Greening the African energy ladder

The role of national policies and international aid

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Contents

1 Introduction

1.1 The study

Although energy is widely recognised as a crucial condition for development, 1.6 billion people worldwide have no electricity and 2.6 billion people still depend on traditional biomass as main energy source. The Dutch government strongly supports the introduction and expansion of the use of renewable energy from solar, wind, geothermal and biomass sources as a tool for sustainable development and to step up international efforts against climate change. In the last few years, the promotion of renewable energy has therefore become a key policy instrument of the Dutch Ministry of Development Cooperation (DGIS). In 2004, DGIS set the goal to provide access to modern energy to 10 million people by 2015. Up to now, around 6.9 million people were granted access. The Dutch government reserved €500 million for the promotion of renewable energy in Dutch partner countries, with a specific focus on sub-Saharan Africa to be invested in the period 2008-2011. As part of the policy, four main activities were identified: 1) promotion of direct investments; 2) promotion of sustainable use of biomass; 3) policy strengthening of development partners; and 4) capacity building at various levels.

This study investigates how the Netherlands can directly and indirectly promote the use of renewable energy in developing countries with the goal to improve access to affordable energy, support development and reduce poverty and increase energy security at the national level. The project is commissioned by the Department of Research and Communication (DCO), Ministry of Development Cooperation (DGIS) both from the Netherlands. The Dutch project partners are the Institute for Environmental Studies (IVM) of the VU University, the Energy research Centre of the Netherlands (ECN), Unit Policy Studies and the Department of Environment and Water, Ministry of Development Cooperation (DGIS).

1.2 The energy ladder

Renewable energy technologies provide multiple benefits that can contribute to addressing vital local and global development challenges (World Bank, 2008). These include:

- *Climate change mitigation and adaptation*: Because they emit no or very low levels of greenhouse gases, renewable energy technologies can help mitigate global climate change impacts.
- *Environmental and health impacts*: Modern renewable energy technologies also reduce the negative health and environmental impacts of air pollution from both conventional power plants and traditional biomass cook stoves.
- *Energy security*: For many developing countries, the use of locally available renewable energy resources can reduce reliance on energy imports, diversify energy supply mixes, and contribute to energy security.
- *Economic development*: Renewable energy systems can support decentralized markets and contribute to local economic development by creating employment, introducing new capital and innovation, and developing new revenue sources for local communities.
- *Least cost generation option*: In many remote areas, renewable energy technologies are economically cost-effective supply options, and can contribute the provision of modern energy services to underserved rural populations in the developing world.

Despite these benefits, it is important to emphasize that it is by no means certain that renewable energy options will always be the optimal choice from the point of view of improving energy access and stimulating development. In many cases, it may be the other

way around in the sense that for individual households fossil fuel options may offer a more attractive alternative from a cost and health perspective. Because the poor hardly contribute to climate change and resource depletion, both in terms of aggregate and per capita impacts, energy access policies are certainly justified in disregarding globally dominant energy issues of climate change and resource depletion in the initial stages of development. The appeal of using renewable energy in Africa depends to a large extent on specific technological, environmental and economic conditions at the national and local level.

The main problem of introducing renewable energy in poor households can be framed through a graphical description of the process of development of poor households in terms of household income levels and household carbon intensity (see figure 1). The resulting curve can be described as the energy ladder (Smith 1987; Barnes & Floor, 1996). The steps of this ladder describe four steps in income level and carbon intensity and the preferred technologies for heat and power at each step. They also describe the process of fuel substitution choices with growing income. The curve presents this process in a more continuous form. Thus this curve can be viewed as an elaboration of the initial stage of the familiar environmental Kuznets curve. Although the energy ladder is not at all undisputed (Evans, 1987; Dowd, 1989; Leach, 1992; Masera et al., 2000) the concept is used here as a heuristic device to frame relevant research questions.

There are two stages in this process of increasing incomes and energy use that are particularly problematic from the point of view of climate change and resource depletion. The first stage can be defined as the poverty trap: when households do not have a substantial cash income they are bound to use traditional biomass in an unsustainable way, particularly from a local environmental, social and health perspective. Yet, they lack the income and opportunities to move to fossil fuels or to use traditional biomass in a more sustainable way. The second stage can be defined as the finance trap: when households have effectively escaped the poverty trap, they are bound to expand their dependence on fossil fuels in a progressive way, because they still lack sufficient financial resources and incentives to make local investments in renewable options competitive against often subsidized fossil fuels or electricity. More background information on the use of renewable energy is provided in Appendix 1.

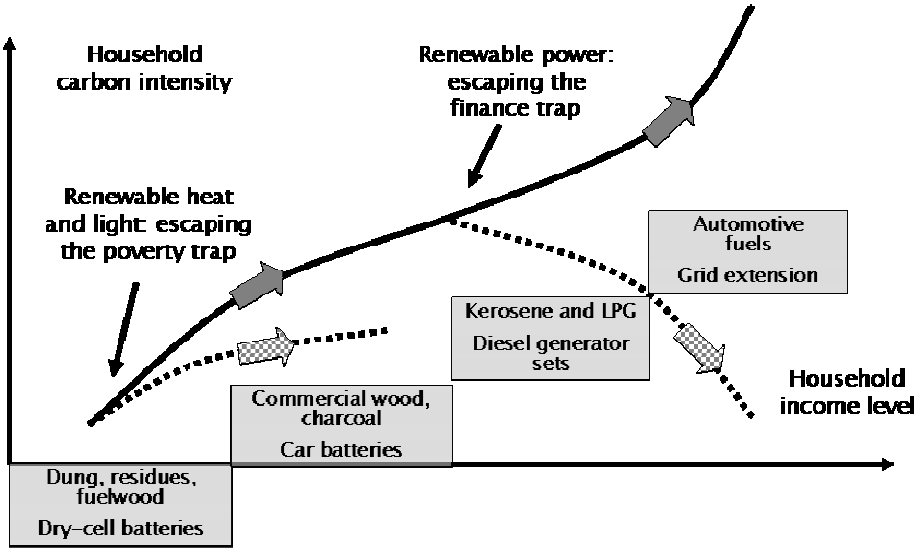

Figure 1 Greening the African energy ladder

1.3 Policy context

One of the main challenges in the coming decade is to scale up renewable energy in the developing world. This requires major actions on a number of fronts - policy, legal, regulatory, technical, and financial. National governments and international organizations support these activities in various ways. The World Bank, for example, has committed more than US$11 billion to renewable energy and energy efficiency in developing countries since 1990 (World Bank, 2009). However, multilateral and government resources alone are inadequate to meet the large investment requirements of scaling up renewable energy services in developing countries. Mobilizing private capital is vital for renewable resources to become more important providers of energy. In turn, private investors need to be provided with risk-adjusted returns from their investments in renewable energy, making them comparable to returns from more traditional energy alternatives. Most national and international organizations recognize the need to engage the private sector and other commercial partners in the development of renewable energy.

1.4 The study approach

The key question to be answered in the IS-Academy is how international, national and local organisations can promote the use of renewable energy in developing nations while improving access to energy and stimulating development. Table 1 provides an overview of the structure of the study. The columns show the main research themes and questions to be focused on. These include: (1) Which [renewable] energy mix is most feasible and appropriate in which context?; (2) What is the performance of renewable energy policies up to now and how can future adoption of these technologies be measured and rated?; and (3) What "enabling environment" is needed for maximum adoption of renewable energy and how can innovation be encouraged?

Table 1 Integrated approach of the study

Stakeholder perspective (methodological approach)	**Research theme 1:** Feasibility and appropriateness of renewable technology	**Research theme 2:** Impacts and adoption of renewable energy	**Research theme 3:** Enabling environment for adoption & innovation
Entrepreneurial perspective (Business modelling)	+++	+	+
Consumer perspective (Behavioural economics)	+	+++	+
Governance perspective (Innovation theory)	+	+	+++

The rows in Table 1 represent the main stakeholders' perspectives on renewable energy and methodological approaches that follow from these perspectives. The three main perspectives are subdivided in: (1) The entrepreneurial perspective aiming, through the use of business models, at identifying business opportunities that help households escape either the poverty trap or the finance trap through the use of commercially viable technological choices (or combinations thereof); (2) The consumer perspective in which conceptual domestic household energy demand model is developed and empirically tested, accounting for renewable and non-renewable energy substitution possibilities in a developing country context; and (3) The governance perspective investigating the adoption and diffusion of renewable energy technologies (RET) by applying an innovation systems approach.

Although each stakeholder perspective / methodological approach will touch upon all research themes shown in the columns, a focal combination between themes and approaches follows naturally, in which the entrepreneurial perspective will focus upon research theme 1, the customer perspective will concentrate on research theme 2, and the governance perspective will specifically address research theme 3. These focal points of approaches and themes will be explained in more detail in the coming Sections.

2 Business models

2.1 Introduction

The appeal of using renewable energy in Africa depends to a large extent on specific technological, environmental and economic conditions at the national and local level. The main goal of the first research theme is to find out which energy source and technology would be most appropriate in which national and local development context. A key factor for evaluating appropriateness is the income level at which a shift between dominating energy technologies is likely to take place as illustrated in the energy ladder (see figure 1). Each step on the energy ladder can be viewed as a window of opportunity to divert from the traditional pattern of increasing carbon intensity and set into motion a substitution process towards less carbon intensive energy sources and technologies.

After determining the preferred energy source and technology for a particular context, the question remains how to get this preferred technology adopted. Although development economists generally agree that the technology driven approach to increasing the share of renewable options in the past has been a failure, it is far from certain that the present emphasis on an integrated, market design approach will easily result in effective implementation of renewable energy technologies without substantial changes in energy and climate policy (Murphy, 2001; Kuriyan, 2008).

2.2 Objectives and research questions

The main objective of this subproject is to **identify business opportunities that help households escape either the poverty trap or the finance trap through the use of commercially viable technological choices** (or combinations thereof). Preferably, these technological choices should not only succeed in improving energy access and stimulating development, but also in addressing problems of climate change and resource depletion. This objective is inspired by recent enthusiasm in the development community for combining technological innovation with entrepreneurial drive in order to tap the market potential of the bottom of the global income pyramid (Prahalad, 2005; IFC/WRI, 2007). In particular, such a search for viable commercial options should help in identifying the technological and economic conditions required to help renewable options compete successfully with fossil fuel options and define the development context within which particular energy choices must be made.

This subproject will deal with the following research questions:

1. Is the concept of an African energy ladder an empirical reality?
2. What business models may be attractive for renewable energy technologies in Africa?
3. What are the implications for energy and climate policies in Africa?

2.3 Approach

Simplified frames of thinking for complex real world problems such as the concept of an energy ladder may suit the abstract view of the researcher, but may at the same time lead to a misleading distortion from reality. So the first step in the analysis will be to look for empirical support regarding the hypothetical connection between economic development, energy use and climate change impacts as illustrated in figure 1. This empirical foundation

will be based on an in-depth literature survey on African energy use. Sources include African energy statistics, household surveys and market research that describe energy use among poor households in relation to income levels. In addition, the lessons learnt from past energy programmes such as rural electrification or improved cook stove initiatives, be it projects linked to official development aid (ODA) or more market oriented mechanisms such as public-private partnerships (PPP), should also provide insight in the different factors that lead to a change in energy use.

The second step of the analysis is the design of a key set of business models that are of particular interest in escaping the poverty and finance trap. The term business model refers to formal descriptions of the core strategies of a company. Core strategies concern the main conceptual building blocks behind successful enterprise. Building blocks commonly distinguished concern the value proposition, the customer base, financial structure, infrastructural requirements and marketing strategies. A business model can sometimes be expressed in a simple phrase such as the shopkeeper model (over the counter sales from local stocks), the hook-and-bait model (cell phones and air time) or the fee-for-service model (where ownership of appliances remains with the business and only services are sold. The design of these business models will be strongly dependent on the steps of the energy ladder to be addressed (income levels) and particular local and national conditions (population density, energy use habits, availability of resources). This part of the thesis will be based on interviews with entrepreneurs in the African energy business and the construction of formal business models. These business models will include a quantitative assessment of financial performance as a function of key parameters concerning market demand, supply costs, financing structure and performance of fossil fuel competitors. Parameters to reflect the impact of fossil fuel price developments, subsidies of non-recurring costs and potential CO_2-credits on renewable energy technology performance will be included.

If there indeed exists some sort of energy ladder in Africa and if there are indeed specific business models suitable for specific renewable energy options along this ladder, then the question remains how energy and climate policies can stimulate sustainable enterprise in Africa. For the two preceding stages of the study, the analysis will focus on experiences available in a broad range of African nations. At this final phase of the study, it will be necessary to confine the analysis to a small range of countries, such as Eastern Africa. A set of concrete suggestions for strategic decision-making about Dutch renewable energy support, both through bilateral and multinational channels, will be developed.

3 Domestic household energy demand models

3.1 Introduction

Households in developing countries, especially in remote rural areas, often face limited choice sets when it comes to energy sources and energy use. Use of sustainable renewable energy sources, such as solar energy or biomass, is seriously constrained by their social and economic conditions. Rural households often depend on cow dung or fuel wood as their main source of energy, and substitution possibilities are almost non-existent. Poverty and environmental degradation go hand-in-hand under these circumstances (e.g. Heltberg et al., 2000).

Few renewable energy sources can compete with traditional fuels on a strict cost basis. However, external costs, i.e. those costs that include the wider social, health and environmental impacts of different energy uses, are not included in existing cost comparisons. The situation is usually different for households in urban areas. Here energy supply and the available choices are perhaps even more limited given population pressures due to increasing urbanization. From the perspective of domestic households, reliability of energy supply through public utilities is often the key issue here (see, for instance, the electricity reliability special issue in the Energy Journal edited by Munasinghe, Woo and Chao in 1988).

An important barrier to the adoption of renewable energy in a developing country context which is central in research theme 2 are behavioural processes of involved households (Sudhakar Reddy and Painuly, 2003). Research theme 2 focuses on domestic household decision-making regarding renewable energy use under constrained circumstances in an African context. There is an impressive stock of empirical literature on domestic household decision-making processes underlying the diffusion and adaptation of renewable energy technologies in developed countries going back to the consumer research in this area in the 1980s (e.g. Labay and Kinnear, 1981; Black et al., 1985; Vaage, 2000; Arkesteijn and Oerlemans, 2005; Caird et al., 2008). From this literature, two important lessons can be drawn. First, the important role of awareness and public programs, which created initial niche markets and allowed a technological learning process to become established (e.g. Menanteau and Levebvre, 2000), and second social acceptance of new technology (e.g. Wüstenhagen et al. 2007). The question obviously is to what extent these experiences in a developed economy context apply to the conditions in a developing country context.

3.2 Objective and research questions

The main objective of research theme 2 is twofold. On the one hand, household surveys will be conducted among communities subjected to renewable energy projects in order to analyse ex-post information about the level of adoption of these new technologies and their impact on their welfare. On the other hand, an ex-ante analysis will be conducted to develop and empirically test a conceptual domestic household energy demand model accounting for renewable and non-renewable energy substitution possibilities in a developing country context.

Important research questions include:

1. What are current levels of awareness of renewable energy sources at individual domestic household level in the specific African context?

2. What are the trade-offs in terms of costs and benefits of alternative energy sources at individual domestic household level in the specific African context, including their external (non-market) welfare implications?
3. What differences exist between energy demand at individual domestic household level in urban and rural areas in the specific African context?
4. How can learning and increased experience improve sustainable renewable energy uptake in the household energy budget?
5. Which institutional-economic conditions enhance renewable energy uptake at domestic household level?
6. What is the price and income elasticity of demand for renewable energy in the specific urban and rural African context?

3.3 Methodological approach

The foreseen methodological approach is based, among others, on behavioural economics and choice theory (e.g. Dubin and McFadden, 1984; McFadden, 1986; Revelt and Train, 1998). Choice theory attempts to model the decision process of an individual or household in a particular context, which is [renewable] energy in this case. Choice modelling may also be used to estimate non-market environmental benefits and costs. Choice Models are able to predict with great accuracy how individuals would react in a particular hypothetical situation. For example, choice experiments can determine under what conditions households would be willing to pay what for particular energy services. Choice Modelling is believed to be the most accurate and general purpose tool currently available for making probabilistic predictions about human decision making behaviour and is found to be extremely well suited for the context of a developing country. A recent example of choice modelling in the context of energy consumption of African households is provided by Abdullah and Mariel (2009).

4 Innovation systems

4.1 Introduction

The adoption and diffusion of new technologies need to be seen as part of the innovation process. Adopting a new technology involves learning, adaptation and change among users of the technology, changes which in turn frequently generate feedbacks to the developers of the technology. This interaction between users and producers of technology allows new technologies to become embedded in new settings, leading to acceptance and efficient exploitation of their potential. In other words, the adoption of technology depends on knowledge and competences amongst adopting firms and other agents (their absorptive capacity, Cohen and Levinthal, 1990) and the process of adoption typically leads to the adaptation of the technology, as it is tailored to local circumstances.

The development of technological capabilities to absorb technologies has long been recognised as being critical in developing country contexts (Lall, 1992; Nelson and Pack, 1999). Such capabilities are required for adoption to occur, but also for the maintenance and optimisation of technologies once they have been adopted. It is well-known that in developing country contexts such capabilities are frequently weak or absent, leading to failed adoption processes and an inability to exploit the productivity and other benefits of new technologies. We would expect these constraints and barriers also to play an important role in the adoption of renewable energy technologies in developing countries, reducing not only their economic significance, but also their environmental effectiveness.

Over the past decade the development of technological capabilities has been further contextualised within 'innovation systems'. Innovation systems have been defined as:

> "... the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987)

The notion of national and sectoral innovation systems has developed rapidly over the past decade or so, including applications to the innovation and diffusion of sustainable technologies in the EU (Bergek and Jacobsson, 2003). One of the key theoretical developments has been the claim that innovation systems perform specific 'functions' that underpin the build-up of technological and institutional capabilities that form the enabling environmental for business innovation around new products, processes and systems (Hekkert et al., 2007; Bergek et al., 2008). These functions include the development of new knowledge, influence of the direction of technological search, market formation and so on.

4.2 Objectives and research questions

The objective of this project is to investigate the adoption and diffusion of renewable energy technologies (RET) in a selective number of African countries by applying an innovation systems perspective. We will map and investigate innovation systems that are developing around RET, assess gaps and weaknesses in innovation systems and propose ways of strengthening these systems, so as to encourage faster and more effective take-up of RETs.

This project is linked to the theme 1 project (business models for sustainable energy) in analysing the broader innovation system within which new business models emerge, and to the theme 2 project (RETs and household energy consumption) in being concerned with the role of an innovation system in creating new markets and knowledge for RETs.

The project will deal with the following research questions:

1. What are the similarities and differences between RET innovation systems in different African countries?
2. What are the strengths and weaknesses of RET innovation systems in these countries?
3. To what extent are technological capabilities related to RETs similar or different to other (energy) technologies?
4. Are innovation systems highly specific to sectors and countries, or can lessons be transferred? If so, under what conditions?
5. How can RET innovation systems be strengthened to ensure more rapid diffusion of technologies and to ensure maximum economic and environmental benefits?

4.3 Approach

In line with much previous research, this project will be comparative across technologies and countries. The first phase of the research will involve a mapping RET adoption and diffusion in various African countries on the IS Academy country lists, with special reference to RETs where there is a Dutch industrial interest. This will enable a choice to be made of country-technology combinations appropriate to this study. We anticipate an analysis of 2-3 different technologies in 2-3 different countries.

The second phase of the project would involve the development of a method for investigating RET innovation systems in an African context, with special attention paid to data available from national authorities and international organisations, including information held by DGIS. This assessment tool would include both qualitative and quantitative elements, with a starting point in the existing 'functions of innovation systems' literature. A comparative analysis will strengthen the analytical and methodological rigour of the project, and provide a better basis from which to make policy recommendations.

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Appendix I. Renewable energy in Africa

To draw the context in which this IS Academy is working, this Section aims to provide a basic background on renewable and conventional energy in Africa. As shown in Figure 1, traditional biomass currently provides roughly 85% of energy consumed in sub-Saharan Africa (SSA), making it the region with the highest dependence on this energy source. Developing countries in other regions have vastly reduced their dependence on biomass by shifting to fossil fuels, and it was generally assumed that the majority of countries in SSA would follow. We find, however, that this is not the case and the access to electricity is 53% and 8% for urban and rural populations, respectively, in SSA, compared to 99% and 88% for North Africa, respectively (IEA 2004).

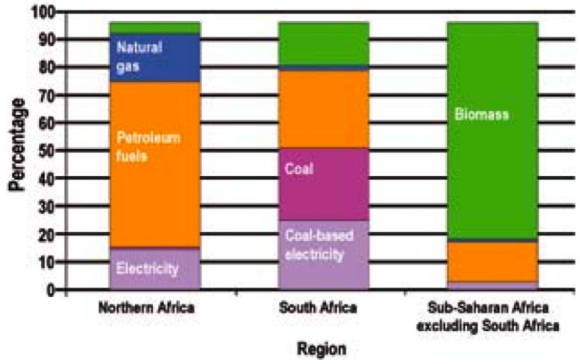

Figure 1: Percentage energy demand by region 2001 (Source: IEA 2004)

The rural areas of SSA pose specific problems caused mainly by their low population density, remoteness and low level of infrastructure resulting in high costs and complexity when attempting to include these areas in a national grid. National power companies have not been able keep up with cities increase in energy demand, and some countries have even seen a drop in capacity due to poor maintenance. This is often due to countries' inability to mobilize local finances for energy resource development, while the increase in foreign direct investment has been mainly confined to upstream oil extraction and has been limited to 10% of the countries in SSA. In addition, a lack of capacity at an institutional level has often resulted in poor energy planning and coordination leading to fragmented energy programmes, especially when integrating off-grid systems with national energy programmes.

The challenges associated with these energy problems are vast. The rural-urban electrification imbalance (see figure 2) creates an uneven spatial distribution of economic activity, contributing to mass rural-urban migration. This has led to the formation of informal settlements around urban areas, increasing the difficulty of urban planning for transport and energy infrastructures. The lack of access to electricity has added to the poor levels of education, health and industrialization, where the latter not only reduces the added value of African products, but also inhibits small-scale enterprises in rural areas.

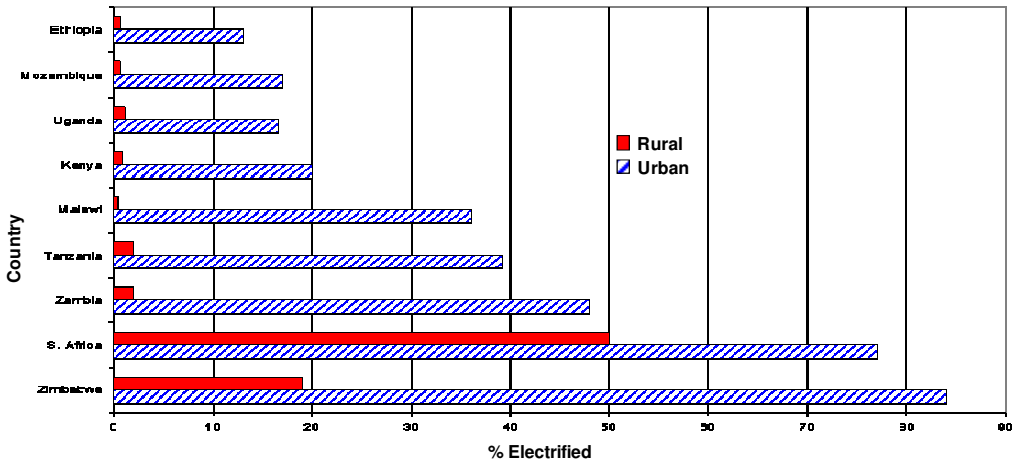

Figure 2: Rural and Urban access to electricity in developing countries, 2001 (Source: UNIDO 2009)

Currently, most rural Africans do not have access to modern fuels, or electricity. The largest form of energy used is traditional biomass for cooking purposes, which is inefficient and carries several health hazards. It is estimated that 393,000 deaths can be attributed to the burning of fuels indoors (WHO, 2006), where the majority was women and children. The local governments' inability to finance other means of energy has often created an unsustainable model, involving high dependence on foreign partners. Through Official Development Aid (ODA) several renewable energy programs exist, however, the large financial barrier of the up-front cost of these technologies is still not overcome. This is especially important when targeting the poorer inhabitants of a country. Several finance models such as the fee-for-service model (e.g. Yeleen Kura in Koutiala, Mali) exist, although the up-front and operating costs still do not make this model viable without large subsidies and investments, in order to offer provide affordable rates. Micro financing has also entered the renewable energy market, allowing communities to use renewable energy technologies for public utilities such as water pumping and lighting, but the scale of deployment is still small.

Organizations such as the World Bank are also aiding local SSA NGOs in financing R & D programs to develop more efficient cookers and means to use traditional biomass. However, the cultural barriers associated with these energy means often lead to low penetration of the technology. As this form of energy is not linked to a cash economy, the purchase price remains an obstacle. It is found that creating working market models for this technology is difficult and external financing is absolutely necessary, especially when trying to increase the local capacity in providing information on the benefits of use. The technology transfer agenda of the United Nations Framework Convention for Climate Change (UNFCCC) is also carefully considering how its Clean Development Mechanism (CDM) can be altered to be able to finance the implementation of more renewable energy projects in SSA. The co-benefits associated with renewable energy, closely interlinked with the Millennium Development Goals, are getting additional international attention (Bali Action Plan). Although this agenda is driven by the abatement of green house gas emissions, it also adds value by presenting a sustainable alternative for poor rural households in SSA.