): 303-311.

Quality: medium-high

Summary: This paper is a case study of the Uttam Urja initiative, a project that used an alternative business model to disseminate photovoltaic lighting technologies in rural areas of

India from 1999 to 2006. The initiative aimed to create a market for renewable energy technology services and to build a supply chain which would meet market demand and would promote delivery and management of energy services through a local supply chain. The main features of the Uttam Urja project included the articulation of expectations which refers to the project's attempt to differentiate itself in the market by creating awareness and brand recognition, social network development which targeted dealer and after-sales service provision which 'piggy-backed' on existing entrepreneurs, learning through after-sales services and from the market in order to develop new products which met specific user requirements and created new niches, and protection to entrepreneurs and end-users through financial innovations.

The paper describes the initiative and analyses its outcomes using the Strategic Niche Management framework. Though the paper is well-written, and the arguments are coherently structured, it is at times unclear how the evaluation data were collected and what the sources were. Nevertheless, the paper describes a range of technological, social, environmental and financial barriers to uptake of photovoltaic lighting technologies. For example, technologies can be deeply embedded in societal norms, values and cultures, and therefore social acceptability is important to examine. Other barriers to renewable energy technologies can include accessibility, reliability and maintenance issues; inconsistent levels of funding through government subsidies; the fact that products do not always cater to regional/local needs; financial barriers for end-users, in particular access to funding for rural households with an agrarian lifestyle; and the nature of programmes which are target-oriented and have low scope for learning, monitoring and evaluating.

The authors found that advertising schemes led to increased sales. Before branding, sales were INR 0.46 million and INR 0.59 million in Bikaner and Rishikesh, respectively. After branding, sales were INR 3.61 million and INR 2.43 million, respectively. Dealer response was also high, with products crossing into 7 adjoining districts and at the end of the project 12 new products were introduced, many of which were more affordable for lower income groups. Finally, innovative financing allowed for increased uptake: group financing systems, soft loans and credit cards all contributed to this. Success of the experiment could be attributed to the following elements: development of a local business network; improved accessibility of products to rural consumers; products were designed to meet local needs which led to greater acceptability; and the portfolio of products on offer meant they could reach a broader market.

Schut M, Slingerland M, Locke A: **Biofuel developments in Mozambique. Update and analysis of policy, potential and reality.** *Energy Policy* 2010, **38:**5151-5165.

Quality: high

Summary: This paper analysed various sources of secondary data, including biofuel proposals submitted from 2006 up to December 2008, in order to examine barriers (policy, biophysical, social, economic and legal) to biofuel use in Mozambique. The review of all dynamics, using recent biofuel development proposals as case studies to understand biofuel development in Mozambique, found that there are numerous interconnected factors relating to development, and particularly the location of developments.

Some of these factors are listed below. *Barriers to policy*: trade agreements (tariffs opening up markets, e.g. SADC trade protocol eliminating tariffs on intra-regional trade within 11 SADC members opens up the market), land law, investment law (government incentives are location specific, affecting location of activities), national biofuel policy and strategy (‘aims to contribute to energy security and sustainable socio-economic development by exploiting agro-energetic resources through stimulating the diversification of the energy matrix, contributing to the well-being of the population and promoting socio-economic development’ (pp5154)). *Biophysical potential:* natural resources (land zoning recently summarized potential on a national scale) (pp5155). *Social and economic factors***:** labour force availability and quality, access to

infrastructure and services, existing processing and storage facilities ('efforts to provide electricity to rural Mozambique are mainly concentrated around urban centres...' due to poor transport infrastructure, service provision, and higher population density and literacy rates in cities) (pp5156).

Steel K: **Dynamics of Growth and Investment in the Kenyan Electric Power Sector,** *Power Engineering Society General Meeting, 2007. IEEE*. 1-5. doi: 10.1109/PES.2007.385906

Quality: high

Summary: This institution working paper describes preliminary findings of a study on electrification (grid vs. off grid) in Kenya, looking at barriers to electrification including technical, socio-economic and financial barriers. The study uses a literature review, then ethnographic methods of interviews and observations, surveys, coupled with system dynamics.

It was found that people are moving off grid due to the unreliable nature of the power, long waits for connections, common outages, and high fees. Many industrial and commercial customers already generate some of their own power. Residential people may be off grid as they are not close enough to the grid. The paper concluded that if people start to move off grid, the grid could have decreased finances to invest in new infrastructure, therefore creating a cycle (which has already been seen in the telecom sector in Kenya and the takeover of mobile phones).

Thiam DR: **An energy pricing scheme for the diffusion of decentralized renewable technology investment in developing countries.** *Energy Policy* 2011: **39**(7). 4284-4297

Quality: high

Summary: This paper is an empirical analysis of pricing mechanisms of renewable energy technologies (particularly wind and photovoltaic) in Senegal. Data were gathered for the model from local interviews and secondary sources.

The barriers to implementation of renewable energy technologies in a country were found to be related to availability of renewable resources (i.e. wind and solar), externalities (tax policies, subsidies, tradable permits) and command and control (standards and regulations).

The study suggests that alongside a shift to market oriented approaches to renewable energy, an improvement in energy governance and the use of local stakeholders to include local constraints and socio economic characteristics is required. The financial conditions of a country could be an obstacle for deployment of renewable technology as many price mechanisms require borrowing from international organisations.

Finally, the paper concludes that investing in renewables requires strong institutional reliability, and therefore depends on political and social structures, and the technology selected should be socially accepted by local end users.

van der Plas RJ, Hankins M: **Solar electricity in Africa: a reality.** *Energy Policy* 1998, **26:**295-305.

Quality: high

Summary: The paper describes the dissemination of SHSs in Kenya, focussing on adopters of PV systems from rural areas in 12 districts across 3 regions of the country: Mount Meru, Western Kenya and Rift Valley – all "high potential areas", meaning areas with fertile soils and mainly export-oriented agriculture. The study attempts a pseudo-random sampling method to establish a

survey group that includes 410 SHS adopters who were investigated during December 1996 to February 1997.

Technical, financial and capacity (skills, knowledge, etc.) aspects of SHSs and a brief history of the SHS market is given. A range of indicators is reported: user-satisfaction, including by SHS size; technical quality and performance of systems, using a range of measures; and market prices for systems and components.

Based on the observations that many users buy the smallest modules available (10 or 12 Wp) and build their systems piecemeal, the paper suggests that there is a need for the PV industries to address this low-power market – small systems (1 to 2 lights) and small deeper-discharge batteries as well as smaller modules. Credit is suggested as a way to overcome the cost barrier of higher quality systems "but less so for initial market entry purchases" (p304). Costs are seen as the main constraint to accelerated use of SHSs. The paper also suggests that access to SHSs means that customers build up their demands for further electrical services and so could be a strategy to develop enough demand to make grid extension economically attractive.

In summary, the paper suggests promotion of a modular approach to technology diffusion/adoption, importers and retailers should provide more information to potential adopters of the real costs and benefits of such components, and training of installers (perhaps with certification) should be implemented to raise the quality of installations (the survey found that those systems installed by a technician or solar company were generally in better technical condition than those self-installed).

Walekhwa PN, Mugisha J, Drake L: **Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications.** *Energy Policy* 2009, **37:**2754-2762

Quality: high

Summary: This paper looks at biogas using family sized digesters in Uganda, assessing socio economic and demographic barriers to their implementation. The data were gathered via a survey between November 2007 and April 2008 from 220 households characterised as 'users' and 'non users', individual interviews and focus group discussions with households and key informants.

It was found that the adoption choice of a technology is a complex set of interactions between comparable technologies and the user's socio-economic and demographic characteristics. Variables affecting biogas adoption are: age of household head, education, household size, size of land of household, number of cattle owned, household daily fuel wood cost and kerosene, gender of head, location of house, monthly household income. A logistic regression using primary data on households was used to find the empirical results which are listed below.

Factors positively promoting biogas development: younger/male head, increased farm income or cattle owned, increased cost of traditional fuels. Factors with a negative impact on biogas adoption include household location and farm size (pp2759). 'On average, biogas users were older, had more years of formal education, owned a larger area of land and spent more on kerosene for household lighting purposes than their counterparts. However, the biogas non-users had larger households, reared more livestock and incurred more expenses for fuel wood for cooking purposes' (pp2758).

This paper shows that characteristics of households can provide good indicators as to reasons for uptake or not of technology, and consideration should be given to economic, social and human behavioural characteristics as well as technical questions when considering biogas technology uptake (pp2759).

Winkler H, Spalding-Fecher R, Tyani L, Matibe K: **Cost-benefit analysis of energy efficiency in urban low-cost housing.** *Development Southern Africa* 2002, **19:**593-614.

Quality: high

Summary: This paper presents the results of a cost-benefit analysis of energy efficiency in urban low-cost housing in South Africa (Cape Town, Johannesburg, and Durban). The authors considered a number of energy-efficiency improvements in low-cost housing, including: ceiling, roof insulation, partition, wall insulation, window, shared walls, compact fluorescent lighting and solar water heating. The method used was discounted cash-flow analysis. All interventions are considered over 50 years, as this is (optimistically) assumed to be the standard economic life of a low-cost house. Affordability was measured by the capital subsidy that would be required to induce consumers to invest in energy efficiency on their own.

The study founded that most of the energy efficiency improvements do not yield a net benefit when a 30 percent discount rate is used, as the future energy savings simply have much less value to consumers with high discount rate. For the 30 square-meter Reconstruction and Development Programme (RDP) house, a capital subsidy of around ZAR 1000 is required. According to the authors, this is a modest amount.

Wolde-Ghiorgis W: **Renewable energy for rural development in Ethiopia: the case for new energy policies and institutional reform.** *Energy Policy* 2002, **30:**1095-1105

Quality: medium

Summary: This paper reviews rural energy policy in Ethiopia. In rural areas in the country, energy is supplied by traditional energy sources. Fuel supply is mainly biomass-based with a very low level of grid electrification. However, biomass supplies are dwindling and it is deemed imperative to find an alternative such as renewable and other non-renewable energy sources. It is found that in Ethiopia, renewable energy technologies are unattainable for rural communities due to high import and customs duties or indecision by manufacturers to invest (pp1098). There are arguments that the reason for low levels of electrification have been due to a low demand for modern fuels, which perhaps is due to an inability to pay for such energy. High costs of rural electrification are also an issue (pp1099) and rural energy development has received a low proportion of funding in comparison to education, road construction and health (pp1100). It can be argued that these problems stem from a discourse in budgetary allocations, with rural energy initiatives under the responsibility of regional governments, therefore not allocated in federal level budgets (although the regional governments receive their allocation from the federal treasury), or that rural energy can be seen as a waste as it is not used for industry or agriculture, only for household use. It is observed that Ethiopia has delayed action with regards to energy infrastructure development in comparison with other African countries. Wolde-Ghiorgis recommends several policy issues that may lead to improved performance of rural energy initiatives (pp1102), including a revision of the national energy policy to include rural energy initiatives, clearly state the responsibilities of the authorities in the policy, and the need to draft new regulations and a new legal framework with regards to deforestation. Aside from these issues, careful consideration of the financial implications and the role of human resources and technical capability are needed.

The World Bank Independent Evaluation Group: **The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits.** *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits,* World Bank; 2008

Quality: high

Summary: This report is a re-assessment of costs and benefits of rural electrification in the World Bank's projects. It reviews recent methodological advances made in measuring the benefits of such projects. The study examines the extent to which changes in the Bank portfolio have addressed concerns regarding the limited poverty impact of rural electrification.

The projects assessed fall into three categories: dedicated rural electrification projects, energy sector projects with rural electrification components, and multi-sector projects with rural electrification components. The study highlights a recent trend in the growth of off-grid electrification, which mostly relies on renewable energy technologies. Most of the projects aim to improve energy supply or to support institutional development. Only 7 percent of projects explicitly address poverty-reduction objectives.

From an economic perspective, the study shows that rural electrification can generate sufficient benefits and that willingness to pay (WTP) for electricity is high so cost recovery tariff levels are achievable. Conventional grid electrification is found to be more efficient from an economic perspective that off-grid, which is more costly and benefits more limited. It is argued that "the economic rationale for funding off-grid alongside grid extension when the latter has the higher economic rate of return is far from clear" (p.17). Social concerns or technology development through learning by doing and expected cost reduction are suggested as arguments for off-grid electrification support.

The study also shows that projects have been more effective in providing infrastructure (although technical problems are still critical) than in supporting institutional development (mainly linked to the lack of financial sustainability). However, the sole provision of infrastructure does not guarantee outcomes (benefits on poor rural populations) are yielded automatically. Specific project design components connecting outputs (infrastructure or number of connections) to outcomes (welfare/development impacts) need to be carefully considered.

One of the main conclusions of the study is the widely recognised fact that the larger share of benefits is captured by the non-poor. From a supply-side, these benefits depend on which communities get connected: normally richer communities close to towns and commerce are prioritised for grid extension. From a demand-side, the benefits depend on which households can afford the connection: when electricity is available, the better-off households get connected to grids and the poorest in those villages or towns remain unconnected. For off-grid SHSs, the better-off families can afford expensive systems. This is also true for off-grid electrification, which has typically been carried out through a private business model. Moreover, lack of information to customers has meant that they do not get the full potential of their access to electricity because they normally restrict consumption on the wrong assumption that they will save money, even when they normally benefit from a fixed charge "lifeline tariff".

The study concludes that the evidence base remains weak for many of the claimed benefits of rural electrification. From a normative perspective, project designs that would enhance project benefits, such as financing schemes for connection charges, consumer education and support for productive uses have to be explored.

4.3 Analysis of cross-cutting issues (qualitative synthesis)

It was not possible to undertake a quantitative meta-analysis, as the studies reviewed used a wide range of methodologies which makes them non-comparable in most cases. Nevertheless, a qualitative meta-analysis was undertaken to provide a discussion on the cross-cutting issues. In this section, the results of the qualitative analysis are presented. The key themes of barriers and interventions are broadly classified into: economic, technical, political/institutional and cultural/social. This classification is to provide a framework to understand them, although it is recognised that the barriers and interventions do not always neatly fall under a single category (these cases are noted).

Barriers

Economic barriers

Economic barriers refer to several factors linked to the ability to afford the installation, maintenance and operation of technologies that facilitate energy services. These barriers can be categorised as:

- Demand-side barriers, such as high costs of technology (capital investment and operational costs), customer preferences, complexity of financial flows and lack of access to finance
- Supply-side barriers, such as low capacity for adequate cost recovery, high cost of infrastructure

Upfront costs are reported strongly and quite consistently in the literature as barriers, irrespective of the technology. Operation and maintenance costs are also discussed regularly, although whether they act as barriers is more contested. Some authors report that low income users are unable to pay for operation and maintenance (Haanyika 2008; Kirubi et al 2009), while other evidence suggests there is high willingness to pay for electricity services, even in poor areas (Ilskog et al 2005). The evidence and arguments for these demand-side factors are of different kinds: for instance, Acker and Kammen (1996) and van der Plas and Hankins (1998) show how Kenyan customers prefer the smallest PV modules available in the market; Kirubi et al (2009) calculate financial flows and cost recovery for a diesel-based mini-grid in Kenya; Winkler et al (2002) report on upfront cost of energy efficiency measures in South Africa; and this type of barrier is also mentioned in empirical research for rural electrification projects in Tanzania (Ilskog et al 2005); Mali (Diarra and Akuffo 2002); Zambia (Haanyika 2008); India (Rehman et al 2010), and mentioned in many interviews (interviewees Collings, Hunt, Bess, Brew-Hammond, Yadoo, Barnett). These demand-side economic barriers are normally linked to a lack of access to finance at several levels: poor rural customers unable to access credits, unreliable or non-existent government subsidies or dependency on donor support.

On the supply side, low population densities and high poverty levels make for unattractive markets because of low energy demand and difficult cost recovery. Supply is further hindered by lack of working capital and financing options for investors and utilities, even where there appears to be high willingness to pay for electricity (Green and Erskine 1999; Ilskog et al 2005). The aforesaid was also mentioned by one interviewee[6]: small enterprises are constrained in "supplying modern energy services to poor people [where economics is concerned, by] lack of equity rather than debt finance, the high transaction costs in developing viable enterprises…and the limited deal flow of viable schemes". Remoteness, cost recovery difficulties and transaction costs were also identified as barriers in three interviews (interviewees Bess, Brew-Hammond, Lockwood).

However, it is also recognised that economic factors do not act independently but in conjunction with other factors. This confers a systemic nature to the barriers analysis presented here, which is often neglected in the research reviewed. For instance, Schut et al (2010) offer evidence from biofuels developments in Mozambique, where infrastructural links, access to goods and services, processing and storage, and skilled labour appear to be more important than the biophysical potential or government policy. In a similar vein, one of the interviewees, in a supplementary note to the interview (see footnote 6), refers to the availability of "complementary inputs"[7] for achieving poverty reduction with modern energy services; and Murphy (2001) argues that techno-

[6] The quote is taken from a supplementary note provided by the interviewee, Andrew Barnett: see Barnett (2010) in the references.

[7] The note gives the example of pumped irrigation having more impact if irrigation ditches are already in place.

economic viability is often overemphasised, detracting from attention to socio-cultural and institutional factors, which are reviewed later in this section.

Technical barriers

The discussion in the literature about technical barriers is consistent in general terms but diverse, ranging from the quality and performance of technological equipment to the capacities to install, use and maintain energy systems at different scales (users, service providers, regulators, institutionalisation of energy service provision), to the social adequacy of the technologies.

Those barriers involving hardware failures or poor performance create direct problems for the use of the energy service and indirect problems by creating perceptions of risk for their uptake. These problems are common for off-grid electrification technologies (renewable and fuel technologies) and grid connected electricity. In some cases this is a problem of technical quality of the components available on the market, as Acker and Kammen (1996) show for Kenyan SHSs in which the most common problems occur with batteries and lights. One interviewee referred to the low quality of components and inflated claims about technical performance creating huge risks for investors (interviewee Barnett) and another reinforced this view mentioning a lack of quality control of imports of PV components in Kenya (interviewee Yadoo). Indeed, Duke et al (2002) report how Kenyan households suffer major financial losses simply because they have had the misfortune to purchase the wrong brand of PV module. Consumers are unable to discern the relative quality of different module brands which brings as a consequence a reduced confidence in PV, creates an important market failure, and generates problems of operation and maintenance.

But even more relevant, 'software' problems of the capabilities for designing, installing and using technologies are commonly and consistently discussed in the literature. Green and Erskine (1999) refer to low levels of technical capacity in the community to operate and maintain SHSs and to a dependency on donors' technical support, which reduce the understanding of users about the limitations of SHSs and result in failures or poor performance. For non-traditional technologies (such as PV and other renewables) the lack of maintenance services and formal operational contracts is an indicator of very low skills levels leading to poor performance and failure (Haanyika 2008; Rehman et al 2010; interviewees Collings, Yadoo, Lockwood). For some established technologies, these problems are not so acute. For example, for those technologies around traditional commercial fuels such as kerosene, diesel or petrol, or services such as battery-charging, there are informal networks that can deliver maintenance. However, generally, management capabilities are weak such that systems (particular installations, but also systems of delivery, maintenance and service) are insufficiently organised and supported. Furthermore, where technical capabilities are developed in rural areas, the skilled people so trained are often attracted to urban areas where there are better job prospects and markets are more established (Green et al 2001).

Another technical limitation to the effective use of modern energy services appears in grid connected areas where unreliable power supply is the norm. In such cases, some users seek their own solutions by using alternative generating technologies, and so face higher costs than otherwise would be the case. For poorer users, this may just mean no service at all. Lee et al (1999) and Foster and Steinbuks (2009) studied the causes of self-provision of electricity by private firms, finding that there is considerable installed capacity in sub-Saharan Africa (on average 6%, but in some countries private self-generation accounts for more than 20% of total installed capacity) and that it depends on firm size, sector and export orientation. In the case of households, Steel (2007), van der Plas and Hankins (1998) and Acker and Kammen (1996) found that some SHS users in Kenya are actually very close to the grid or are moving off-grid. There may be many reasons for this but one suggested by Acker and Kammen (1996) was the slow process of establishing a grid connection (in which local politics can be a frustrating factor) compared with the speed of buying and installing a SHS. This evidence suggests that off-grid or

decentralised power generation could play an important role in energy access in the future, particularly in Sub-Saharan Africa where generation, transmission and distribution infrastructure is weakly developed (World Bank 2008), although, as Murphy (2001) concludes, "energy transitions in rural areas are incremental processes" (p173), highly dependent on the accumulations of technological capabilities at the individual and regional scale, a "hard slog" (p187) process.

Political/Institutional barriers

The politicisation of energy service delivery and its impact is discussed in some of the literature, and was mentioned by a number of our interviewees. Kirubi et al (2009) talk of political interference, while elsewhere there is reference to corruption and the behaviour of vested interests. In the case of Mozambique, Mulder and Tembe (2008) attempt to explain some of the difficulties in implementing institutional changes such as power sector reform with reference to the resistance of vested interests, including some in government. The government, they claim, has not funded power sector reform and so it has, in effect, been blocked. Two interviewees referred to the case of India and the free provision of electricity to farmers, who form a powerful voting bloc (interviewees Lockwood, Barnett). The flipside of this observation is that where there are few votes to be gained, such as in sparsely populated rural areas, there may be little political incentive or will to drive energy-service provision. Two interviewees expressed the view that lack of political will is an impediment to extending energy services to rural areas (interviewees Brew-Hammond, Yadoo). In the case of Apartheid-era South Africa, Hofmeyr (1995) found that the lack of political power amongst farm-worker households, resident on commercial farms, was an important reason why they were either constrained in their electricity consumption by the farm owners or were not connected to the grid even when it was available on the farm. And, at the local level, politics and conflict are reported as constraints to the use of energy services. A study of multi-functional platforms in Mali and Burkina Faso, for example, reports that 60% of non-functioning platforms were the result of social or organisational problems that were caused by conflicts at different levels (Nygaard 2010, p1197).

At a more technical level, the literature reports many of the difficulties posed by institutional weaknesses or dysfunctional constraints of various kinds. Some of these relate to capabilities, as discussed above under technical barriers, but others arise from weak policy implementation mechanisms or the complexities of policy interactions, unstable policy environments, or the influence of shifting donor priorities. A study in Zambia, for example, implies that a long administrative chain from policy objectives to implementation to set up a Rural Electrification Fund resulted in drastically reduced funds. Instead of the budgeted ZMK 12 billion in 2000, only ZMK 7 million was made available (Haanyika 2008, p1054). Mangwengwende (2002), discussing power sector reform in Zimbabwe, lists a number of tariffs – lifeline tariffs and special agricultural tariffs – and explains that attempts at their rationalisation were constrained by the failure to establish a predictable and sustainable tariff-setting process. Mulder and Tembe (2008) argue that shifting donor priorities can introduce complexities into the policy process, particularly where they conflict with the long term needs of infrastructural development. And Lee et al (1999) compare the self-provision of energy services among firms in Nigeria, Indonesia and Thailand; responses to poor-performing electricity supply. They find that Nigerian firms are highly constrained by strict regulations that do not allow private provision of infrastructural services (although many firms generate their own power in any case), while the Indonesian and Thai cases are much more open with consequently much higher rates of self-provision.

Cultural/Social barriers

Often under-considered as determinants of success or failure in the uptake of modern energy services, social and cultural barriers arise in regard to the ways in which technologies fit with social practices, and can inform understanding of other types of barriers.

As already mentioned in the discussion on economic barriers, the dispersed nature of rural populations (Kirubi et al 2009), and behaviour such as theft of grid electricity or PV modules (Green and Erskine 1999), poses difficulties for the expansion of energy markets into rural areas. Dispersed and often low demand can create unfavourable conditions in which to provide reliable and affordable service. In addition, the remoteness of rural livelihoods makes it difficult to prevent theft, further undermining service (interviewee Collings).

However, cultural practices, status of owning a particular technology (such as PV), acceptability of technologies and design versus needs, are claimed to be particularly important for whether an energy technology will be adopted by users. Some authors suggest there can be misalignment between technological design, on the one hand, and practices and needs on the other (e.g. Rehman et al 2010). According to one informant, this is particularly relevant with cooking practices and thermal needs, but less so for electricity (interviewee Brew-Hammond). Some technologies can be seen as status-enhancing while others are the opposite, or the same technology can be viewed positively by some and negatively by others. Green and Erskine (1999) discuss the preference for accessing grid electricity instead of SHSs but also find that, for some rural dwellers, owning a SHS creates enhanced status, which helps to explain increasing levels of theft and vandalism.

Interventions

Economic interventions

Finance and credit are suggested by many as ways to help make energy services cheaper for poorer people in order, mainly, to overcome the upfront costs of conversion technologies and, in some of the literature, to help with grid connection charges. For other energy services, subsidies are usually suggested. There are also suggestions for coupling income-generating activities to energy-service provision in order to increase the commercial viability for the service provider as well as create opportunities for energy users to generate income, thereby helping them afford better services. There is little strong evidence in this category of intervention, although some of it is suggestive of the potential for success. Some of the studies are based on empirical research into market dynamics; some are modelling or simulations; and others investigate specific interventions.

Acker and Kammen (1996), reporting on the Kenyan SHS market, give examples of where credit was extended to dealers who were then able to extend it to SHS buyers and increase sales. They supplement this with examples from other developing countries, using these to suggest that the Kenyan utility could become involved in credit schemes for PV. Also discussing the Kenyan experience, van der Plas and Hankins (1998) suggest that credit could be given for buying higher quality systems, having found that these were more likely to continue to provide consistent services than the lower quality or smaller systems. However, they suggest that the private sector should also focus on providing smaller systems that are specifically designed to meet low power needs as this was clearly an important entry point for many people. Unfortunately, no high quality studies were found in the academic literature on sub-Saharan Africa of consumer-financing experiences. One study in India does provide some discussion of consumer-financing. Rehman et al (2010) investigate a market development project in which soft loans were provided from state-owned and cooperative banks, and a credit card was introduced, under schemes that were sensitive to the variable incomes of farmers. They report that there was increased uptake of SHSs as a consequence of these financing schemes. In a more general assessment of rural electrification, the World Bank (2008) reports that credit and consumer financing schemes have been limited in its interventions, suggesting that the evidence remains weak.

A few studies investigate the experiences of fee-for service or cost-recovery electrification schemes, though the findings are mixed. The Global Environment Facility (GEF) supported a

project in Zimbabwe that intended to create a market for solar lighting systems targeting low income rural inhabitants (Mulugetta et al 2000). The authors question the extent to which these goals were achieved, suggesting that well-off rural dwellers were more likely to have benefited from the fee-for-service approach. Also, without any integration of the project into a national policy strategy or other measures of accountability and monitoring, the project was focussed on creating incentives to meet its own target of installing 9000 systems, which led to market-distorting behaviour. This resulted in little attention to longer-term efforts at local capability building or ensuring adequate management, operation and maintenance for after-sales services. Once the project finished, any capabilities that had been developed were quickly lost. The World Bank report (2008) also highlights that the larger share of the benefits rural electrification yields are captured by the non-poor. However, it is also suggested that cost recovery is achievable and that there is a high willingness to pay for electricity in rural contexts.

Ilskog et al (2005) and Kirubi et al (2009) report on cost-recovery electrification schemes that appear to have been more successful. Discussing a cooperative-led project in Urambo in Tanzania, Ilskog et al identify a range of factors to explain success. Financial support for investments and covering the initial problems with recovering operational costs, ability and willingness to pay among consumers for at least the full operating cost of the service, and committed international assistance from the Stockholm Environment Institute (SEI) and Swedish International Development Cooperation Agency (Sida) were all important. Kirubi et al (2009) describe a community-led diesel-powered micro-grid electrification scheme in Kenya, which received a capital grant and technical assistance from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and German Assisted Settlement Project (GASP). The scheme included a number of productive elements. Based on their findings, they argue that such schemes have high potential to reach adequate levels of cost recovery, particularly where they enforce cost-reflective tariffs and link to productive uses that generate income and improve the load factor. They also argue that the provision of capital subsidies in such programmes can be justified.

Subsidies are discussed by others, some for interventions other than electrification. Winkler et al (2002), for example, model subsidies for energy efficient measures in low cost housing in South Africa. They find that the high discount rates of the poor mean most energy efficiency subsidies do not yield net benefits. Where benefits do appear, they are for measures that are already attractive and so do not require subsidies. Hofmeyr (1995), however, calculated that cost-effective electrification subsidies for worker households on electrified farms in South Africa were possible, assuming low cost technologies and the use of on-farm labour and equipment. For un-electrified farms, PV systems could also be cost-effective and were cheaper per household than the utility's urban electrification costs. Dube (2003) attempts to model the effect of a subsidy policy on the affordability of electricity in Zimbabwean cities. The analysis suggests that the existence of subsidies is not decisive for the affordability of energy, although the removal of subsidies would impact more negatively on vulnerable groups. A more significant barrier to accessing electricity is the upfront cost, not recurrent costs (even without subsidies).

Finally, by contrast with the experiences in electrification in much of sub-Saharan Africa, Peng and Pan (2006) describe China's rural electrification programme. This began in 1949 and developed through three stages. Initially, investment was primarily in irrigation and agricultural production, and electrification was slow. The second stage saw the transfer of local electricity systems to local government management. Alongside this transfer, small hydropower investments enabled the electrification of 653 counties; and significant investment was directed to rural poverty reduction. By 1998, the rate of access was above 96% in rural households, although more than 8 million rural households still had no access. The final stage included construction in rural electrified counties of hydropower stations, a rural grid renovation programme and the introduction of government subsidies. Indeed, one interviewee mentioned that there were huge amounts of transfer from rich to poor in China via government subsidies (interviewee Barnett).

Technical interventions

Interventions to address technical challenges in increasing the use of modern energy services can be categorised into those dealing with hardware options and problems, those concerned with capabilities of various kinds ('software'), and those to do with regulations. The literature covers these issues either by developing recommendations based on the problems identified in the field or with reference to the experiences of specific interventions.

The World Bank (2008) assessment of rural electrification found that interventions leading with hardware provision tended to be more successful than interventions related to institutional development. However, the study shows that technical problems of infrastructure provision are still critical and that the benefits of rural electrification do not follow automatically from hardware availability.

On interventions dealing with software issues, studies from Kenya, once again, feature prominently. Acker and Kammen (1996), as well as van der Plas and Hankins (1998), recommend education and training on the supply side. The study by van der Plas and Hankins (1996) found that SHSs installed by trained technicians or solar companies tended to be in better condition than those that were self-installed and so suggest that training, which could be certified, is likely to raise the quality of systems and hence service to the consumer. Acker and Kammen include a number of other recommendations as well. They suggest that demonstration systems would raise awareness about the benefits of PV, something that had helped to prime the early Kenyan market, but a measure no longer well supported by development agencies. They also speculate that Kenya could be helped to develop manufacturing capabilities in PV, beginning with the encapsulation of cells. The hope would be to lower the price to the consumer, and they cite experiences from other countries to support the view that this approach could work. Ilskog et al (2005) identify training and other technical support as important factors in the success of the project they studied in Tanzania. The staff of the cooperative managing the electrification scheme was given training and further technical support whenever needed, including from the national utility. In contrast, Mulugetta et al (2000) describe the GEF Zimbabwe SHS project as having paid little attention to local training; focussing, instead, on short term project targets. As mentioned in the previous section, once the project finished, any capabilities developed during the project quickly vanished. Thus, although the evidence is consistently reported in the literature that training and capacity building are needed, it is not clear what kinds of training and capacity building these should be in different contexts and how these should be assessed.

But even if capabilities are developed, Haanyika (2008), discussing electrification by grid extension or decentralised micro-hydro and PV in Zambia, notes that technical standards and service levels might need to be lowered to take account of local conditions. This contradicts other voices in the literature who call for the development and enforcement of standards, or point to perceived benefits of standardisation. D'Agostino et al's (2011) analysis of China's Renewable Energy Development Programme (REDP) claim that manufacturers perceived benefits from the emphasis the REDP placed on standardisation and compliance for higher quality products. However, these did not appear to trickle down to dealers or end-users who reported buying products solely on price. Duke et al (2002) recommend performance testing of PV components and public disclosure about their quality as a way to address information failure in the Kenyan market. And a more general information failure issue was raised by an interviewee (interviewee Barnett). Data on the field and context specific performance of technologies are not available to the consumer (or others such as investors) making it difficult to make choices when faced with a number of options. It is well-known, for instance, that a PV module loses efficiency as its temperature rises but understanding what this would mean for a consumer in their particular circumstances is practically impossible.

However, according to some authors in the literature, addressing capabilities or technical performance issues in isolation is not sufficient. The discussion has already mentioned the

cautionary note from Murphy (2001) that an emphasis on the techno-economic viability of particular options can detract from other important factors. Green and Erskine (1999), studying a PV project in South Africa, observe that it was not clear the extent to which issues beyond the technical aspects were addressed; issues such as engaging a broad range of actors who can create the institutional and market structures needed to sustain the development of the project. Each of these actors could be expected to have certain capabilities and access to information that could facilitate learning from the market, as Rehman et al (2010) report from their study of a PV project in India. As a result of such linkages, learning from the market and after-sales service facilitated the development of 12 new products, many of which were more affordable by lower income groups. The findings from the analysis of China's Renewable Energy Development Programme by D'Agostino et al (2011) also reinforce the need for retrospective learning and research into robust and pragmatic life-cycle approaches to renewable energy programmes. Diniz et al (2011) also report on their experience in implementing a PV rural electrification programme in Brazil and conclude that a range of interrelated criteria addressing costs, capabilities and social factors are most likely to lead to successful outcomes.

Political/Institutional interventions

Interventions to address political and institutional barriers are wide ranging, although not exhaustive. There are many to do with strategic aspects of policy making, and also concerned with policies and institutions themselves from national down to the level of the firm. The weakest part of the literature appears to be at the political level where it is presumably more difficult to implement interventions.

From the strategic perspective, the interventions seem to be derived mainly from observations of problems in the field and not necessarily systematic empirical studies. These recommendations centre around the ideas of integration and coordination. The most general of these is that there needs to be stability in the institutional policy making environment; a recommendation arising from the difficulties experienced in rationalising Zimbabwe's tariffs (Mangwengwende 2002). Mulugetta et al (2000) suggest that projects should be aligned with national frameworks and policies in order to raise the chances of their impacts being sustainable. Kirubi et al (2009), and two interviewees, suggest that energy service policies should be integrated or coordinated with other development policies (interviewees Brew-Hammond, Barnett). These might include policies for agriculture, health, education and commerce, and there should be more sector-wide approaches involving coordination between bilateral donors and national governments. One other suggestion is that it would make sense to start with local institutional structures that are seen to work and then build on these (interviewee Lockwood). In terms of starting with local institutions, the example of China's electrification programme is perhaps instructive. It is commonly understood that China's governance is heavily centralised and it was from the centre that the electrification programme began. However, over time, management responsibility was successfully transferred in phases from central government to the local level (Peng and Pan 2006).

At the level of policy itself, power sector reform receives some attention. However, it has a patchy record. Karekezi and Kimani (2002) discuss some of the impacts such reform can have on the poor, especially where tariffs are increased steeply. They cite examples from Ghana, where tariff increases caused riots, and Kenya, which experienced protracted political debates about the reform. The World Bank (2008) also found that interventions operating at the institutional level, primarily regarding financial sustainability concerns, have been less successful. One interviewee observed that much of power sector reform has been focussed on ownership to the neglect of governance; that private ownership will not, in itself, necessarily change the problems of politicisation and patronage that the energy sector has attracted in so many countries (interviewee Lockwood). Nevertheless, privatisation of some kind may open opportunities to address some of the challenges of infrastructure development, as reported by Lee et al (1999) in their comparative study of self-provision of power in Nigerian, Indonesian and Thai firms. Indeed, such reform

could enable new business models of energy-service delivery at the micro-level, as suggested in Kirubi et al (2009) and Duke et al (2002), helping to develop supply chains as witnessed in the Indian SHS project analysed by Rehman et al (2010). Of course, firm level activity in a private market has been seen to create problems of poor quality products and information asymmetries. This was seen in the Kenyan PV market, but Duke et al (2002) suggest these problems can be mitigated through measures such as standards, certifications, voluntary actions of companies, warranties, testing procedures and disclosure.

The weakest area of the literature examined here is that concerned with the political level. It is clear that many studies conclude there is a need for political will, and this was also expressed by a number of interviewees, whether at the national level or the local (interviewees Brew-Hammond, Yadoo, Lockwood, Barnett). Indeed, Ilskog et al (2005) claimed that institutional commitment and strong local leadership were important success factors in the cooperative-led rural electrification project they studied in Tanzania. However, there seems to be little in the literature selected for this review that demonstrates interventions to overcome more high-level political difficulties. For example, Hofmeyr (1995) reveals the problems created by Apartheid for farm-worker families but gives no examples of how to increase the political power of marginalised groups. Rather, the paper recommends greater participation and recognition of the status of farm workers as individuals. Such interventions might overcome the power asymmetries against marginalised groups but no evidence was captured in this review, suggesting that either such evidence should be specifically targeted by other reviews or there is a need for further study into governance issues around energy access.

Cultural/Social interventions

Strategies to overcome cultural and social barriers fall into a number of categories. Marketing, awareness and education are all linked and often recommended in the literature. Not so commonly reported are strategies that learn from users and the market, although they do feature to a certain extent and were mentioned by a number of interviewees. And, linked to this, some discuss the importance of understanding needs and designing products to suit those needs. Some of these strategies overlap with other interventions discussed above, which is perhaps testament to the deep-seated and pervasive nature of the importance of these aspects in the adoption and use of modern energy services.

Marketing, awareness and education can all be seen as forms of information and, as such, play overlapping roles. Of course, they are distinct as well. Marketing, for instance, serves to sell a product and this can lead to inflated claims about performance, as noted in the above discussions. Measures to address this information failure have already been discussed above and include the recommendations of Duke et al (2002) in trying to reduce the impacts of poor performing modules on the Kenyan PV market. Dwelling on the Kenyan market, calls for reducing the information deficit have been made since at least 1996 in, for example, the paper by Acker and Kammen (1996), who suggest that the provision of independent information and advice would be a cost-effective way to reduce the perceived risks to consumers. Similarly, van der Plas and Hankins (1998) recommend the provision of information on the real costs and benefits of PV, except that they suggest this be done by importers and retailers. The importance of information amongst users is underlined in the findings in a study of LED lantern marketing in Malawi by Adkins et al (2010). Their survey of 54 households that purchased a lantern revealed that 21 had heard about or seen a lantern through a focus group discussion or sensitisation meeting, 14 at a vendor's store, 12 through a friend or acquaintance and seven through other sources (Adkins et al 2010, p1091).

The benefits of learning from the market are expressed in Rehman et al (2010), especially in developing branding, which is shown to have had a significant effect on sales. Brand promotions through simple slogans, paintings on walls, banners, newspaper articles and many other mechanisms were used. Increased sales followed: before branding, sales were INR 0.46 million

and INR 0.59 million in Bikaner and Rishikesh, respectively; after branding, sales were INR 3.61 million and INR 2.43 million, respectively. Dealer response was also large after branding, with products crossing into seven adjoining districts. Green and Erskine (1999) question whether marketing and promotional activities were well designed in the SHS project they studied in South Africa, where the authors suggest that efforts were too focussed on the technical aspect of the technology and not on encouraging rural inhabitants to buy SHSs.

The notion of designing for user needs is also evident in van der Plas and Hankins (1998). They recommend private actors to develop small PV systems that have deeper-discharge batteries specially designed for the energy-use patterns of many Kenyan households who are buying systems piecemeal. Likewise, Acker and Kammen (1996) suggest that small systems such as solar lanterns could be a way to deliver small amounts of power in quality systems to users. And a number of interviewees expressed the importance of aligning with both user needs and cultural practices (interviewees Collings, Brew-Hammond, Yadoo), although one interviewee also distinguished between thermal and cooking practices, and electricity use (interviewee Brew-Hammond). He asserted that cultural factors play a larger role in thermal and cooking practices than in electricity use.

Finally, a small amount of literature focuses on gender specific interventions. For example, Nygaard (2010) describes electricity generation programmes under the management of women's groups. The study found that the women's groups faced difficulties in operating and managing the multi-functional platforms supported by donor funding. However, it is not clear from Nygaard's discussion whether the problems were related to gender. The argument, instead, suggests that the fundamental issue was that community-group management of businesses was unfamiliar in the particular contexts studied. This management form had been imposed by donors. Nygaard argues, therefore, that development aid should build on local structures rather than new institutional forms; something also supported by one of our interviewees (interviewee Lockwood).

Summary

As noted at the beginning of this review, modern energy services are not easily defined. It is apparent from the discussion in this section on cross-cutting issues that they depend on a variety of different societal needs to be fulfilled (at the domestic, commercial or other productive levels) which, in turn, depend on the context in which the services are needed (e.g. urban or rural) as well as the existing technological, institutional and social capabilities to develop interventions. Furthermore, energy carriers and technological options are diverse, adding complexity to the analytical and normative nature of understanding barriers to, and interventions for, increased use of modern energy services.

We also noted that our classification of barriers and interventions is not straightforward. In many of the discussions it is apparent that barriers interact with each other, and interventions do not map easily from particular barriers, howsoever they are conceived. This, together with our observation of the complexity of modern energy services, points to the importance of understanding barriers and interventions in integrated ways. This is something that was raised by some papers in the literature in regard to political and institutional strategies, and underlined by several informants. Therefore, our categorisation of barriers and interventions is likely to have missed the interlinked nature of the factors limiting the use of modern energy services, and the integrated and systemic characteristics of interventions to overcome these limiting factors. To some extent, this reflects the state of the academic literature: there seems to be a relative lack of high quality research, particularly in an African context, which attempts to pull together such integrated understanding.

However, it also seems to reflect a potential problem with the concept of a barrier itself. One of our interviewees noted that the world's poorest people face difficulty translating their needs into market demands, precisely because of their poverty (interviewee Barnett). A barrier implies the

restriction of some process – in this case, the translation of human needs into market demands. But, as a market demand is expressed with money, and the poorest people do not have money, the barrier concept becomes problematic. Much of the analysis presented in the literature of barriers and interventions is focussed on market solutions to increasing the use of modern energy services. Such interventions rest on making new sources of finance available to stimulate market demand – either by increasing incomes of the poorest people or through some form of financial assistance. The important consequence of this is that simply removing many of the technical, social and institutional barriers to energy access discussed in this review will not change the low incomes of the poorest people. This reinforces the need for systemic or integrated strategies to improve access to modern energy services by the poor which provide them with long-term, sustainable opportunities to generate surplus cash income.

Nevertheless, and bearing in mind these caveats and the limitations of a systematic review discussed in Section 5 below, Table 6 presents a summary of the nature of the evidence which is present in the 41 papers reviewed and synthesised above about the different barriers, and interventions that might overcome them. The criteria used to determine the relative strength and/or consistency of the evidence are as follows:

Consistent: Evidence from the 41 papers reviewed is regularly and consistently reported about the nature of the barrier or intervention to address it.

Proof of concept: Evidence from the 41 papers reviewed is empirically weak, but the few pieces of empirical evidence that do exist are strongly suggestive of proof of concept for the barrier or intervention to overcome it.

Contradictory: Evidence from the 41 papers reviewed is strongly contradictory, with strong evidence for contradicting arguments about a barrier or intervention.

Mixed: Evidence from the 41 papers reviewed is mixed, with both weaker and stronger evidence presented, but not enough of each to determine an overall strength assessment.

Weak: Evidence from the 41 papers reviewed is weak with only a few papers providing evidence about the nature of the barrier or intervention.

In the conclusions section (see Section 6), we further elaborate on the policy implications and research challenges that arise from our findings. Where relevant, the criteria above are also used to characterise the relative strength and consistency of the evidence that backs up these conclusions.

1 **Table 6: Synthesis of Evidence and Strength Criteria**

Type of Barrier	Description/ Category	How the barriers are characterised in the reviewed literature	Comments about the strength of the evidence, and cross-cutting observations
Economic (demand-side)	Upfront cost	High cost of energy technology hardware (reported for both off grid – renewables and diesel gen-sets – and grid extension) is a barrier.	Consistent: This barrier is strongly and consistently reported in the reviewed literature.
	Maintenance and operational costs	This type of barrier is characterised by high operational and maintenance costs of rural electrification and self provision of electricity in industry, but the argument is contested. Some authors indicate the inability of low income users to pay for maintenance and operational costs (Haanyika 2008; Kirubi et al 2009) whereas others suggest there is high willingness to pay for electricity service even in poor areas (Ilskog et al 2005).	Mixed: The evidence about high operational and maintenance costs of energy service provision is regularly mentioned in the reviewed literature and there are some discussions about the efficiency and efficacy of subsidies. However, this type of barrier seems to be very context specific.
Economic (supply-side)	Inadequate cost recovery	There are several reasons explaining this type of barrier such as low population densities, distance and dispersed nature of rural populations, low load factors, and non reflective tariff structures.	Consistent: The literature addressing this barrier suggests integrated approaches might work better in which productive and income generating activities are linked to energy service provision.
	High cost of infrastructure	This barrier is linked to high upfront costs (demand-side) and authors refer to lack of access to finance, low income levels of customers, inadequate levels of public capital.	Proof of concept: As per rural electrification (and electrification in general), there are some successful cases in which public funds and access to credit have been used. The reviewed literature suggests these initiatives have to be linked to institutional and policy frameworks.
Technical	Quality and performance of technological equipment	This type of barrier refers to quality and performance of hardware. It is mainly discussed in the case of SHSs (low quality equipment and installations: Acker and Kammen 1996; van der Plas and Hankins 1998) and MFPs (Nygaard 2010)). In the case of grid electricity, this refers to poor performance and unreliability of service (Lee et al 1999).	Consistent: This barrier is consistently referred in the literature and is linked to availability of information about technology, quality standards, and warranty and certification/enforcement schemes.
	Low technical capacity to adequately maintain and operate energy systems	This software barrier is referred to in many different aspects, including: low skills and knowledge amongst end users and local technicians in the case of SHSs and other decentralised energy technologies (MFPs, micro-grids); low capacity of public utilities to operate and maintain power stations and electric networks; dependence of donors' technical support; and poor managerial skills to provide adequate after-sales services (Green and Erskine 1999, Haanyika 2008, Lee et al 1999, Foster and Steinbuks 2009, Nygaard 2010).	Consistent: This barrier is consistently referred to in the literature. It is linked to institutional factors (support from public policies, standards, sector reform, etc.) but there seems to be little thorough research analysing the inter-relationships.

Political and Institutional factors	Political	There is little empirical evidence in the literature, but some interviewees highlighted a lack of political will (Brew-Hammond; Yadoo), and others refer to political interference (Kirubi et al 2009), suggesting that political barriers are important. Also mentioned by some interviewees was the power of voting blocs which could hamper the implementation of cost effective measures to improve access to energy services (Lockwood; Barnett).	Weak: This type of barrier is mentioned often in the literature but there is a lack of empirical research focusing on politics and power balances and the impact on transitions to modern energy services
	Institutional weaknesses, corruption and vested interests	These barriers refer to difficult to implement sector reforms, inadequate delivery capacity and lack of accountability of energy policy.	Proof of concept: There are examples in the literature where sector reforms have involved the institutionalisation of access to electricity (mainly rural electrification) through specific institutions or agencies, devoted funding mechanisms and enactment of legislation and regulation. However, much of this is descriptive and there seems to be a lack of research and analysis on the dynamics of such institutional processes and the impacts of policies.
	Political invisibility of rural population	This barrier refers to the lack of power and mechanisms to bring rural populations/farm-workers into energy policy deliberation/implementation (Hofmeyr, 1995).	Weak: There is evidence of this situation in only one paper reviewed, although the evidence is convincing in this particular case. If this kind of situation is more widespread (which is likely) then it is an important area for more thorough research.
Cultural/Social	Misalignment of technological system design and social practices and users' needs	This barrier arises because energy products (technological designs) do not always cater to regional and local needs, as interventions are designed and implemented from centralised institutions (Rehman, et al, 2010).	Proof of concept: There is some evidence of the mismatch between technological solutions and the fulfilment of needs and consideration of local practices. However, the reviewed literature does not put a particular emphasis on the issues of strategic approaches and systemic understanding of the framing of access to energy
	Desirability of energy technologies	This refers to barriers which arise from the relative desirability of energy technologies and include the status enhancing role of owning PV technology in rural areas and problems of theft which are linked to this. It also addresses whether grid or off-grid technologies are desirable, and in what circumstances. For example, PV normally provides limited electricity and therefore cannot fulfil users' needs or demands.	Contradictory: The evidence is contested in this area. There is a lack of more comprehensive analyses aimed at understanding cultural preferences, and linking needs to impacts of access to energy.

2

Type of Intervention	Description/ Category	How these interventions are characterised in the reviewed literature	Comments about the strength of the evidence
Economic	Access to finance and credit	The literature refers to financial/economic mechanisms to overcome upfront cost of (energy conversion) technology/connection costs. There are examples of access to credit to PV dealers who extended it to customers and credit to access better quality equipment. There was no academic study found about consumer-financing experiences in SSA, but evidence of soft credits in India has been reported.	Mixed: There seems to be an emphasis on interventions focusing only on economic incentives/mechanisms, which might result in a lack of consideration of other factors such as capacity building, adequate management and maintenance/operation.
	Subsidies and grants	The literature demonstrates that capital grants/investment subsidies are important in the case of expensive electrification and other energy services. It is argued that capital support works better when provided alongside technical assistance and mechanisms to recover operational costs (Kenya: Kirubi et al 2009; Tanzania: Ilskog et al 2005). However, it is also shown that subsidies might not yield net benefits in the case of energy efficiency (Winkler et al 2002). In the case of increased use of electricity, modelling suggests that subsidies are not decisive as upfront costs are probably more significant (Dube 2003).	Proof of concept: There is isolated but strong evidence on the importance of well designed subsidies when poor people are targeted to improve access to modern energy services.
	Fee-for-service approaches	Though broadly promoted, it is suggested that this type of approach might be ineffective in targeting the poor/poorest rural populations, thereby decoupling the social role of access to energy and market development/technology diffusion.	Mixed: There is some evidence about fee-for-service interventions and the high willingness to pay, but it is also suggested that these interventions do not reach poor people as intended.
	Linking energy services to productive activities	These type of interventions improve the ability to pay; the likelihood of success of cost-reflective tariffs and cost-recovery. Productive activities improve load factor, thereby improving financial viability of electrification projects. Evidence is provided from China (Peng and Pan 2006) and Kenya (Kirubi et al 2009).	Proof of concept: This sort of intervention is in general supported and suggested but there is not enough empirical evidence interrogating the processes underlying effective interventions.
Technical	Hardware options and problems	Interventions tend to focus on the provision of hardware by means of market development or government or donor-led interventions. However, quality and performance of equipment is frequently raised as an important issue to be addressed for both grid and off-grid electrification.	Consistent: The evidence is strong however there seems to be lack of comprehensive ex-post evaluation of interventions. This type of intervention is clearly linked to the existence of adequate regulations, standards, information and training, suggesting there is a need for more integrated and systemic approaches to interventions.
	Software or capabilities	Interventions of this type involve training and education of technicians which may raise the quality of installations, provide better service to consumers and raise awareness and knowledge. This is particularly seen in the case of PV in Kenya with demonstration systems (Acker and Kammen 1996; van der Plas and Hankins 1998) and in Tanzania (Ilskog et al 2005). However, Mulugetta et al (2000) argue that any capabilities acquired vanish quickly after project assistance finishes if those capabilities are not fostered with a view to the local context.	Mixed: Strong evidence on the importance of training and development of technical capabilities. However, the provision of training alone does not guarantee good service provision or adequate technical support as capabilities might vanish in the absence of institutional support structures and/or opportunities to continue practising. There is not enough known about what kinds of capacity development is needed, and how these assessments are done.
	Regulations and information	These types of interventions refer to consistent application of regulations and standards which might help to ease technical barriers. For many types of energy technology (grid, PV, mini hydro), some authors suggest that technical standards might need to be lowered to better fit local conditions such as households' quality and materials and use of local materials (Haanyika 2008), but others argue that standards and certification of energy equipment must be developed and enforced (Duke et al 2002).	Contradictory: Many authors warn about the need to address technical interventions alongside other factors such as engagement of a diversity of actors, socio-cultural, and interrelated economic/market conditions. However, others suggest social and technical/capabilities approaches are most likely to generate learning and lead to successful results.

Political/ Institutional	Strategies and policy making	This type of intervention is mainly centred around recommendations for strategic policy making, including: policy coordination and integration between energy and other sectoral/development policies (Kirubi et al 2009), long term policy stability and integration with national frameworks (Mulugetta et al 2009); and tariff rationalisation (Mangwengwende 2002). Power sector reform has been widely introduced across the world and increasingly in SSA. However, much of the reviewed literature does not refer to governance and impacts of the reforms on the poorest segments of the population (Karekezi and Kimani 2002; Lee et al 1999).	Proof of concept: There is a patchy record on interventions focusing on strategic policy making. However, it is clear that where strong, focused and stable policies have been developed, access to modern energy services has improved and is likely to have better impacts on development processes. There seems to be a need for further research about different approaches to policy-making (top-down/centralised vs. bottom-up/decentralised) and at different levels (international/donors; national governments; local authorities/government).
	Political	Interventions of this type refer to politically motivated power sector reforms. There is evidence of political debate and riots due to some implications of power sector reforms (i.e. tariffs increased), but no systematic study of the politics of such reforms was found. However, some studies and experts conclude that political commitment and leadership at different levels are keys to success in improving fair access to energy (Ilskog et al 2005; Hofmeyr 1995) but there seems to be little in the literature that systematically investigates interventions and political dynamics that help overcome these hindering factors.	Weak: This seems to be the weakest area in the literature, but one that is frequently considered critical, and therefore is identified as an important area for further research. Many of the cases are given as examples and anecdotal evidence.
	Institutional	This type of intervention refers to the establishment of appropriate institutional arrangements and structures. There seems to be no consensus on whether the institutional structure has to follow bottom-up or top-down approaches. Instead, the analyses and expert opinions suggest that interventions at various levels may be necessary; the important consideration being whether they are aligned with each other or not.	Proof of concept: Suggested by many authors, but there is no particular literature addressing institutional change, the adequacy of institutional structures and the alignment of institutions to local conditions and national/donors' imperatives.
Cultural/ Social	Marketing and awareness	In general, reported interventions in this area aim to address an information failure about technology options, potential and real benefits of energy technologies. This can be done by different actors. Duke et al (2002) and Acker and Kammen (1996) suggest reducing the risk to consumers through independent provision of information about performance, relying on improvement of the market. Others rely on the role of technology suppliers (van der Plast and Hankins 1998). Adkins et al (2010) show the variety of means consumers use to access information about LED lanterns.	Proof of concept: There is consistency about the importance of marketing and awareness raising at different levels, and focusing on different actors: from users, to market actors, to policy-makers. However, there seems to be no linking between these types of interventions, and more integrative and systemic approaches that involve coordination at the policy-making level to support market development and the involvement of users.
	Users participation and market learning	This type of intervention focuses on understanding users' needs/wants and learning from the market. For example, Rehman et al (2010) show the benefits of developing branding leading to increased sales. Green and Erskine (1999) and D'Agostino et al (2011) suggest that effective marketing needs to focus not only on technical aspects but also on how the information is used and internalised by customers so they make purchase decisions beyond price factors.	Proof of concept: Many authors mention the need to adequately involve users in the process of developing and diffusing energy technologies, particularly renewable energy. However, beyond recommendations on the importance of delivering information and learning from users (and the market), it is not clear the extent to which existing research has addressed the role of users in the shaping of technology and the role they play in the development of policies and projects, or how cultural factors affect the design and performance of energy technology.

3

5. Discussion

The conduct of the study was limited in some ways due to the broad scope of the review question, the breadth to be covered in both the academic and grey literature, and the resource constraints on the project. The searches and the analysis were therefore limited in several ways, including a greater emphasis in the academic literature on Sub-Saharan Africa and a targeted focus in the grey literature on interventions and lessons learned in Sub-Saharan African countries. There is also private sector evidence and analysis in existence on the topic, but this was inaccessible for the purposes of this project. It also emerged from the interviews and the peer review that it seems in this field in particular there is more 'tacit' knowledge that rests with practitioners and is highly location specific, therefore making it difficult to 'manualise', or in other words report formally in the literature which would be captured in this kind of systematic approach.

Future enquiry and analysis might therefore focus more strongly on unearthing this kind of tacit knowledge, in addition to barriers and interventions in BRICS countries, and on the vast body of grey literature which exists for these countries. This type of work would be highly complementary to the present review and together could provide a good evidence base from which to make future policy decisions.

In addition to the limitations in scope, related methodological limitations exist, including limitations in the search terms and in the heterogeneity of the studies. The latter is due to the fact that the majority of studies reviewed were qualitative in nature and heterogeneity of study type and output prevails. For qualitative studies, it was not easy to determine the factors which contribute to methodological rigour because of the diversity of disciplinary approaches present in qualitative research. In quantitative research, problems related to analytical approach and study design are usually discussed in terms of reliability and validity (both internal and external). These terms are less appropriate for qualitative research. Instead 'equivalents' were used such as dependability/audit ability in place of reliability, credibility/authenticity in place of internal validity, and transferability/fittingness in place of external validity (Miles and Huberman 1994; Lewis and Ritchie 2003). However, inevitably the nature of such assessments may have the implication of some studies which provided useful insights, but did not meet the full quality standard, were not included. In addition, due to the experience and expertise of the review team, there were limitations in the extent to which a more detailed quantitative analysis of the review papers could be done. Future reviews in this area might conduct a much more targeted analysis.

Other methodological limitations include the limiting of the study search to papers published only in English, as well as the need to limit the scope of the search terms by introducing the strategy of including 'energy' or 'electricity' alongside every set of search strings. While the former may have the effect of biasing the results towards English speaking countries, the latter should have prevented the exclusion of some types of energy services which are not explicitly related to electricity generation, however we recognise that there may, nevertheless have been some limitations this restriction introduced. In addition, any study which includes an analysis of grey literature is limited in the extent to which the grey literature can be adequately covered, the databases vary significantly and cannot be searched in similar ways, and the quality of the reports is often difficult to judge. The review team has taken steps to address this by using different combinations of search terms and triangulating our search with stakeholder interviews to ensure the most relevant grey literature was captured, but there will inevitably be reports which the team was not able to capture. A future review might focus solely on the grey literature so that all available resources could be concentrated on this data source.

6. Review Conclusions

Implications for Policy/Management

With respect to barriers to modern energy services some of the main policy implications are discussed first.

1. For the sake of clarity, the review has analysed barriers and interventions in four separate categories (economic/financial, technical, political/institutional and social/cultural). This separation is reflected in many of the papers reviewed. However, the evidence base also includes many instances where these barriers are inter-related. For example, the economics of new energy hardware is often dependent on the political and institutional context in a developing country. It is therefore important that the analysis of barriers from a policy perspective should take these inter-relationships into account, and would benefit from taking an integrated approach to the analysis of barriers and hence, to interventions.

2. The review has analysed a wide range of barriers to modern energy services. It is difficult from the evidence base reviewed to produce a simple hierarchy of such barriers which identify their relative importance. However, there is an understandable emphasis on economic and financial barriers as being the most pervasive and important. One obvious reason for this is that the poor have very limited incomes. This limited spending power makes sustainable improvements in energy access particularly difficult to achieve, even if the costs of modern energy services are significantly reduced.

3. Within the category of economic and financial barriers, the upfront costs of new energy hardware (whether for electricity generation or energy efficiency on the supply side and energy efficient devices on the demand side) are a particular problem. We found the evidence for this to be **consistent** and strong. Access to finance to help users cover these costs is often limited, which may in many cases be linked to political/institutional barriers. Other costs are important too, including operational costs. The evidence reviewed suggests that even if upfront cost barriers are overcome, ongoing operating costs can be too high for owners in some cases (though this depends on the technology in question, and what kind of service model has been used to finance it). We found the evidence on operational and maintenance cost barriers to be **mixed**, with their importance heavily dependent on context. In addition to these demand side barriers, the review found **consistent** evidence of supply side economic barriers associated with inadequate cost recovery for energy service providers; and **proof of concept**[8] evidence on the high up front costs of investing in infrastructure.

4. Within the category of technical barriers, the literature reviewed makes it clear that these are both hardware and 'software' (skills) related. There is **consistent** evidence from the review that problems have arisen due to the poor performance of hardware, either due to its low quality, a lack of information or a lack of certification schemes. As this evidence suggests, skills and capabilities for installation, operation and maintenance of energy hardware are very important too – and there is often insufficient attention to these when new hardware is supplied. Again, there is **consistent** evidence for the importance of these operation and maintenance barriers, though there is a lack of research on how institutional factors contribute to these barriers.

5. Institutional and political barriers are extremely varied within the evidence base reviewed. In some cases, papers emphasised the constraints imposed by particular institutional arrangements (e.g. the lack of power sector reform that restricts private provision). Overall,

[8] Our definition for 'proof of concept' is given in the summary at the end of section 4.3 above, along with the other assessment terms. However, for convenience, the proof of concept definition is repeated here: "Evidence from the 41 papers reviewed is empirically weak, but the few pieces of empirical evidence that do exist are strongly suggestive of proof of concept for the barrier or intervention to overcome it."

the evidence is **proof of concept** within this sub-category. Barriers due to a lack of political will, political interference and the power of political opposition are often mentioned, but we found that the specific evidence was **weak** with respect to these barriers. Related to this, there is **weak** evidence about the extent to which effective policy making for rural electrification is hampered by a lack of power amongst rural populations. It is clear from the papers reviewed that institutional arrangements and the prevailing political climate can have very large impacts on other barriers – particularly those that are economic and financial.

6. Cultural barriers are also closely related to other barrier categories in the review, though they bring up distinctive issues. Whilst many papers mention such barriers, the evidence for the importance of these barriers is **proof of concept** (in relation to the misalignment of technical system design and social needs) or **contradictory** (in relation to the desirability of particular energy technologies amongst potential users). As noted above, there is also **consistent** evidence that there are social barriers associated with a lack of operations and maintenance capabilities for new technologies.

Turning to interventions to overcome these barriers to modern energy services for the poorest people, the review comes to the following conclusions.

1. Given that there is significant evidence that different categories of barrier are related, it is important to approach interventions in an integrated way. This evidence, which comes from studies of a number of different countries, points to a need for interventions that address interdependent economic, technical and social factors. Added to this, it is important that any desire to reach general conclusions about successful intervention strategies does not downplay the importance of local context. The diversity of evidence in this review illustrates that it is unlikely that a 'one size fits all' approach to overcoming barriers to modern energy services will be effective.

2. A range of economic strategies and interventions have been successful, many of which included funding for the installation of new equipment. Some of the studies reviewed said that these are more likely to work if users are willing and able to cover the full operational costs of new equipment (but not necessarily the upfront costs). Overall, the evidence is **proof of concept** for the effectiveness of subsidies and grants (i.e that there are isolated examples of strong evidence of this), and **mixed** for the effectiveness of interventions that strengthen access to finance and credit. Alternative fee-for-service approaches to overcome economic barriers are discussed in the literature, but the evidence for their effectiveness is also **mixed**. The evidence suggests that this approach is not effective in reaching the poor. Some studies also emphasised the importance of supporting income generating activities through energy access, though the specific evidence for the effectiveness of this is **proof of concept**.

3. With respect to technical interventions, there is **consistent** and strong evidence that the provision of hardware needs to be accompanied by interventions to promote sustainable performance over time. These include regulations, standards information and training. The evidence on the latter is **mixed**. Whilst there is strong evidence that training to develop the capabilities of technology users is important, it is also clear from the evidence reviewed that training alone does not guarantee good performance. There is a lack of evidence on what kinds of user capacity development are needed to improve outcomes. There is **contradictory** evidence on the need for the enforcement of regulations and standards to overcome technical barriers to the adoption of new technologies.

4. This leads on to interventions relating to institutions and the policy/political environment in which these interventions take place. The evidence that strategic policy making and policy co-ordination (e.g. to link energy access policies to wider development strategies) is effective is **proof of concept**. However, the evidence stresses that policy stability has an important role to play in improving access to modern energy services. There is a need for further research to understand the relative effectiveness of different approaches to policy making. Whilst power

sector reforms are often an important focus for debate and are controversial, the evidence in the papers we reviewed is **weak** and anecdotal on how the politics of these reforms influences their effectiveness.

5. With respect to electrification programmes in sub-Saharan Africa, the BRICs literature reviewed suggests that there may be lessons to learn from the experience of China, but also from Brazil and India in relation to smaller scale electrification programmes, particularly those involving renewable energy technologies. One of the papers reviewed showed how a step by step approach was taken by the Chinese government over a long period of time to improve electrification rates. Of course, care is needed in drawing such lessons – not least the differences in economic, political and institutional context in China when compared to many lower income countries.

6. The evidence that interventions to address cultural and social barriers are effective is **proof of concept**. In other words, there is some isolated evidence that these interventions are effective, but the evidence base in weak in general. There is evidence that interventions to market and raise awareness of new technologies can be effective in some cases, but the analysis of these interventions does not seem to consider them together with other, complementary interventions that might be required. Many studies also mention the need to involve users in developing and diffusing energy technologies, but there is a lack of research on how users affect technologies, policies and projects.

Implications for Research

This section summarises some implications for further research, with a particular emphasis on some of the gaps in the evidence base that have been identified. These implications include:

- In general, the evidence base found to answer our question was patchy in quality, consistency and strength. The criteria used to assess this evidence base are given in Appendix C, and discussed in detail in section 3.4. High quality studies incorporate credibility and defensibility of design, a transparently reported methodology and coherence of analysis. It would be especially helpful if studies – whether in the academic or practitioner literatures – were to adopt designs and analytical approaches that meet these criteria. Having said this, there are some very good studies available which provide rigorous analysis of both barriers and interventions. But, given the volume of literature in this field, the number of high quality studies that are sufficiently rigorous to meet the criteria we applied in this review is limited. This is particularly the case with respect to high quality studies that take an integrated approach to the analysis of barriers and interventions. As noted above, many of the studies reviewed illustrated the inter-relationships between the four named categories of barriers and interventions, but there is a tendency to analyse these categories separately.

- There are several specific areas where further research is required to strengthen the evidence base, including:
  a) Consumer financing (e.g. of solar home systems), for example via credit schemes;
  b) The strength of information barriers to the adoption of new energy technologies;
  c) The importance of political barriers, for example due to vested interests or corruption, and how these impact on communities with little political power;
  d) The interaction between technical and cultural barriers to the adoption of new technologies; and
  e) What specific capabilities are required to support the adoption and diffusion of new technologies to improve energy access. These specific capabilities could include capabilities for operations and maintenance, manufacturing, design, policy development and implementation, and running businesses.

- The grey literature focusing on energy access is particularly extensive, and this is likely to continue to grow – particularly given that 2012 is the UN year of sustainable energy for all.

Whilst it is fair to assume that the academic literature has been subjected to higher standards and independent scrutiny, some grey literature has also undergone rigorous peer review. It adds significantly to the available knowledge base, but resource limitations mean that it could not be comprehensively reviewed for this study. A further systematic review of this literature might be warranted given its scope and potential value.

- The evidence base found is not evenly distributed from a geographical point of view. Some sub-Saharan African countries are a particular focus for academic and grey literature (e.g. Kenya), and therefore there may be opportunities to focus more in future on those countries that are relatively less well studied.
- Most of the literature and research on energy access that was reviewed focuses on electricity. Whilst this literature is highly relevant and important (not least because providing affordable energy access to rural areas is particularly challenging), this coverage is not comprehensive. Significant gaps in the literature are apparent with respect to other energy services such as heating, communications, and productive uses of electricity.
- There is surprisingly little literature that seeks to learn lessons from the BRICs countries for lower income developing countries. Whilst care is needed in drawing any lessons of this kind (as noted above), there is potential for more research in this area. One possible example (also noted above) is the long term Chinese electrification programme – and how it has been relatively successful in achieving its aims.
- Finally, some of the papers reviewed emphasised the need for much better monitoring and evaluation of interventions that have been made – particularly with respect to their effectiveness. These evaluations are not only required to fulfil donor requirements for reporting and budgetary control. Genuinely independent evaluations could also strengthen the evidence base in general – and help to underpin more effective interventions in future.

7. Competing interests

One team member, Jim Watson, at the Sussex Energy Group has published widely on the more general topic of energy and development. Relevant publications are listed below in Appendix D. Rob Byrne, another team member, managed a small solar energy project in Tanzania between October 1997 and October 2000 and was a founding member of the Tanzania Solar Energy Association (TASEA) and served on its interim executive committee for several months before completing a contract in Tanzania (2000). TASEA has now become the Tanzania Renewable Energy Association. It is a membership organisation, involving public and private sector actors, as well as individuals interested in promoting renewable energies for development in Tanzania. In order to mitigate against the risk of biasing our review, we have built in a three-person review process, with additional research oversight by a fourth team member, to ensure objectivity. Other authors declare that they have no competing interests. A full list of relevant, and potentially conflicting publications by study authors, is given in Appendix D.

8. Acknowledgments

This study is funded by the UK Department for International Development (DFID). We thank Mr. David Woolnough, the project lead at DFID, for engaging with us throughout the study, as well as his colleague, Leanne Jones; and Barbara Livoreil and Andrew Pullin at the Centre for Environmental Evidence for their advice on undertaking Systematic Reviews. We also thank Roberta Shanman at the RAND Library for her help in undertaking the study search. Thanks are also due to Ms Stephanie Diepeveen for the advice she provided in the early stage of the protocol development; Victoria Wakefield-Jarrett who has helped us in collecting hundreds of articles

from online library; and Professor Joanna Chataway for her internal quality assurance of the draft report before it was submitted for peer review. We would also like to thank the following individuals with whom we conducted key informant interviews: Andrew Barnett (The Policy Practice), Morgan Bazilian (UNIDO), Mike Bess, Prof Abeeku Brew-Hammond (KNUST, Ghana) Simon Collings (GVEP International), Steven Hunt (DFID), Matthew Lockwood (IDS) and Annabel Yadoo (University of Cambridge and Renewable World).

All views expressed in this document are those of the authors and do not necessarily represent the views of the Department for International Development (DFID), SPRU, or the RAND Corporation.

9. References

Acker RH, Kammen DM: **The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya.** *Energy Policy* 1996, **24:**81-111.

Adkins E, Eapen S, Kaluwile F, Nair G, Modi V: **Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi.** *Energy Policy* 2010, **38:**1087-1097.

African Development Bank Group: **Tanzania Rural Electrification Project: Project Performance Evaluation Report (PPER).** *African Development Bank Group*; 1996.

Barnett A: **Energy and the Reduction of Poverty: A Narrative by Andrew Barnett,** *The Policy Practice Limited*, Brighton, January 2010

Bazilian M, Sagar A, Detchon R, Yumkella, K: **More heat and light.** *Energy Policy*, 2010, **38**: 5409-5412.

Brew-Hammond A, **Energy access in Africa: Challenges ahead.** *Energy Policy* 2010, **38:** 2291-2301.

Campbell B, Vermeulen S, Mangono J, Mabugu R: **The energy transition in action: urban domestic fuel choices in a changing Zimbabwe.** *Energy Policy* 2003, **31:**553-562.

Cherni J, Kentish J: **Renewable energy policy and electricity market reforms in China.** *Energy Policy,* 2007 **35**: 3616-3629.

Clough L: **Marketing Challenges and Strategies for Micro and Small Energy Enterprises in East Africa.** *GVEP International*; 2011.

Collings S: **Phone Charging Micro-businesses in Tanzania and Uganda.** *GVEP International*; 2011.

D'Agostino AL, Sovacool BK, Bambawale MJ: **And then what happened? A retrospective appraisal of China's Renewable Energy Development Project (REDP)**. *Renewable Energy,* 2011. 36(11): 3154-3165.

DFID, AusAID and 3ie: **Systematic Reviews in International Development – Call for Proposals**. UK Department for International Development, Australian Agency for International Development and the International Initiative for Impact Evaluation; 2010. Available at: http://www.3ieimpact.org/userfiles/file/AusAID-DFID3ie%20Final%20Call%20for%20Proposals.pdf

DFID: **Energy for the Poor: Underpinning the Millennium Development Goals**. UK Government Department for International Development, London, UK; 2002.

Diniz ASAC, Machado Neto LVB, Camara CF, Morais P, Cabral CVT, Oliveira Filho D, Ravinetti RF, Franc ED, Cassini DA, Souza MEM, Santos, JH, Amorim M, **Review of the photovoltaic energy program in the state of Minas Gerais, Brazil.** *Renewable & Sustainable Energy Reviews*, 2011. 15(6): 2696-2706.

Dube I: **Impact of energy subsidies on energy consumption and supply in Zimbabwe. Do the urban poor really benefit?** *Energy Policy* 2003, **31:**1635-1645.

Duke RD, Jacobson A, Kammen DM: **Photovoltaic module quality in the Kenyan solar home systems market.** *Energy Policy* 2002, **30:**477-499.

Foster V, Steinbuks J: **Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa.** *Policy Research Working Paper 4913*. World Bank: African Sustainable Development Front Office; 2009.[Online]. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2009/04/30/000158349_20090430142027/Rendered/PDF/WPS4913.pdf

Gaunt CT: **Meeting electrification's social objectives in South Africa, and implications for developing countries**. *Energy Policy*, 2005. **33**(10): 1309-1317.

Gough D: **Weight of evidence: a framework for the appraisal of the quality and relevance of evidence**, in Furlong J, and Oancea A, (eds.) *Applied and Practice-based Research, Special Edition of Research Papers in Education*, 2007 **22(**2): 213-228.

Green JM, Erskine SH: **Solar (photovoltaic) systems, energy use and business activities in Maphephethe, KwaZulu-Natal.** *Development Southern Africa* 1999, **16:**221-237.

Green JM, Wilson M, Cawood W: **Maphephethe rural electrification (photovoltaic) programme: the constraints on the adoption of solar home systems.** *Development Southern Africa* 2001, **18:**19-30.

Guimarães L, Caracaleanu C, Sy B, N'Dongo A, Sankaré O: **Energy affordability in the Sahelian region.** *Applied energy* 2003, **76:**9-13.

Gumbo R, Katsvairo L, Asai K: **State of photovoltaic home systems in Zimbabwe.** *IEEE*; 2003: 2640-2643 Vol. 2643

Gustavsson M, Ellegård A: **The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia.** *Renewable energy* 2004, **29:**1059-1072.

Haanyika CM: **Rural electrification in Zambia: A policy and institutional analysis.** *Energy Policy* 2008, **36:**1044-1058.

Hofmeyr IM: **Towards adequate and equitable energy provision for farmworker families.** *Development Southern Africa* 1995, **12:**273-279.

Ilskog E, Kjellström B, Gullberg M, Katyega M, Chambala W: **Electrification co-operatives bring new light to rural Tanzania.** *Energy Policy* 2005, **33:**1299-1307.

Karekezi S, Kimani J: **Status of power sector reform in Africa: Impact on the poor.** Energy *Policy* 2002, **30**:923-945.

Karekezi S, Kithyoma W: **Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?** *Energy Policy* 2002, **30:**1071-1086.

Karekezi S, Sihag A: **Energy Access theme results Synthesis/Compilation Report.** Global Network on Energy for Sustainable Development, Roskilde, Denmark; 2004.

Ketlogetswe C, Mothudi T: **Solar home systems in Botswana--Opportunities and constraints.** *Renewable and Sustainable Energy Reviews* 2009, **13:**1675-1678.

Kirubi C, Jacobson A, Kammen DM, Mills A: **Community-based electric micro-grids can contribute to rural development: evidence from Kenya.** *World Development* 2009, **37:**1208-1221.

Lee KS, Anas A, Oh G-T: **Costs of Infrastructure Deficiencies for Manufacturing in Nigerian, Indonesian and Thai Cities**. *Urban Studies*, 1999. **36**(12): 2135-49.

Lewis J, Ritchie J: **Generalising from Qualitative Research**, in Lewis J, and Ritchie J, (eds.) *Qualitative Research Practice: A Guide for Social Science Students and Researchers*, Sage Publications, London, Thousand Oaks and New Delhi; 2003.

Mapako M: **Provision of Long-term Maintenance Support for Solar Photovoltaic Systems - Lessons from a Zimbabwean NGO.** *Journal of Energy in Southern Africa* 2005, **16:**21-26.

Miles M, Huberman, A: ***Qualitative Data Analysis: An Expanded Sourcebook, 2nd ed.***, Sage Publications, London, Thousand Oaks and New Delhi; 1994.

Modi V, McDade S, Lallement D, Saghir, J: **Energy Services for the Millennium Development Goals.** Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project and World Bank, New York; 2005.

Mulder P, Tembe J: **Rural electrification in an imperfect world: A case study from Mozambique.** *Energy Policy* 2008, **36:**2785-2794.

Mulugetta Y, Nhete T, Jackson T: **Photovoltaics in Zimbabwe: lessons from the GEF Solar project.** *Energy Policy* 2000, **28:**1069-1080.

Murphy JT: **Making the energy transition in rural East Africa: Is leapfrogging an alternative?** *Technological Forecasting and Social Change* 2001, **68:**173-193.

Nygaard, I., **Institutional options for rural energy access: Exploring the concept of the multifunctional platform in West Africa**. *Energy Policy*, 2010. **38**(2): 1192-1201.

OECD-IEA: **Energy Poverty: How to make modern energy access universal?** *Special early excerpt of the World Energy Outlook 2010*, IEA-UNDP-UNIDO, International Energy Agency, Paris; 2010.

Peng WY, Pan JH: **Rural electrification in China: History and institution.** *China & World Economy*, 2006. **14**(1): 71-84.

Pereira, M.G., M.A.V. Freitas, and N.F. da Silva, **Rural electrification and energy poverty: Empirical evidences from Brazil**. *Renewable & Sustainable Energy Reviews, 2010*. **14**(4):1229-1240.

Practical Action: **Poor People's Energy Outlook 2010**. Rugby, Warwickshire: Practical Action; 2010

Rehman, I.H., Kar A, Raven R, Singh D, Tiwari J, Jha R, Sinha PK, Mirza A, **Rural energy transitions in developing countries: a case of the Uttam Urja initiative in India**. *Environmental Science & Policy, 2010*. **13**(4): 303-311.

Schiffmand, L.G., Kanuck, L., **Consumer behaviour,** 1987. 3rd edn. Englewood

Cliffs, NJ: Prentice-Hall.

Schut M, Slingerland M, Locke A: **Biofuel developments in Mozambique. Update and analysis of policy, potential and reality.** *Energy Policy* 2010, **38:**5151-5165.

Steel K**, Dynamics of Growth and Investment in the Kenyan Electric Power Sector.** *Power Engineering Society General Meeting, 2007. IEEE* , pp.1-5, 24-28 June 2007

Thiam DR: **An energy pricing scheme for the diffusion of decentralized renewable technology investment in developing countries.** *Energy Policy* 2011, 39(7) 4284-4297.

UNDP: **Energizing the Millennium Development Goals**. United Nations Development Programme, New York; 2005.

UNDP-WHO: **The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa.** United Nations Development Programme and World Health Organization, New York; 2009.

UN-Energy: **The Energy Challenge for Achieving the Millennium Development Goals**. United Nations; 2005.

Urban F: **Climate-Change Mitigation Revisited: Low-Carbon Energy Transitions for China and India.** *Development Policy Review* **27**(6): 693-715; 2009.

van der Plas RJ, Hankins M: **Solar electricity in Africa:: a reality.** *Energy Policy* 1998, **26:**295-305.

Walekhwa PN, Mugisha J, Drake L: **Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications.** *Energy Policy* 2009, **37:**2754-2762.

WDI: **World Bank World Development Indicators January 2009, listing of countries by income group.** ESDS International, (Mimas) University of Manchester; 2009.

383 Winkler H, Spalding-Fecher R, Tyani L, Matibe K: **Cost-benefit analysis of energy efficiency in**
384 **urban low-cost housing.** *Development Southern Africa* 2002, **19:**593-614.

385 Wolde-Ghiorgis W: **Renewable energy for rural development in Ethiopia: the case for new**
386 **energy policies and institutional reform.** *Energy Policy* 2002, **30:**1095-1105.

387 The World Bank Independent Evaluation Group: **The Welfare Impact of Rural Electrification: A**
388 **Reassessment of the Costs and Benefits.** *The Welfare Impact of Rural Electrification: A*
389 *Reassessment of the Costs and Benefits,* World Bank; 2008

390

Appendix A: Search terms for academic literature

List 1a: Modern energy services

- "modern energy service*"
- electric* OR electrif*
- "mobile *phone charg*" OR "cell *phone charg*"
- batt* OR "batt* charg*"
- refrigerat*
- heat*
- freez* OR cool
- light* OR illuminat*
- communication OR radio OR television OR TV or "information and communication technolog*" OR ICT
- "thermal comfort"

List 1b: Modern energy technologies (required to deliver and/or use the services)

- "modern energy technolog*"
- "Platform technolog*"
- "high technolog*"
- "decentrali$ed grid" OR "modern decentrali$ed grid" OR "mini$grid"
- "energy system"
- micro$hydro*
- pico$hydro*
- bio$fuel* OR bio$gas OR bio$ethanol OR waste
- photo$voltaic* OR PV OR "solar home system*" OR SHS
- ("traditional fuel*" OR "traditional bio$mass" OR bio$energy) AND (substitute* OR reduce*)
- "solar power" OR "solar energ*" OR "solar panel" OR "solar water heater" OR SWH
- "wind power" OR "wind energ*"
- "wind turbine" OR "wind generat*"
- "renewable energ*"
- energy$efficien*
- "sustainabl* energy system"
- "gas turbine*"
- "nuclear power"
- "fuel cell*"

List 2: Barriers

- barrier
- difficult*
- challenge
- obstacle
- obstruction
- technical
- access
- poverty
- financ*
- politic*
- polic*
- econom* OR cost

- infrastructur*
- capacity
- cultur*
- social
- awareness
- availabil*
- affordabil*
- institution*
- law OR legal
- gender
- "female headed household"
- constrain*
- constrict*
- restrict*
- prevent*
- road$block OR block*
- enabl*

List 3: Interventions

- intervention*
- interference
- investment*
- loan* OR "concessionary loan*" OR concession* OR "soft loan*"
- "market development"
- "public$private partnership*" OR PPP
- subsid*
- micro$credit OR micro$finance
- "capacity building"
- "development programme" OR "development program"
- adopti*
- diffusi*
- enabl*
- facilitat*[9]
- help
- enhanc*
- roadmap

List 4: Effectiveness measures

- effectiv*
- useful OR use
- success*
- cost-effectiveness
- "economic growth" OR "productive use"
- Health OR "eye disease" OR "eye infection" OR "respiratory disease"
- uptake
- roll-out

[9] We note the terms "enabl*","facilitat*", "help", "enhance*" and "roadmap" under the list of interventions (List 3) can also be interpreted as antonyms of barriers, so it would be equally valid to list them under the list of barriers (List 2). In practice, it makes no difference which list they are on as long as they are included at least once.

- scale-up OR “scaling up”
- replicat*
- improvement AND (“rate* of access” OR “level* of access”)

List 5: Geographic search terms

- sub-Saharan Africa OR Africa OR SSA
- “developing countr*”
- “southern countr*”
- “global south”
- “low income countr*”
- “least industriali$ed countr*” OR LDC
- “poor countr*”
- “developing region”
- “developing econom*”
- “underdeveloped countr*”
- “third world”
- Benin
- “Burkina Faso”
- Burundi
- “Central African Republic”
- Chad
- Comoros
- “Democratic Republic of the Congo” OR DRC
- Eritrea
- Ethiopia
- “The Gambia”
- Ghana
- Guinea
- Guinea-Bissau
- Kenya
- Liberia
- Madagascar
- Malawi
- Mali
- Mauritania
- Mozambique
- Niger
- Rwanda
- Senegal
- “Sierra Leone”
- Somalia
- Tanzania
- Togo
- Uganda
- Zambia
- Zimbabwe
- Afghanistan
- Bangladesh
- Cambodia

- “Democratic Republic of Korea” OR “North Korea”
- “Kyrgyz Republic”
- “Lao PDR” OR “Lao People’s Democratic Republic” OR Lao
- Myanmar
- Nepal
- Tajikistan
- Uzbekistan
- Vietnam
- Haiti
- Yemen

Appendix B: Grey literature search terms

A * in the lists below indicates that no specific search terms were used, but rather all titles under energy-related categories which were already built into the database were collected. This strategy was used to minimise the risk that our search terms did not unnecessarily limit the search as one is not always able to determine the robustness of different databases and associated search engines.

World Bank

- **Search terms:** energy OR fuel OR fuels OR electricity OR electric OR power resources
  (Search terms applied to titles only)
- **Document type:** Publications and Research
- **Date:** 1995/01/01 to 2011/11/01
- **Topics:** Energy
- **Region:** Africa, East Asia and Pacific
- **Language(s):** English

OECD Papers

- **Search terms:** *
  (Search terms applied to full text)
- **Theme:** Energy in PAPERS
- **Language(s):** English

OECD Stats

- **Search terms:** *
  (Search terms applied to full text)
- **Theme:** Energy in STATISTICS
- **Language(s):** English

3i3

- **List of Systematic Reviews:** Agriculture & Rural Development

Global Village Energy Partnership (GVEP)

- **Studies and reports:** all

AFREPREN

- **Publications:**
  - Books and book chapters;
  - Pre - Print Articles Published in Energy Policy Special Issue of 2002 on Africa Published by Elsevier Science Limited, United Kingdom
  - Pre- Print Articles Published in Other Leading Energy Journals
  - Pre -Print Articles Published in Conference Proceedings
  - Presentations during Conference Proceedings

- Occasional Papers

Renewable energy and energy efficiency partnership (REEEP)

- **Projects:** completed projects

World Health Organisation (WHO) website

- **Search terms:** energy OR fuel OR fuels OR green OR power OR electricity (Search terms applied to titles only)

World Health Organisation (WHO) Library

- **Search terms:** energy OR fuel OR fuels OR green OR power OR electricity (Search terms applied to titles only)

United Nations

- **Subjects:** energy

African Development Bank

- **Project/Programme Completion Reports**
  - Countries: all countries
  - Topic and sector: energy and power

International Energy Agency

- **Publications and Papers:** Non-OECD Countries

Appendix C: Detailed quality review criteria list

Detailed qualitative review	Credibility of findings [Yes/No/Not applicable]	· Findings/conclusions are supported by data and study evidence · Findings/conclusions have a coherent logic · There is evidence of validation/triangulation of findings to support or refine findings · Quotations are numbered or otherwise identified to demonstrate they are not from one/two people
	Breadth and depth of study findings (scope for wider inferences) [Yes/No/Not applicable]	· Study aims and design is set in the context of existing knowledge/understanding (e.g. literature review to summarise knowledge to date) · Findings are presented/conceptualised in a way that offers new insights/alternative ways of thinking · Presents the potential for wider inferences from the study: o Describes how findings are relevant to the wider population from which the sample is drawn o Describes the contexts in which the study was conducted to allow applicability to other settings to be assessed o Discusses the limitations on drawing wider inferences
	Extent to which the study **addresses original aims and purposes** [Yes/No/Not applicable]	· Clear statement of study aims and objectives, and clearly state reasons for any changes in objectives · Findings are clearly linked to the purposes of the study · Discusses limitations of study in meeting aims (e.g. gaps in coverage, restricted access to setting or participants, unresolved areas of questioning, time constraints, etc)
	Defensibility of **design** [Yes/No/Not applicable]	· Discusses how overall research strategy was designed to meet the aims of the study

		· Discusses the rationale for study design; including convincing arguments for different features of research design (e.g. multiple methods, time frames, reasons for components of research, etc) · Use of different features of design/data sources evident in findings presented · Discusses limitations of research design and their implications for the study evidence · Describes any changes made to design, their justification, and implications for the study
	Defensibility of **sample** design and coverage [Yes/No/Not applicable]	· Target sample is appropriate to accessing the type of knowledge sought · Discusses how sample/selections allowed required comparisons to be made · Sample profile is detailed o Describes location/areas and how/why chosen o Describes population of interest and sample's relationship to it o Discusses missing coverage and implications for evidence o Documents reasons for non-participation/exclusion among the sample o Discusses access and methods of approach and how these might have affected participation and coverage o Discusses why some people may have chosen not to participate
		· Data collection tools were piloted · Data collection was comprehensive, flexible and sensitive enough to provide a complete and/or rich description o E.g. time with participants, 1+ methods of data collection, following up? o Discusses how fieldwork methods or settings may have influenced data collected o Discusses the saturation of data

		· Clear discussion of data collection tools/approach o Who conducted data collection o Procedures and documents used for collection and recording; conventions for field notes o Checks on origins, status and authorship o Audio or video recording of interviews, discussions and/or conversations (or justification for why not) · Steps taken to ensure participants were able and willing to contribute · Discussion of strengths and weaknesses of data sources and methods
	Quality of the approach and formulation of the **analysis** [Yes/No/Not applicable]	· Data analysis methods were systematic o Describes the form of original data o Clear rationale for choice of management methods, tools and package o Evidence of how analytic categories, classes, labels, etc have been generated and used o Discussion, with examples, of how any constructed analytic concepts/typologies have been devised and applied · Balanced analysis in the extent to which it is guided by preconceptions or by the data o Diversity of perspectives explored o Discussion of bias in forming the research question (e.g. funding agencies) o Examines the researcher's own role in influencing data collection · Detailed and clear portrayal of data sources and the context for data sources (e.g. background, personal context, origins) · Clear conceptual links between analytic commentary and presentation of original data

		o Explores alternative explanations o Displays negative cases and how they lie outside main proposition; or how propositions have been revised to include them
	Clarity and coherence of **reporting** [Yes/No/Not applicable]	· Demonstrates link to aims of the study/research questions · Provides a narrative or clearly constructed thematic account; and has a useful structure and signposting to guide the reader · Provides accessible information for intended target audience(s) · Key messages are highlighted or summarised
	Clarity of **assumptions**, that have shaped the form and output of the study [Yes/No/Not applicable]	· Discussion/evidence of the main assumptions, hypotheses and theoretical ideas on which the study was based and how these affected the form, coverage or output of the study · Evidence of openness to new and alternative ways of viewing the subject · Discussion of how error or bias may have arisen in design, data collection and analysis and how it was addressed, if at all · Reflections on the impact of the researcher on the research process
	Further comments on quality	Elaborate as necessary
	Overall rating of quality	High/Medium/Low

Appendix D: List of publications by authors with potential conflicts of interest

Byrne, R. (2011) Learning Drivers: rural electrification regime building in Kenya and Tanzania, DPhil thesis, SPRU, University of Sussex, Brighton.

Byrne, R. (2011) "Micro-energy systems in low-income countries: learning to articulate the solar home system niche in Tanzania", in M. Schäfer, N. Kebir and D. Philipp (eds.) Proceedings of the International Conference: Micro Perspectives for Decentralized Energy Supply, Technische Universität Berlin, 7th to 8th April 2011:207-219.

Byrne, R., A. Smith, J. Watson and D. Ockwell (2011) "Energy pathways in low-carbon development: from technology transfer to socio-technical transformation", STEPS Working Paper 46, STEPS Centre, Brighton.

Byrne, R., A. Smith, J. Watson and D. Ockwell (2012) "Energy Pathways in Low-Carbon Development: The Need to Go beyond Technology Transfer", in D. Ockwell and A. Mallett (eds.) Low Carbon Technology Transfer: From Rhetoric to Reality, Routledge, London and New York.

Mallett, A., D. Ockwell, J. Watson et al. (2009) UK-India collaborative study on the transfer of low carbon technology: Phase II Final Report, Brighton and New Delhi, SPRU and TERI.

Ockwell, D., R. Haum, A. Mallett and J. Watson (2010) "Intellectual property rights and low carbon technology transfer: Conflicting discourses of diffusion and development" Global Environmental Change 20(4): 729-738.

Ockwell, D., A. Ely, A. Mallett, O. Johnson and J. Watson (2009) Low carbon development: The role of local innovative capabilities, Brighton: Sussex Energy Group and ESRC STEPS Centre, University of Sussex.

Ockwell, D., J. Watson et al (2007) UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology, Final Phase 1 Report to Defra and the Indian Ministry of Environment and Forestry.

Ockwell, D., J. Watson, A. Verbeken, A. Mallett and G. MacKerron (2009) "A blueprint for post-2012 technology transfer to developing countries", Sussex Energy Group Policy Briefing No. 5, December.

Ockwell, D., J. Watson, G. MacKerron, P. Pal and F. Yamin (2008) "Key policy considerations for facilitating low carbon technology transfer to developing countries", Energy Policy 36(11): 4104-4115.

Wang, T. and J. Watson (2009) China's Energy Transition: Pathways for Low Carbon Development, Brighton: Tyndall Centre and Sussex Energy Group, University of Sussex, April.

Wang, T. and J. Watson (2009) "Scenario analysis of China's emissions pathways in the 21st century for low carbon transition", Energy Policy 38(10): 3537-3546.

Watson, J., Byrne, R. et al (2011) UK-China Collaborative Study on Low Carbon Technology Transfer. Final report to the Department of Energy and Climate Change. Brighton: SPRU, University of Sussex.

Watson, J. and R. Byrne (2012) “Low-carbon Innovation in China: The Role of International Technology Transfer”, in D. Ockwell and A. Mallett (eds.) Low Carbon Technology Transfer: From Rhetoric to Reality, Routledge, London and New York.

Watson, J. and R. Sauter (2011) “Sustainable innovation through leapfrogging: A review of the evidence” International Journal of Technology and Globalisation 5: 170-189

Watson, J. and O. Johnson (2010) Renewable Energy Technologies for Rural Development, UNCTAD current studies on science, technology and innovation, Geneva, UNCTAD.

Watson, J. and R. Sauter (2008) Technology Leapfrogging: A Review of the Evidence, Report for the Department of International Development, Brighton: SPRU, University of Sussex.

Appendix E: Pilot search results

Web of Science pilot search

We undertook a pilot search in the Web of Science using all of the modern energy services terms in List 1a combined with the barriers terms (List 2). Although this is only a partial search (no technologies terms from List 1b or intervention terms from List 3), the total number of hits was over 22,000, with many irrelevant hits. It is particularly problematic with databases that are not specifically focused on energy, as there were terms that could have other meanings (e.g. “light”, “illuminate, or “waste”). The review team therefore refined the search strategy to include the terms “energy or electricity or power or fuel” in every search in order to improve the relevance of our search.

World Bank Pilot Search

- **Search terms:** energy OR fuel OR fuels OR electricity OR electric OR power resources (Search terms applied to titles only)
- **Document type:** all
- **Date:** 1995/01/01 to 2011/11/01
- **Topics:** Energy
- **Region:** Africa, East Asia and Pacific
- **Language(s):** English

This pilot search resulted over 4000 hits, many of which were press releases. Therefore, we refine our search by limiting the keywords to titles only and restricting the document type to “Publications and Research”. This greatly reduced the number of relevant hits. We had 205 hits in our final search.

Appendix F: List or file of articles excluded at full text stage

Peer-reviewed academic papers (75 articles)

Ablethomas, U., et al., Dissemination of Photovoltaics in the Gambia. Renewable Energy, 1995. 6(5-6): p. 507-513.

Anas, A., et al., Why Manufacturing Firms Produce Some Electricity Internally. 1999.

Angel-Urdinola, D. and Q. Wodon, Do Utility Subsidies Reach the Poor? Framework and Evidence for Cape Verde, Sao Tome, and Rwanda. Economics Bulletin, 2007. 9(4): p. 1-7.

Asamoah, J., The uptake of energy conscious housing design in South Africa as a mitigation of emission of greenhouse gases, in Greenhouse Gas Control Technologies. 1999. p. 653-657.

Bawakyillenuo, S.E.A.b.h.c., Policy and Institutional Failures: Photovoltaic Solar Household System (Pv/Shs) Dissemination in Ghana. Energy & Environment.

Berg, S.V., M.G. Pollitt, and M.e. Tsuji, Private initiatives in infrastructure: Priorities, incentives and performance. 2002. 234: p. 234.

Brew-Hammond, A., Energy Access in Africa: Challenges Ahead. Energy Policy, 2010. 38(5): p. 2291-2301.

Brew-Hammond, A.C.-R.A., Reducing rural poverty through increased access to energy services : a review of the multifunctional platform project in Mali. 2004, Bamako, Mali: United Nations Development Programme, UNDP Mali Office. 80 p.

Cawood, W., An affordable formula for financing solar electrification. Siemens Review, 1996. 63(3-4): p. 23-24.

Coudouel, A., A.A. Dani, and S.e. Paternostro, Poverty and Social Impact Analysis of Reforms: Lessons and Examples from Implementation. 2006. 520: p. 520.

Covarrubias, A.J., Lending for electric power in sub-Saharan Africa. 1996. 93: p. 93.

Davidson, O.R. and J.E.A.j.t.r.d. Turkson, Overcoming financial barriers to wider use of renewable energy technology in Africa. International Journal of Global Energy Issues.

Davis, M., Rural household energy consumption - The effects of access to electricity - evidence from South Africa. Energy Policy, 1998. 26(3): p. 207-217.

Deichmann, U., et al., The economics of renewable energy expansion in rural Sub-Saharan Africa. 2010.

Diarra, D.C. and F.O. Akuffo, Solar photovoltaic in Mali: potential and constraints. Energy Conversion and Management, 2002. 43(2): p. 151-163.

Eberhard, A.E.A.e.g.u.a.z. and K.N. Gratwick, IPPs in Sub-Saharan Africa: Determinants of success. Energy Policy.

Egels, N., CSR in Electrification of Rural Africa. Journal of Corporate Citizenship, (18): p. 75-85.

Ellegard, A., et al., Rural people pay for solar: experiences from the Zambia PV-ESCO project. Renewable Energy, 2004. 29(8): p. 1251-1263.

Gillwald, A., The Poverty of ICT Policy, Research, and Practice in Africa. Information Technologies & International Development: p. 79-88.

Gudmundsdottir, G.B., When does ICT support education in South Africa? The importance of teachers' capabilities and the relevance of language. Information Technology for Development. 16(3): p. 174-190.

Guèye, C., New Information & Communication Technology Use by Muslim Mourides in Senegal. Review of African Political Economy. 30(98): p. 609-625.

Gullberg, M., et al., Village electrification technologies - an evaluation of photovoltaic cells and compact fluorescent lamps and their applicability in rural villages based on a Tanzanian case study. Energy Policy, 2005. 33(10): p. 1287-1298.

Habtetsion, S. and Z. Tsighe, The energy sector in Eritrea-institutional and policy options for improving rural energy services. Energy Policy, 2002. 30(11-12): p. 1107-1118.

Hafkin, N.J. and S. Huyer, Women and Gender in ICT Statistics and Indicators for Development. Information Technologies & International Development. 4(2): p. 25-41.

Harries, M., Disseminating wind pumps in rural Kenya-meeting rural water needs using locally manufactured wind pumps. Energy Policy, 2002. 30(11-12): p. 1087-1094.

Hodge, J., Liberalising communication services in South Africa. Development Southern Africa. 17(3): p. 373-387.

Hosman, L., Policies, Partnerships, and Pragmatism: Lessons from an ICT-in-Education Project in Rural Uganda. Information Technologies & International Development. 6(1): p. 48-64.

Jumbe, C.B.L., F.B.M. Msiska, and M. Madjera, Biofuels development in Sub-Saharan Africa: Are the policies conducive? Energy Policy, 2009. 37(11): p. 4980-4986.

Karekezi, S., Poverty and energy in Africa - A brief review. Energy Policy, 2002. 30(11-12): p. 915-919.

Kassenga, G.R., Promotion of renewable energy technologies in Tanzania. Resources Conservation and Recycling, 1997. 19(4): p. 257-263.

Kassenga, G.R., The Status and Constraints of Solar Photovoltaic Energy Development in Tanzania. Energy Sources Part B-Economics Planning and Policy, 2008. 3(4): p. 420-432.

Kebede, B., A. Bekele, and E. Kedir, Can the urban poor afford modern energy? The case of Ethiopia. Energy Policy, 2002. 30(11-12): p. 1029-1045.

Kenny, A.E.A.a.a.c.z., Prospects for nuclear power in Sub-Saharan Africa in the 21st century. International Journal of Global Energy Issues.

Khennas, S., Urban waste management for small scale energy production. 2003, [Sri Lanka: s.n.]. 81 p.

Kivunike, F.N., et al., Perceptions of the role of ICT on quality of life in rural communities in Uganda. Information Technology for Development. 17(1): p. 61-80.

Knoef, H.A.M., The UNDP/World Bank monitoring program on small scale biomass gasifiers (BTG's experience on tar measurements). Biomass & Bioenergy, 2000. 18(1): p. 39-54.

Le Roux, D., The proposed construction of the nuclear pebble-bed reactor at Koeberg - an assessment of nuclear energy as a sustainable energy resource in relation to other alternative natural resources. 2005. p. 113 leaves ; 30 cm. Dissertation: Thesis (LL.M. (Faculty of Law))--University of the Western Cape, 2005.

Lenehan, A.M., Photovoltaic water pumping and its potential for application in community water supply in South Africa. Water Sa, 1996. 22(3): p. 257-262.

Mangwengwende, S.E., Tariffs and subsidies in Zimbabwe's reforming electricity industry: steering a utility through turbulent times. Energy Policy, 2002. 30(11-12): p. 947-958.

Matthee, K.W., et al., Bringing Internet connectivity to rural Zambia using a collaborative approach, in 2007 International Conference on Information and Communication Technologies and Development. 2007. p. 46-57.

Meso, P., P. Musa, and V. Mbarika, Towards a model of consumer use of mobile information and communication technology in LDCs: the case of sub-Saharan Africa. Information Systems Journal. 15(2): p. 119-146.

Minges, M., Mobile cellular communications in the Southern African region. Telecommunications Policy. 23(7/8): p. 585.

Mulugetta, Y., Human capacity and institutional development towards a sustainable energy future in Ethiopia. Renewable & Sustainable Energy Reviews, 2008. 12(5): p. 1435-1450.

Nanka-Bruce, O., The Socioeconomic Drivers of Rural Electrification in Sub-Saharan Africa. Journal of Energy and Development, 2008. 33(2): p. 215-47.

Odendaal, N., Splintering Urbanism or Split Agendas? Examining the Spatial Distribution of Technology Access in Relation to ICT Policy in Durban, South Africa. Urban Studies (Sage Publications, Ltd.). 48(11): p. 2375-2397.

Olukoju, A., 'Never expect power always': Electricity consumers' response to monopoly, corruption and inefficient services in Nigeria. African Affairs, 2004. 103(410): p. 51-71.

Organisation for Economic, C.-o., Development, and B. World, Liberalisation and Universal Access to Basic Services: Telecommunications, Water and Sanitation, Financial Services, and Electricity. 2006. 272: p. 272.

Otiti, T.E.A.t.p.m.a.u. and W.O. Soboyejo, Limited Contribution of Photovoltaic Energy Technology to Economic Development of Sub-Saharan Africa. Perspectives on Global Development & Technology.

Parawira, W.E.A.a.y.c.u., Biogas technology in sub-Saharan Africa: status, prospects and constraints. Reviews in Environmental Science & Biotechnology.

Peters, J., C. Vance, and M. Harsdorff, Grid Extension in Rural Benin: Micro-manufacturers and the Electrification Trap. World Development, 2011. 39(5): p. 773-83.

Pollitt, M.G., Ownership and performance in electric utilities: The international evidence on privatization and efficiency. 1995. 240: p. 240.

Ramana, P.V.e., Rural and renewable energy: Perspectives from developing countries. 1997. 317: p. 317.

Rhodes, J., A Strategic Framework for Rural Micro-Enterprise Development: The Integration of Information Communication Technology (ICT), E-Commerce, Marketing, and Actor-Network Theory. Perspectives on Global Development & Technology. 8(1): p. 48-69.

Sebitosi, A.B. and P. Pillay, Energisation of rural Sub-Saharan Africa: Grappling with poor sustainability, in 2006 Power Engineering Society General Meeting, Vols 1-9. 2006. p. 3130-3134.

Sebitosi, A.B. and R. Okou, Re-thinking the Power Transmission Model for Sub-Saharan Africa. Energy Policy, 2010. 38(3): p. 1448-54.

Sheya, M.S. and S.J.S. Mushi, The state of renewable energy harnessing in Tanzania. Applied Energy, 2000. 65(1-4): p. 257-271.

Sosovele, H., Policy Challenges Related to Biofuel Development in Tanzania. Africa Spectrum, 2010. 45(1): p. 117-129.

Spalding-Fecher, R., et al., The economics of energy efficiency for the poor - a South African case study. Energy, 2002. 27(12): p. 1099-1117.

Stage, J. and F. Fleermuys, Energy Use in the Namibian Economy from 1995 to 1998. Development Southern Africa, 2001. 18(4): p. 423-41.

Stassen, H.E., Small-scale biomass gasifiers for heat and power: A global review. 1995. 61: p. 61.

Tall, S.M., Senegalese &Eacute:migr&eacute:s: New Information & communication Technologies. Review of African Political Economy. 31(99): p. 31-48.

Tatietse, T.T., et al., A new and rational approach to modelling and designing potable water and electricity supply systems in African cities. Building and Environment, 2000. 35(7): p. 645-654.

Teferra, M., Power sector reforms in Ethiopia: options for promoting local investments in rural electrification. Energy Policy, 2002. 30(11-12): p. 967-975.

Tewari, D.D. and T. Shah, An assessment of South African prepaid electricity experiment, lessons learned, and their policy implications for developing countries. Energy Policy, 2003. 31(9): p. 911-927.

Turkson, J. and N. Wohlgemuth, Power sector reform and distributed generation in sub-Saharan Africa. Energy Policy, 2001. 29(2): p. 135-145.

Turkson, J., Attracting capital for electric power development in sub-Saharan Africa: A multipronged approach, in Energy and Economic Growth: Is Sustainable Growth Possible?, Vols 1-3. 1997. p. 583-591.

Turyareeba, P.J., Renewable energy: its contribution to improved standards of living and modernisation of agriculture in Uganda. Renewable Energy, 2001. 24(3-4): p. 453-457.

Uprety, K., Transboundary Energy Security: Emerging Legal and Institutional Framework for Electricity Trading in Southern Africa. Journal of Energy & Natural Resources Law.

van Eijck, J. and H. Romijn, Prospects for Jatropha Biofuels in Tanzania: An Analysis with Strategic Niche Management. Sectoral Systems of Innovation and Production in Developing Countries: Actors, Structure and Evolution, 2009: p. 335-66.

van Horen, C. and G. Simmonds, Energy efficiency and social equity in South Africa: seeking convergence. Energy Policy, 1998. 26(11): p. 893-903.

vandenBroek, R. and L. Lemmens, Rural electrification in Tanzania - Constructive use of project appraisal. Energy Policy, 1997. 25(1): p. 43-54.

Viebahn, P.E.A.p.v.w.o., Y.E.A.y.l.c.e. Lechon, and F.E.A.f.t.d.d. Trieb, The potential role of concentrated solar power (CSP) in Africa and Europe-A dynamic assessment of technology development, cost development and life cycle inventories until 2050. Energy Policy.

Weggelaar, S., New strategies to enhance the thermal and energy efficiency of housing in South Africa. 2002. p. xvii, 249 leaves.

Youm, I., et al., Renewable Energy Activities in Senegal: A Review. Renewable & Sustainable Energy Reviews, 2000. 4(1): p. 75-89.

Grey literature (9 articles)

Kalumiana, O. S. Rural Energy Access: Promoting Solar Home Systems in Rural Areas in Zambia - A Case Study. AFREPREN/FWD.

Mbaiwa, J. E. An Assessment of Policies and Programme designed for the Production and Distribution of Modern Renewable Energy to Rural Areas in Botswana. University of Botswana, Harry Oppenheimer Okavango Research Centre.

GVEP International 2010. Kenya Briquette Industry Study. London: GVEP International.

World Bank 2010. IBRD Partial Credit Guarantee (PCG) to advance Botswana Power Sector Development. World Bank.

Nguema-Ollo, J. B. 2006. Republic of Benin, Project for the Electrification of 17 Rural Centres: Project Completion Report. African Development Fund.

Fikru, B., Assefaw, M., Amu, O. & Shannon, E. 2005. Mozambique, Electricity II Project: Project Completion Report. African Development Fund.

African Development Bank 2011. Summary of the Environmental and Social Management Plan: Electricity Transmission and Distribution Network Development Project. African Development Bank.

African Development Bank Group 2011. Energy Sector Policy of the African Development Bank Group (Draft). African Development Bank Group.

United Nations 2008. Innovation for Sustainable Development: Local Case Studies from Africa. United Nations.

Appendix G: Counts of grey literature on barriers

Country	Count
	Grey literature
All Africa	5
Angola	1
Benin	1
Botswana	3
Burkina Faso	1
Burundi	1
Cameroon	1
Cape Verde	1
DR Congo	1
Eastern Africa	1
Ethiopia	2
Ghana	1
Kenya	5
Liberia	1
Mali	3
Middle East and North Africa Region	1
Mozambique	1
Nigeria	2
Rwanda	1
Senegal	1
Sierra Leone	1
South Africa	1
Southern Africa	4
Sub-Saharan Africa in general	8
Tanzania	4
Uganda	6
Zambia	1
Zimbabwe	2

Year	Count
	Grey literature
2005	3
2006	3
2007	2
2008	8
2009	11
2010	10
2011	5
N/S	6

Type of energy service or technology analysed	Count
	Grey literature
Electricity or electrification	18
Battery or battery charging	1
Refrigeration	0
Heat or thermal comfort	6
Lighting or illumination	2
Mobile phone charging	1
Hydropower	6
Biofuel, biogas, bioethanol or waste	7
Solar or photovoltaic	8
Wind power	0
Gas turbine	0
Nuclear power	0
Fuel cell	0
Improving energy efficiency	1

Intervention	Count
	Grey literature
Sector reform	26
Market-based intervention	3
Financial	8
Marketing	1

Barrier	Count
	Grey literature
Financial/Cost	21
Cultural	3
Technical	8
Institutional/regulatory	13
Capacity (Skill)	3

Appendix H: Counts of grey literature on interventions

Country	Count
	Grey literature
Benin	1
Botswana	2
Cape Verde	1
Kenya	3
Mozambique	1
Nigeria	1
Tanzania	3
Uganda	2
Zambia	1
Zimbabwe	1
Sub-Saharan Africa in general	3

Year	Count
	Grey literature
2005	2
2006	1
2007	1
2008	2
2009	1
2010	3
2011	2
N/S	4

Type of energy service or technology analysed	Count
	Grey literature
Electricity or electrification	8
Battery or battery charging	1
Refrigeration	0
Heat or thermal comfort	0
Lighting or illumination	1
Mobile phone charging	1
Hydropower	1
Biofuel, biogas, bioethanol or waste	5
Solar or photovoltaic	3
Wind power	0
Gas turbine	1
Nuclear power	0
Fuel cell	0
Improving energy efficiency	0

Intervention	Count
	Grey literature
Sector reform	9
Market-based intervention	2
Financial	1
Marketing	1