SMART VILLAGES

New thinking for off-grid communities worldwide

Providing village-level energy services in developing countries

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Technical Report 1

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Key words:
Off-grid energy, rural development, renewable energy

Smart Villages

We aim to provide policy makers, donors and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries - technological, financial and political - and how they can be overcome. We are have chosen to focusing on remote off-grid villages, where local solutions (home- or institution-based systems, and mini-grids) are both more realistic and cheaper than national grid extension. Our concern is to ensure that energy access results in development and the creation of 'smart villages' in which many of the benefits of life in modern societies are available to rural communities.

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Contents

Executive Summary

A scoping study has been undertaken of the provision of village-level energy services in India, Tanzania and Ghana, three Commonwealth countries. The study has been funded by the Malaysian Commonwealth Studies Centre and has arisen from discussions during 2011 between Malaysian Commonwealth Studies Centre and the European Academies Science Advisory Council (EASAC). Its aims have been to:

- evaluate the potential of candidate technologies to meet the needs of rural communities in developing countries;
- review the social, economic, and policy/ regulatory factors influencing the uptake and implementation of alternative technologies;
- identify the distinctive contribution of a potential EASAC study in relation to other initiatives in the focus countries; and with a view to a second phase study
- design workshops to be held in the focus countries to inform, and bring together, key stakeholders, and identify who those stakeholders are.

This scoping study report will inform a decision on a second phase study, which would be undertaken by EASAC in collaboration with the relevant national Academies, to inform key stakeholders in the focus countries on appropriate technologies and the conditions necessary for their development and implementation, bring stakeholders together in those countries to stimulate the establishment of appropriate development and implementation initiatives, and advise European policy makers concerned with international development on the associated scientific and policy issues to inform development of EU policy.

The study's concern is the 1.3-1.6 billion people in the world without access to electricity, and the 2.7 billion people without clean cooking facilities. The report provides an overview of the issues associated with the provision of sustainable energy services to these populations, who are largely situated in rural villages, including an evaluation of appropriate energy technologies and a review of the opportunities arising from access to energy, not least to transform educational opportunities. For each of the focal countries – India, Tanzania and Ghana – the current energy landscape is reviewed and the issues arising from village energy provision are explored through series of case studies.

A general conclusion from this scoping study is that while there are both Government-led and NGO initiatives, village energy provision needs to be higher up Governments' agendas, which tend otherwise tend to take a more centralised view, emphasising large-scale electricity generation and grid extension. Such approaches prioritise urban populations and often offer rural populations little immediate prospect of reliable access to electricity.

The case studies identify photovoltaic cells and biomass-based technologies as key options, but small scale hydro and wind generators can also play a role according to local circumstances. Choosing the most appropriate technology is only one of the necessary ingredients for successful rural energy service provision. Indeed, institutional capacity, availability of an adequately trained and technically proficient human resource, and the social context are often more important to the sustainability of an energy service than the technology selected. A consistent message is the effectiveness of social business (or social enterprises) as a model for knowledge transfer and development. A social business can be profit or non-profit; it combines business methods and strategies to achieve philanthropic outcomes.

There are also opportunities emerging through the parallel development of technologies and initiatives which rely on a supply of sustainable electricity. For example, there is significant opportunity arising from the provision of energy and the availability of low power consuming information communication devices. This includes power for connected tablets and mobile phones, which open up new opportunities for education and business.

Several recurrent barriers to success were identified through the case studies, including:

- the lack of sufficient technically proficient people to design, install and maintain energy installations;
- difficulties for entrepreneurs and their prospective clients in accessing 'affordable capital' and/or subsidy/incentive schemes;
- poor quality products, which can get a technology a bad name, and the poor availability of reliable information to enable purchasers to distinguish the good from the bad; and
- the limited standardisation of rural energy as a way to ensure good business practice and enable scale-up.

The report discusses various responses to address these barriers. It concludes that a phase 2 study has the potential to add value to existing initiatives to address village energy provision, and would appropriately be taken forward by EASAC working in collaboration with the national Academies of the countries concerned. The Academies are a preferred source of authoritative scientific advice for governments and society and have good 'convening power' if workshops are set up to bring together key players to address key issues associated with village energy development. Such workshops would need to select a limited number of key issues to address, and the report makes suggestions as to where the focus may most appropriately lie.

Chapter 1: Study aims and motivation

1.1 Study aims

This report summarises the findings and recommendations of a scoping study of the provision of village-level energy services in developing countries, in particular India, Tanzania and Ghana, all members of the Commonwealth. The scoping study has been funded by the Malaysian Commonwealth Studies Centre (MCSC) and has arisen from discussions during 2011 between MCSC and the European Academies Science Advisory Council (EASAC). Its aims have been to:

- evaluate the potential of candidate technologies to meet the needs of rural communities in developing countries;
- review the social, economic, and policy/regulatory factors influencing the uptake and implementation of alternative technologies;
- identify the distinctive contribution of a potential EASAC study in relation to other initiatives in the focus countries; and with a view to a second phase study
- design workshops to be held in the focus countries to inform, and bring together, key stakeholders, and identify who those stakeholders are.

A second phase study will follow which, taken together with the scoping study, will have the overall aims of:

- informing key stakeholders in the focus countries on appropriate technologies and the conditions necessary for their development and implementation;
- bringing stakeholders together in those countries to stimulate the establishment of appropriate development and implementation initiatives; and
- advising European policy makers concerned with international development on the associated scientific and policy issues to inform development of EU policy.

As trailed above, it is anticipated that the second phase will involve holding workshops involving key stakeholders in the focal Commonwealth countries. The second phase will be undertaken by EASAC, with financial support provided by MCSC, and in collaboration with relevant national Academies in India, Tanzania and Ghana, and with the networks of Academies corresponding to EASAC in Asia and Africa (AASA (http://www.aasa-net.org/) and NASAC (http://www.nasaconline.org/).

1.2 Motivation for the Study

The motivation for the study and its concern with provision of village-level energy services is well-expressed by a recent report from the International Energy Agency (IEA, 2011):

"Modern energy services are crucial to human well-being and to a country's economic development; and yet globally over 1.3 billion people are without access to electricity and 2.7 billion people are without clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia and 84% are in rural areas."

Taking India as a specific example, over half of India's 27000 villages (487 million people) are not connected to electricity grids and depend on state-distributed and subsidised kerosene, on animal and human energy, candles and biomass including cow dung and charcoal (Neale, 2008; Harriss-White et al, 2009).

Looking ahead, Practical Action's 'Poor people's energy outlook 2012' report expresses the concern that globally, "Without a change of course, by 2030 the total number of people without access to electricity will still be almost 900 million, 3 billion will cook on traditional fuels, and 30 million people will have died of smoke-related diseases" (Practical Action, 2012).

As a consequence of such considerations, the United Nations General assembly has designated 2012 as the 'International Year of Sustainable Energy for All', and the UN Secretary-General is leading a 'Sustainable Energy for all' initiative which has as one of three objectives ensuring universal access to modern energy services by 2030 (http://www.sustainableenergyforall.org).

The European Commission has recently proposed to focus its development aid on sustainable energy (alongside sustainable agriculture) to reduce developing countries' exposure to global shocks such as climate change, and volatile and escalating energy prices (European Commission, 2011). In doing so, it aims to tackle inequalities in developing countries, ensuring that poor people have better access to energy along with other essential services. Issues of development, climate change mitigation, and resilience in the face of climate change are inextricably interlinked as discussed in Annex 2. Improving energy security at national, regional and global levels is a key aim of EU and UN policies (European Commission, 2011; UNDP, 2000).

As pointed out by the International Energy Agency (IEA, 2011), modern energy services are crucial to economic and social development, but escalating global energy prices are pushing energy out of reach of those most at need. For example, oil prices in real terms are now around 5x what they were when OECD countries were at a similar stage of development as developing countries that import oil today (IEA, 2011).

The United Nations Development Programme (UNDP, 2011), focusing on the link between sustainability and equity, points to the availability of affordable sustainable energy as being necessary to enable access to education, and to tackle health problems. The Interacademy Medical Panel has concluded that the health co-benefits of providing access to clean sustainable energy are similar in value to the costs of the climate change abatement strategies (IAMP, 2010).

1.3 Conduct of the study

The scoping study has been carried out over the period December 2011 to March 2012 by a team comprising:

- Meghan Bailey: DPhil student at the Environmental Change Institute (ECI), University of Oxford, and acting as an independent consultant on this study;
- Justin Henriques: Post-doctoral researcher at the ECI, University of Oxford;
- John Holmes: Senior Research Fellow in the Department of Earth Sciences at the University of Oxford, Secretary to the EASAC Energy Programme, and acting as an independent consultant on this study; and
- Ruchi Jain: recently graduated from the Environmental Change and Management MSc at the ECI, University of Oxford, and acting as an independent consultant on this study.

Annex 1 provides short biographies of each of the study team.

The study has identified the needs for energy services in 'off-grid' villages and rural communities in India, Tanzania and Ghana (for example for lighting, cooking, motive power, communication, and education) and evaluated the merits of candidate technologies to meet them. While the focus has been on energy needs most appropriately met by electricity, where alternative energy vectors could also be used, their relative merits are discussed. Currently available, and potential future (next 5 to 20 years), technologies have been considered, and their technical characteristics, costs and R&D needs evaluated.

Social and cultural factors have an important influence on the suitability and uptake of technologies and have consequently been reviewed. Consideration has been given to what commercial and financing frameworks are needed, and similarly, for the policy and regulatory settings. A key consideration has been the 'embedding' of energy systems to ensure their sustainable use over time.

1.4 Report overview

The next chapter presents an overview of the present situation, describing the current state of access to energy services and the impacts and opportunities presented by the introduction of rural energy services. Chapter 3 surveys appropriate energy technologies, research institutions, financing mechanisms and models for technology transfer. Chapters 4 and 5 present the country studies, summarising the national and rural energy landscape in each case, identifying key stakeholders, actors and initiatives, and presenting and analysing case studies of the application of particular technologies.

Taking stock of the findings presented in earlier chapters, Chapter 6 then draws together conclusions on the issues facing village level energy development and how they may be addressed, and presents a view of the scientific and policy contributions that could potentially be made by an EASAC-led phase 2 study. Reports and papers drawn on in the study are listed at the end of each chapter (at the end of Chapter 3 for Chapters 2 and 3), and supporting detail is presented in annexes. Cost and price data are presented in euros and in the currencies recorded in the source material using exchange rates of 66 Indian rupees (INR) and 1.33 US dollars ($) to one euro (€).

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CHAPTER 2: OVERVIEW OF PRESENT SITUATION

Author: Justin J Henriques

The lack of access to energy services in rural communities in developing countries restricts educational opportunities, leads to negative public health and environmental impacts, and inhibits economic growth. This chapter of the scoping study provides an overview of the state of access to energy in rural communities in developing countries, impacts from lack of access, and opportunities that arise from provision of energy services. It also discusses the advantage of using distributed, renewable energy to provide these energy services. This chapter draws on the author's work in Henriques (2011).

2.1 The current position

Inadequate access to sustainable forms of energy in developing countries has devastating public health and environmental effects, and threatens global energy security. Sustainable provision of energy services to rural communities can alleviate these negative impacts, and encourage development and education.

Key Statistics

- 3 billion people use traditional fuels for household energy
- 1.5 million die per year from the indoor air pollution created by traditional fuels
- 1.3 – 1.6 billion people are without electricity, with the large majority living in rural communities
- In sub-Saharan Africa, less than 10% of rural households have access to electricity

2.1.1 Public Health

Of the 3 billion people who use traditional fuels like charcoal for household energy, 1.5 million die each year from the high particulate air pollution created by these fuels in poorly ventilated spaces (Reinhardt, 2006). For example, the negative impacts of kerosene lamps for lighting are well documented (Bruce, Perez-Padilla et al., 2000; Bruce, Perez-Padilla et al., 2002; WHO, 2006), including the release of toxins during combustion, contribution to upper respiratory disease, and safety concerns such as fire hazards and accidental ingestion.

Household energy is itself a basic human need and is central to the satisfaction of basic nutrition and health needs (UNDP, UNDESA et al., 2000). For example, 95% of staple foods in developing communities must first be cooked prior to consumption (DFID, 2002). Household energy drives activities such as cooking and heating, pumping technologies for irrigation systems, and water and sanitation services. Thus, access to household energy is a precursor to the provision of all essential infrastructure services.

2.1.2 Local and National Development

Barnes and Floor (1996) argue that the lack of access to household energy and associated infrastructure inhibits economic growth and development in developing countries. Energy infrastructure is often a prerequisite for income generating activities, increasing productivity and education.

Energy consumption increases with development. Figure 2.1 demonstrates this by charting annual country per capita energy consumption data (EIA, 2009) against the UN composite index of development (UNDP, 2009): the Human Development Index (HDI). The UNDP uses the HDI as a composite index measuring average achievement in three basic dimensions of human development: a long and healthy life, access to knowledge, and a decent standard of living. In Figure 2.1, each point on the graph represents a single country. The x-axis is the total energy in gigajoules per capita per year consumed by a country. The y-axis is the HDI ratio (scaled from 0 to 1) for a given country.

The interpretation of Figure 2.1 is that as a country's HDI increases at the low energy end of the graph, its total energy consumption per capita exponentially increases. It then tails off when energy levels approach industrialised country levels. Thus, expected increases in the quality of life and standards of living in developing countries will likely correspond to increases in total energy consumed per capita. As a country's population increases, this will cause greater demand for energy infrastructure and services, which will generally increase the cost of the scarce resource. Further, the increased demand for energy to fuel development and support continued population growth threatens global energy security.

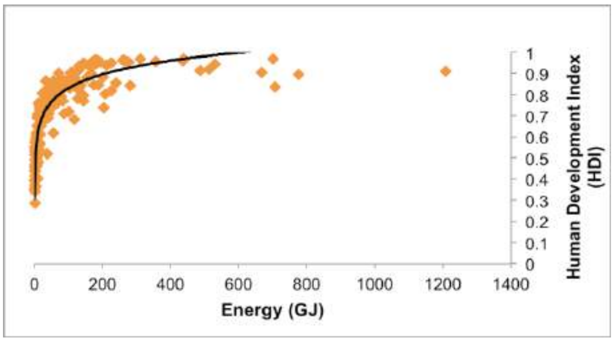


Figure 2.1: Per capita energy consumption and the Human Development Index (HDI). Data Source: EIA (2009); UNDP (2009).

2.1.3 Education

Other negative impacts of reliance on fuels such as wood, charcoal and kerosene include inhibiting educational and social activities. For example, kerosene lamps are insufficient for the purpose of reading (Nieuwenhout, de Rijt et al., 1998), typically producing between 1 to 6 lux (Mills, 2003) (one lux is equal to one lumen per square meter). This light output is well below the recommended lighting requirements for task-specific activities (50 lux (Nieuwenhout, de Rijt et al., 1998)) and reading (200 to 500 lux (Lindsey, 1997; Siemens, 2006)). Although kerosene is higher on the "energy ladder" than charcoal and wood (Bruce, Perez-Padilla et al., 2002), it has been shown to be more expensive per unit of light output than electric-based alternatives (Mills, 2003). In contrast to kerosene, renewable distributed energy micro-generation technologies for lighting have demonstrated positive impacts on health, the environment, and education (Zahnd and Kimber, 2009). However, their widespread sustainable use is often limited because of high cost, unsustainable supply chains, and lack of technically proficient human resources to support their installation and maintenance.

Low-power information technologies are transforming the education landscape in many developing countries. Examples of these technologies include low-cost computers, tablets, and e-readers (*see Chapter 3). These technology of course require power, but by design are battery driven (i.e. as opposed to terminals that require continuous power supply) and have a low power draw (e.g. 2 watts). Some of these information technology devices are also internet enabled, which decreases the "digital divide" between developed and developing countries. Indeed, recently access to the internet was declared to be a basic human right by a United Nations Human Rights Council* (UN, 2011).

2.1.4 Inequalities

In many developing countries, up to 90% of the population can be affected by the lack of access to adequate and sustainable supplies of energy (Barnes and Floor, 1996), with 1.6 billion people without electricity globally (EIA, 2009). Approximately 3 billion of the world's population use traditional fuels for household energy (Reinhardt, 2006), the large majority of whom live in developing countries. There are large inequities associated with the global distribution of energy. UNDP, UNDESA et al. (2000) state that the richest 20% of the world's population uses 55% of primary energy, while the poorest 20% uses only 5 per cent.

Women and children often spend more time than men in the living spaces adversely impacted by traditional energy sources, thus disproportionately carrying the health burden, with over half of the deaths occurring in children. Nearly 800,000 children die each year as a result of indoor air smoke from cooking (WHO, 2006). It is important to note that increasing access to energy services in rural communities in developing countries does not uniformly mitigate the associated effects of lack of access of all socio-demographic groups. Indeed, in some instances increasing access may exacerbate pre-existing gender inequalities by reinforcing them (e.g. men may have preferential access through education to new information technology opportunities). Thus, programmes must be designed to ensure access is equitably increased across a community.

There are inequities in access between the rich-poor and rural-urban populations in developing countries. In general, the poor in developing communities spend more time and effort to obtain energy services that tend to be of lower quality than the energy services available to the rich (UNDP, UNDESA et al., 2000). Unsurprisingly, there is unequal access to energy services in rural populations versus urban populations. For example, the large majority without access to electricity live in rural communities (Barnes and Floor, 1996). In the case of sub-Saharan Africa, less than 10% of rural households have access to electricity (Karhammar, Sanghvi et al., 2006). Further, rural households may spend as much as a third to a half of their monetary income on energy services (Lorenzo, 1997), representing a significant proportion of their revenue.

2.1.5 Environmental

The environmental effects of unsustainable energy use in developing countries are well documented (Goldemberg, Reddy et al., 2000) and include mass deforestation. For example, one of the cited factors contributing to Haiti's deforestation is the illegal harvesting of wood to produce charcoal (Dolisca, McDaniel et al., 2007), which is often made by the poor through the inefficient pyrolysis[1] of wood. This kind of environmental degradation disproportionally and negatively affects the poor, who often directly rely on environmental resources for their livelihood. The effects of unsustainable energy use are local, regional, and global.

Energy use patterns can be linked directly to environmental challenges, such as urban and indoor air pollution, acidification, awnd global warming. Arguably, unsustainable energy consumption is the single largest contributing factor to global detrimental environmental impacts. Venema and Rehman (2007) argue that providing modern energy services through decentralized renewable energy, particularly to the rural poor, can positively redirect the ecological and social factors that contribute to climate change.

2.2 Rapid urbanization

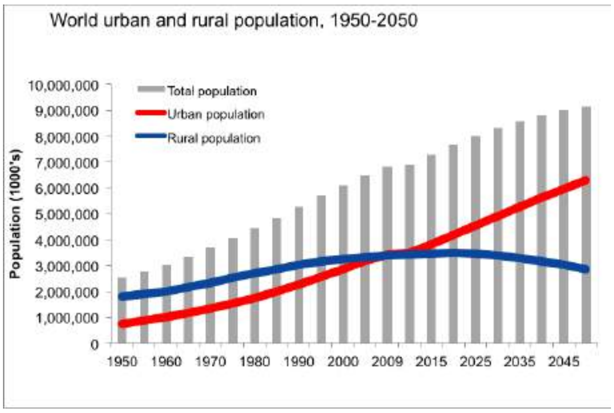


Figure 2.2: World urban and rural population, 1950-2050. Data Source: UNEP, 2009.

Currently, 50% of the world's population live in cities (Population Reference Bureau, 2009), and the world is projected to continue to urbanize to 2050 (Figure 2.2). Further, global population estimates from UNEP project the majority of population growth increases to 2050 to be in developing countries (Figure 2.3). Many developing

1 Combustion in a low oxygen environment to remove moisture and other impurities

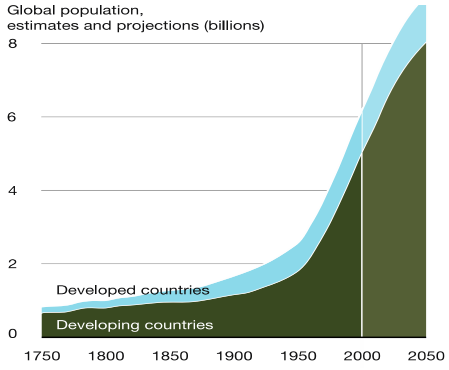
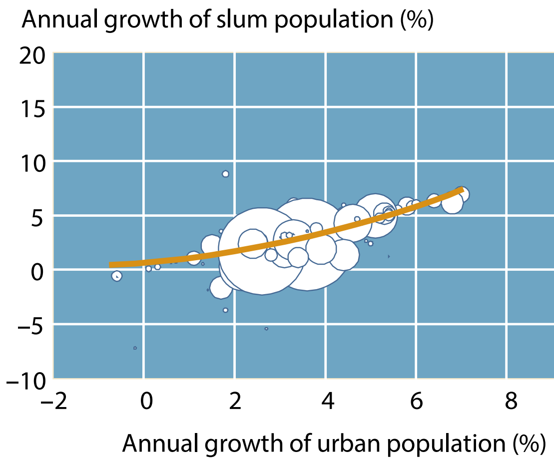


Figure 2.3: Global population estimates and projections (billions).
Source: UNEP, 2009 By designer Hugo Ahlenius, UNEP/GRID-Arendal[2]



Source: Kilroy 2008.

Figure 2.4. Annual growth of slum population in per cent. Source: World Bank (2009)

countries are experiencing rapid urbanization, which causes negative impacts such as strain on often-weak infrastructure and the characteristic growth of slums (Figure 2.4). Nairobi, Kenya, for example, had a population at the time of its independence in 1963 of 350,000, and in 1994, the population was 1.5 million (Figure 2.5). It is estimated to have had a population between 2.8 and 4 million persons by the year 2010 (Rakodi and NetLibrary, 1997). Nairobi infrastructure was not intended to handle such rapid growth, as is the case with other developing countries' rapidly growing cities.

The rural poor in developing countries often move to cities to access modern services, including energy infrastructures. This is a contributing factor to the rapid urbanization that many cities in developing countries are experiencing. Providing energy infrastructure to rural communities can help curb rural-urban migration (UNDP, UNDESA et al., 2000) and more sustainably develop rural areas. This is especially important with the projected increases in global urbanization (Population Reference Bureau, 2009).

Focusing on household energy development in rural communities will curb the rapid rural-urban migration that contributes to the characteristic growth of slums, and increase equity in energy access. It is noted though that many of the technologies and approaches to deployment discussed in this report will also be applicable in the urban slums which are symptomatic of the rapid growth of cities.

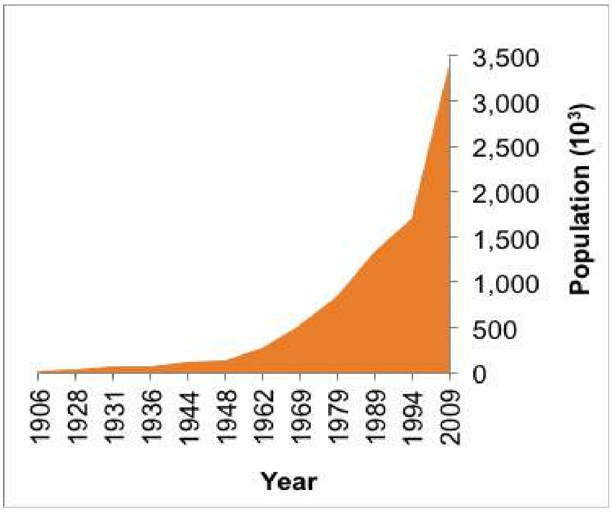


Figure 2.5. Nairobi's population growth, 1906-2009. Data Source: Rakodi and NetLibrary (1997) from 1906-1994, (UNDESA, 2009; Undesa 2009) to 2009.

2 http://www.grida.no/graphicslib/detail/trends-in-population-developed-and-developing-countries-1750-2050-estimates-and-projections_1616

2.3 Using distributed energy for energy provision

Providing access to household energy in rural communities is essential for mitigating the health, environmental, and financial burden for the rural poor. However, centralized provision faces significant challenges. For example, in the case of electric grid extension to rural areas, it is nearly impossible for utilities to be profitable (Henriques and Louis, 2010) due in large part to low rural household energy consumption, insufficient population densities, high construction cost of transmission lines[3], and transmission losses. As these projects require long planning and implementation time-horizons, they are unable to address the present challenges and effects from the use of traditional fuels by rural populations. Further, because of the significant capital costs, investments can be politically motivated or ignore informal settlements. Finally, centralized provision requires lengthy and sometimes complex supply chains, which when broken cause intermittent failure and unreliable service.

In contrast to centralized provision of household energy, distributed energy micro-generation[4] technologies can contribute significantly to providing energy access to the rural poor. These systems can have lower life cycle cost and provide a diversity of technologies to meet specific energy end-use applications in developing communities more appropriately. Additionally, they are less sensitive to corruption and governance instability and are amenable to the relatively low load densities typical of developing rural communities. There is some evidence to suggest that the monthly electricity consumption by households in

Development Need		Typical energy services for off-grid households	Electricity Demand kWh /month, per household
House-hold energy need	Lighting	5 hours / day at 20W for a household	2-6
	Radio/Music	5 hours per day at 5W per household	
	Communication	2 hours per day at 10W per household	
	Potable water	Electric pump providing the community with 5 litres per day per capita	
Medical services		2.5 kWh / day for basic services in a rural clinic for 100 households	0.5-1
Education		2.5 kWh /day for lighting, water pumping, copying, computer, copier, TV, Video, radio etc. in a school for 100 households	0.5-1
Productive (income generating uses)		5 kWh / day for equipment used by workers from 10 households	0-20
TOTAL			3-30

Table 2.1. from G8 (2001), “Typical Energy Service Requirements in the Form of Electricity for Off-Grid Populations in Developing Countries”.

3 these lines can account for 80-90% of the total budget (Lysen, 1994) of grid extension

4 i.e., modular power-generating technologies that have either electrical or thermal applications whose energy production is geographically close to the site where the energy will be used.

rural communities in developing countries rarely exceeds 30-50kWh[5]. In many instances, the daily power requirement is even lower, for example, to power a 1W LED (light emitting diode) for several hours during the evening or to charge mobile phones. This makes distributed energy technology ideally suited to meet this demand. Distributed energy technologies also have shorter time-horizons for planning and implementation.

It is important to note that energy demand varies largely by region, country, and culture. Thus, establishing a baseline for basic energy consumption is challenging. Table 2.1 lists electrical demand for a typical household of five in developing countries except for transportation or cooking demand. It is useful to note that new technologies (e.g. LED bulbs) have significantly decreased the total power demand for some services (e.g. lighting) in recent years, subsequent to the preparation of the data presented in table 2.1.

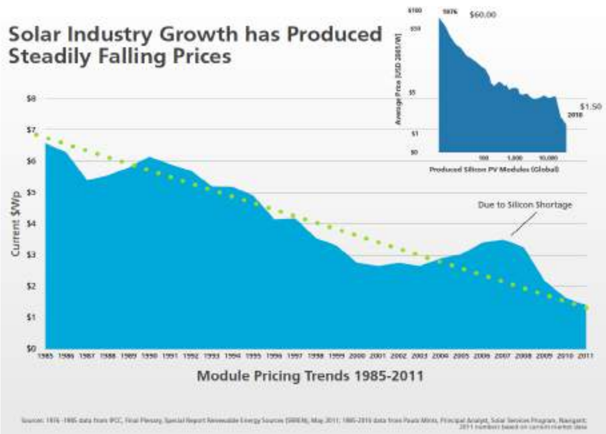


Figure 2.6: Decrease in cost of solar photovoltaics over time (As produced in Climate Progress[6]). Data sources: 1976-1985 data from IPCC, Final Plenary, PSpecial Report Renewable Energy Sources (SRREN), May 2011; 1985-2010 data from Paual Mints, Principle Analysis, Solar Service Program, Navigant; 2011 numbers based on current market data.

A premium should be placed on utilization of renewable[7] energy. These technologies are scalable, require relatively low capital, are environmentally sustainable, and often have less complicated supply chain requirements. The cost of many of these technologies has decreased significantly over the last several decades (see Figure 2.6 for solar photovoltaics). Further, as energy consumption increases with a country's development, using renewable technologies to meet emerging energy needs mitigates demand on the finite resources of fossil fuels. However, widespread sustainable use is often limited by nontechnical challenges, including lack of initial capital investment, unsustainable supply chains, and lack of technically proficient human resources.

Using distributed renewable energy provision is an opportunity to create a low-carbon energy infrastructure in rural communities from the onset of development. Thus, in some ways, rural communities are able to "leapfrog" historical carbon-intensive energy infrastructures. The concept of technological leapfrogging is that communities with underdeveloped infrastructure or technology can progress more rapidly to adopting current technology without first having to proceed through a sub-optimal historical technology. The classic example of this is the progression directly to mobile phone networks without first having to build extensive and expensive landline telephony networks. In this instance, many industrialised countries are faced with the challenge of transition from carbon-intensive energy infrastructure to low-carbon energy. The challenge in these countries (locked-in legacy infrastructure) is not faced in developing countries.

5 Practical Action, Decentralised energy schemes: The options for most rural poor. http://practicalaction.org/decentralised-energy-2. *Accessed 1 March 2012.*

6 Lacey, Stephen. Solar is Ready Now: 'Ferocious Cost Reductions' Make Solar PV Competitive. June 9, 2011. Climate Progress, edited by Joe Romm. Accessed 10 March 2011. http://thinkprogress.org/romm/2011/06/09/241120/solar-is-ready-now-"ferocious-cost-reductions-make-solar-pv-competitive/

7 e.g., photovoltaic cell, wind turbines, biogas, and producer gas

Chapter 3: Survey of Technologies, Research Institutions, Financing Mechanisms and Models for Technology Transfer

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First, this chapter provides a description of some of the technical characteristics of a representative list of distributed renewable energy for use in developing communities. It then reviews some of the research institutions that are working on aspects of these technologies. Finally, the chapter concludes with a discussion of some of the mechanisms available for technology transfer. This chapter draws upon the author's work in Henriques (2011).

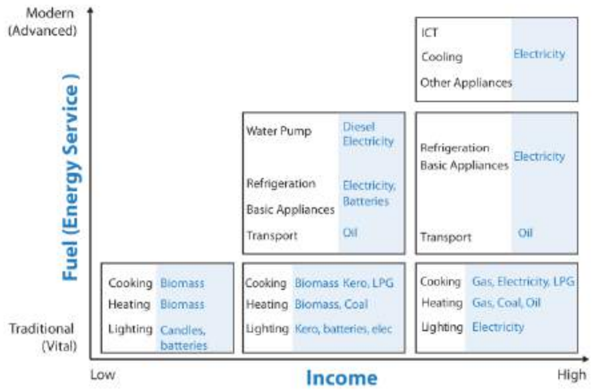


Figure 3.1: Example of Household Fuel Transition and Energy Ladder. Data Source: IEA (2002).

3.1 Survey of Technologies

There are a number of technologies that can be employed in providing village level energy in developing countries. The categories of energy generating technologies considered in this scoping study include:

1. Solar electric (e.g. photovoltaic)
2. Solar thermal
3. Biofuels
4. Micro-hydro electric
5. Micro-wind electric

These technologies are higher on the energy ladder than traditional energy sources. The concept of the energy ladder is that as per capita income increases there is a transition towards cleaner burning, "commercial" energy sources as illustrated in Figure 3.1.

Each technology's description includes an analysis of its potential to provide village level energy, and discussion of the potential barriers to technological transfer, relative capital costs, research and development needs, and where applicable provides information on manufacturing, installation and maintenance requirements. In recent years there has been a number of synergies between developments in technologies for producing electricity and low-power application technologies. For example, the proliferation of low-cost white LEDs over the last decade enables the use of low-power photovoltaic panels for lighting that otherwise would have been insufficient to power lighting based on incandescent technologies. Technologies that produce useful energy are listed first, followed by energy using technologies.

3.1.1 Energy production technologies

The first class of technologies discussed are those whose main function is the production or generation of energy. These technologies may be broadly differentiated between those that generate electricity for lighting, motive power, and for mobile phones, laptops etc., and those whose main product is useful heat, generally for cooking but sometimes for space heating such as the efficient direct combustion of organic

material and concentration of solar thermal energy. Some technologies such as the production of a combustible biogas may be used for both.

In the case of electricity generating technologies, it is possible to develop micro-grids to deliver electricity to a group of houses, a village or a group of co-located villages. These grids distribute electricity across a small network to meet local needs, typically below 11 kV, and with components including generation, storage, and distribution technologies (Ulsrud, Winther et al., 2011). There are a number of social, technical, and institutional challenges associated with the successful creation, operation, and maintenance of micro-grids (Ulsrud, Winther et al., 2011).

As with energy demand, project costs of energy technologies for rural applications vary significantly by community, region, and country, and relative costs continue to shift rapidly as the deployment of some technologies expands rapidly (e.g. photovoltaics), and others make less rapid progress (e.g. wave energy). In rural communities where loads are low, cost comparisons between technologies can be misleading due to the scale of the technology required to meet demand. Nonetheless, some indicative figures for candidate energy technologies are presented in Annex 3.

The following paragraphs briefly summarise key characteristics of the various technologies that may be considered for the provision of more sustainable energy in villages.

Photovoltaics

Photovoltaic (PV) cells, often referred to as solar panels, convert solar radiation to direct current (DC) electricity. They do this by using energy from a photon to move electrons between valence and conduction bands in the substrate material (often silicon-based). Substantial R&D efforts are being devoted worldwide to make PV cells cheaper, more reliable and more efficient. Local knowledge is needed to sustainably utilise the technology relating to PV cells' ability to effectively capture the insolation and requirements for appropriate sizing of PV systems. Insolation is the sun's radiative energy striking a surface, "defined as the instantaneous, hourly, or annual solar radiation on a surface, W/m2" (Kreith and West, 1997).

Power: .5 watts to several kilowatts. Application: Electricity

Biogas

Biogas technology (anaerobic digestion) produces methane gas that can be combusted to produce useful heat, typically for cooking, or generate electricity. While there are many types of biogas digesters, this section focuses on a fixed-dome batch digester. Biogas technology captures the methane product of the anaerobic (i.e. process that occurs in the absence of oxygen) digestion (i.e. a series of processes that includes the chemical breakdown and fermentation of feedstock facilitated by bacteria) of an organic feedstock (i.e. material used to supply or fuel a process). The products of the digestion are a mixture of methane (60-70 per cent by volume), carbon dioxide (30-40 per cent by volume), and trace impurities (carbon monoxide, hydrogen, hydrogen sulphide, and nitrogen) (Buren, 1979).

The feedstock used for biogas digesters is often a combination of manure and starchy plants, such as potatoes, mixed into slurry with water and fed into the inlet of the air and watertight chamber. As the anaerobic bacteria break down the organic matter, the gas rises to the top of the chamber where it exits by the gas outlet. Shifts in density and incoming slurry allow the processed slurry to flow naturally out of the outlet. This effluent acts as a good agricultural fertilizer which is relatively pathogen free, and has been shown to increase crop yield (Buren, 1979).

To use the methane for cooking it is generally directly combusted. Methane is cleaner burning than traditional fuel because it produces less particulates (e.g., soot) during combustion. It is also considered to be a higher fuel on the energy ladder.

Application: Direct combustion (e.g. cooking); Electricity generation (e.g. with generator)

Micro-wind (electric turbine)

Wind turbines utilise the forces from wind to drive a mechanical rotor, which is generally connected to a generator and batteries. Wind turbines are of course sensitive to the variability of wind resources. Thus, one of the challenges of using wind as a source of energy is properly siting the turbines, a non-trivial task that requires expertise. Another challenge for village level wind turbines is cost. In the developing country context, wind power may not benefit from the system of subsidies (through policy) that help wind to be competitive in many industrialised countries.

Power: 200 watts to 50 kilowatts. Application: Electricity

Micro-hydro

Also known as pico-hydro, micro-hydro generally utilises local streams to generate electricity by mechanically driving a generator. As with other energy technologies, micro-hydro requires the consideration of technical and socio-political consideration (Sovacool, Bambawale et al., 2011). As they require regular operational and maintenance support, developing supporting institutional arrangements is important. As the hydrological resource that this technology often relies upon is a common-pool resource, it is important to have a high degree of community involvement for successful micro-hydro projects.

Power: 100 watts to 1MW. Application: Electricity

Biochar Pellets

Biochar, wood pellets, or similar fuels are produced through the pyrolysis and compression of an organic feedstock. Pyrolysis is the process of removing water content in a low-oxygen environment. Feedstock for producing biochar or pellets can include wood (or woody plants), corn husk, and sugar cane. It is attractive in part because of the ability to use "waste" products from one process as a feedstock for the production of biochar or pellets.

In their natural state, biomass fuels can be difficult to transport because of their size or weight, and generally have high water content. Due to these factors, they are often inefficient and unpredictable during combustion. Thus, the removal of water content through pyrolysis, and compression of the biomass feedstock assists in a more reliably burning fuel that is easier to transport, and can be combusted within fuel efficient stoves.

The sustainable production and use of biochar or wood pellets depends upon careful management of environmental and institutional factors. The use of wood based fuels can also contribute to environmental degradation (e.g. deforestation) if the feedstock is not properly managed.

Application: Combustion

Concentrated solar thermal

Parabolic solar cookers use the energy from the sun to dry, cure, heat, bake or otherwise prepare food for eating. The technology can also be used to pasteurize water or to generate steam, for example for sterilisation in hospitals. The technology facilitates the safe preparation of food with minimal labour input. In less developed areas that depend on wood as a fuel source for cooking, large amounts of time and energy must be devoted to gathering wood and preparing/

maintaining a cooking fire. Food preparation via a solar cooker eliminates this burden.

"Parabolic solar cookers are curved concentrator cookers that cook at high temperatures, but require frequent adjustment and supervision for safe operation. Of solar cookers, they provide the best performance of all the types." Safety considerations include damage to eyesight if insufficient precautions are taken. Of the classes of solar cookers, they are more complex to manufacture due to the panels or curved reflective material used.

Application: Cooking, sterilsation

Concentrating solar power

In concentrating solar power (also called 'solar thermal electricity') a high-temperature heat source is created by concentrating the sun's rays to produce electricity in a thermodynamic cycle. Of the four CSP technology families, three (parabolic troughs, tower and linear Fresnel) are being developed for applications at a scale of 10's and 100's of MW, and are therefore too big for the village-level developments being addressed by this study. The fourth, comprising a parabolic mirror which concentrates the sun's rays to a central point to drive a Stirling engine, is being developed at a unit size of around 10-50 kW which could be suitable for village applications.

However, the technology is more expensive than PV and comprises sophisticated technology, particularly in the form of the Stirling engine (requiring high levels of technical capacity for installation and maintenance). In view of these considerations, and in the absence of thermal storage systems, which provide an advantage for other families of CSP technologies over PV but are not yet available for parabolic dish technologies, this technology is unlikely to be preferred over a PV installation.

Application: Electricity

Biolite Homestove™

BioLite stoves are efficient cook stoves that burn wood to use the thermal energy for cooking whilst also generating electricity for small electrical applications (e.g. mobile phone charging, lights, etc.). The thermal efficiency gains in combustion come both from insulation as well as a small fan that improves combustion via increase air flow. The fan is driven by redirecting some of the thermal heat from combustion to drive a thermoelectric module. Excess electricity can then be used for small electronic devices. Biolite HomestoveTM is specifically designed for use in developing countries, with marketed smoke emission reductions up to 95% while simultaneously providing phone charging and light via LED bulbs.

Application: Cooking, Mobile charging

Producer gas

Producer gas refers to a category of technologies that converts organic material (e.g. plant material) to a combustible gas through gasification. The gasification process produces hydrogen, carbon monoxide, and other gasses, and this mixture combusts similarly to natural gas. The produced gases can either be used for heat for cooking or industrial processes, or as fuel for an electric generator. This category includes technologies such as that used in *Husk Power* technologies (see Chapter 4).

Application: Electricity, Cooking, Industrial process heat

Microbial fuel cell

A relatively new application currently being developed and piloted by Lebone Solutions. This technology produces very low power (e.g. for charging mobile phones or powering low-power LED lights) through the metabolism of organic waste. The basic construct is a pot filled with soil, with a metallic anode placed at a certain depth in the soil, and the cathode resting on the top of the soil that is exposed to oxygen.

Application: Electricity for lighting, mobile phone charging

Microgrids

Microgrids are simply a local grouping of electricity generators, (often coupled with energy storage), and users linked by power lines at the village level. Microgrids can be created through a combination of many of the aforementioned energy generating technologies. As will be seen in several of the case studies, there are business models that use microgrids as a way of selling "subscriptions" to electricity access in rural developing communities.

3.1.2 Key energy using technologies

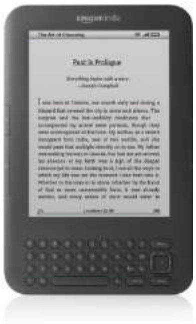
This sub-section describes key emerging technologies that use electricity to deliver services (e.g. light, communication and information).

Light emitting diodes

One of the common renewable distributed energy technologies for meeting lighting needs is the combination of light emitting diodes (LEDs) with a photovoltaic cell battery recharge system (Nieuwenhout et al., 2001). Examples include Barua (2001) in Grameen Shakti in Bangladesh and Mala et al. (2008) in Kiribati. Photovoltaic cells are ideally suited to meet this demand because of the generally low power requirement for lighting.

Application: Lighting. Power demand: ~.5 watts

E-readers



E-readers (e.g. Amazon's Kindle) can enable access to large libraries of books for schoolchildren. There are several organisations that facilitate the donation and distribution of these devices, including Worldreader (http://www.worldreader.org/). This organisation's mission is to provide access to digital books through e-book technologies. They generally operate through donations.

Application: Reading. Power draw: ~5 watts

Aakash tablet computer

The Aakash tablet is an approximately €26 (US $35[8]), Android-based, 7-inch, touch screen tablet computer created by the British company DataWind (http://datawind.com/). It is manufactured at an Indian-based company Quad Electronics. It is an internet-connected device aimed at increasing internet penetration in the India to the estimated one billion without access (there are only an estimated 18 million internet subscribers and 120 million internet users) (Timmons, 2010). The tablet will be sold by the Government of India, who provides a subsidy enabling a selling price of around €26 compared to a production cost of €37 (Raina and Timmons, 2011). It has been met by significant demand, with an updated model due in April of 2012. However, there has been significant criticism including the very slow speed (e.g. slower than cheap mobile phones) , poor battery life (80 to 150 minutes), poor construction, and no

8 *Press Information Bureau, Minstry of Human Resource Development, Government of India. Low Cost access –Cum-Computing Device Unveiled by Shri Kapil Sibal, 22-July 2010* http://pib.nic.in/newsite/erelease.aspx?relid=63417 *. Accessed 3-February 2012.*

access to the Android market which sells apps and media making it difficult to upgrade software and services (Bhattacharya, DEVI et al., 2012).

Application: Education, Internet. Power draw: 2 watts

Raspberry Pi Computer

The Raspberry Pi computer (developed by the Raspberry Pi Foundation, http://www.raspberrypi.org/) is "ultra" low cost (~€26.25) and lower power, only consuming 2 watts of power. It was designed as an educational tool for teaching children about programming. While it does have some application in the developing country context, there are some drawbacks. For example, it requires access to an external display, which typically requires not insignificant amounts of energy to power. Another drawback for the developing country context is the lack of integration with wireless technology for internet access.

One laptop per child

One Laptop per Child (OLPC) is a project that provides a rugged, relatively low cost, and wirelessly connected laptop for children. It is supported by two U.S. non-profit organisations, one based in Miami called 'One Laptop per Child Association' (OLPCA) and another based in Cambridge called the 'OLPC Foundation' (OLPCF). These organisations together direct the development and creation of the devices. The laptop costs approximately €156.75 (US $209).

Mobile vaccine refrigeration

Limited access to energy services in rural communities impacts the availability of health care services. For examples, immunization programmes often require consistent refrigeration (Jimenez, Olson et al., 1998). Many of the generating technologies discussed above can be used to expand national immunization programmes to remote areas (Jimenez, Olson et al., 1998), and have the potential for supporting other health services in rural communities. While current refrigeration technologies are generally expensive, there is some evidence that costs will decrease. Generally, the vaccine refrigeration systems are efficient refrigerators combined with a distributed electricity generating technology (e.g. photovoltaic panels) combined with energy storage (e.g. battery array).

3.2 Research and related institutions

This section reviews a sample of some of the institutions that are currently working on aspects of distributed renewable energy for application in rural communities in developing countries.

The **Renewable and Appropriate Energy Laboratory** (RAEL) (http://rael.berkeley.edu/about) is based in the University of California, Berkeley in the Energy and Resources Group and the Department of Nuclear Engineering. Its focus in on new research, development, project implementation, and community outreach related to renewable energy. They have completed design and testing of rural energy technologies, including efficient cookstoves. They work with Lawrence Berkeley National Laboratory, which leads projects on the development of improved cookstove technology on efficiency, emissions, stove use, combustion optimisation, and stove modelling (http://cookstoves.lbl.gov/).

At Columbia University's Earth Institute, Dr. Vijay Modi created the **Modi Research Group (**http://modi.mech.columbia.edu/) that has a broad range of research activities including those focused on rural energy access. This group plays a lead role in the Millennium Villages project (http://www.millenniumvillages.org/).

Engineering for Change (E4C) is a network of international engineers, scientists, nongovernmental organizations, local community advocates and innovators working to solve global challenges, including rural energy access and technology development (https://www.engineeringforchange.org/). It is an online platform founded by the American Society of Mechanical Engineers, the Institute of Electrical and Electronics Engineers, and Engineers Without Borders USA. There is potential to use this existing network as a platform for other rural energy networks.

The **International Science Programme** (ISP) at Uppsala University focuses on funding and supporting research activities in developing countries in order to build sustainable capability in the chemical, physical and mathematical sciences. One of the networks supported by the ISP is concerned with developing solar energy in developing countries.

The **Low Carbon Energy for Development Network** (LCEDN) is a network of researchers, policy-makers and practitioners in the UK who focus on increasing research capacity in low-carbon development in developing countries. This network includes experts in international development, science and technology, and renewable energy transitions. LCEDN focuses on interdisciplinary research, collaborating with research universities in the UK and with UK government institutions. Their research includes the discussion, and the generation, of ideas for funding.

The **HEDON Household Energy Network** (http://www.hedon.info) is a large knowledge-sharing network for practitioners that work on household energy solutions for developing countries. According to the German Agency for International Cooperation (GIZ), it is one of the oldest and most active grassroots networks that with household energy and improved cookstoves.

Founded in 1996, **Appropriate Rural Technology Institute** (ARTI) (http://www.arti-india.org) is a group of scientists, technologists and social workers that develop sustainable technologies for rural communities. They have worked on improving a number of rural energy technologies, most notably the ARTI Biogas Plant. Other projects have included improved cook stoves and sugarcane based charcoal briquettes. They are based in Maharashtra in India.

3.3 Models for Knowledge & Technology Transfer

This subsection reviews some of the models that are used for the transfer of knowledge and technology to rural communities in developing countries. This includes a review of some of the business models employed in some of the case studies. These kinds of models are desirable as they are often the mechanisms that enable scaling up of technologies.

3.3.1 Social Businesses

Socially focused small business development is a valuable tool for ensuring sustainable supply chains. Businesses are self-motivated to ensure that parts are available and can stimulate local economies.

Yunus (2009) describes the concept of a "social-business" as businesses which have a social cause or good as their single maximizing objective. Yunus proposed the theory that businesses have one of two mutually exclusive objectives: predefined social good and profit maximization. For Yunus, social-businesses have the properties of (1) a predefined social good, and are (2) financially viable, self-sustaining, and do not pay dividends. There are several benefits associated with social-businesses for providing a service such as household energy. These benefits include the natural integration of built in feedback loops that self-regulate quality, and encouragement of innovation in service provision.

A social-business with the defined social good of providing household energy technology for rural communities in developing countries can naturally develop programmatic support to integrate the technology sustainably. Specifically, such a business would naturally be self-motivated to ensure access to adequate supply of spare parts for repairs (e.g., develop sustainable supply chains), provide financing through micro-credit, and develop a skilled workforce.

Another example is Prahalad's "new capitalism", that uses business as a tool for providing services and products for bottom of the pyramid markets (Prahalad, 2005). Both new capitalism and social-business are attempts to design business to be both producers of product and people.

3.3.2 Community Credit Systems

Generally, credit is unavailable or inaccessible (e.g., prohibitively high interest rates) to households in developing communities. In a community with low financial capacity, financial credit tools can assist in developing financial capacity. This has the additional benefit of developing local institutional capacity, as it naturally facilitates the formation and organization of entities that assist in administration and regulation of other community activities.

Micro finance is a financial instrument that can be used to provide small-product based loans at reasonable interest rates to low-income households. A United Nations Department of Economic and Social Affairs (UNDESA) (UNDESA, 2009) report cites micro finance (e.g., micro-credit) as one promising source of local private investments in green infrastructure. UNDESA states that there were an estimated 7,000 micro-credit institutions in 2006, serving approximately 80 million people across 65 countries some of which were developing countries. The report goes on to cite Hammill, Matthew et al. (2008) who argue for micro finance as a source of finance for climate adaptation, and Rippey (2009) who sees opportunity for micro finance to support cleaner cooking products and bio-fuels for developing countries.

Micro finance is a self-replicating tool when used to facilitate household energy technology. Initial investments in the micro financing entity self-replicate through interest and repayments. It builds local credit systems in developing communities, with the potential for these entities to evolve into community banking systems that enable people to borrow for income generating activities (e.g., purchasing a dairy cow or sewing machine).

3.3.3 Opportunities to change international aid policy

Because bilateral and multilateral institutions play an important role in financing public utilities in developing countries, they should be considered and incorporated in the evaluation of policies. This is especially true with regard to the development of a renewable energy infrastructure in rural communities. Thus, an internal or external policy developed for aid organizations can have direct public policy aspects. One policy would be to set a minimum per cent requirement for investments in renewable household energy in rural communities in the aid portfolios of multilateral institutions. This policy would facilitate the increased use of renewable energy technology and rural energy development. Funding opportunities and schemes are outlined in Annex 4.

3.4 Risks to intervention failure

The Renewable Energy and Energy Efficiency Partnership (REEEP) and United Nations Industrial Development Organization[9] (UNIDO) published a training manual[10] which cites common barriers and limitations to widespread use of renewable energy, including (New and Matteini, 2007):

1. Technical issues
    a. Design and installation skills

9 Energy and Cleaner Production Branch
10 Sustainable Energy Regulation and Policymaking for Africa: http://africa-toolkit.reeep.org/

   b. Quality control and warranties
   c. Maintenance and after-sales service
   d. Training
   e. Local technical infrastructure development

2. Non-technical issues
   a. Awareness
   b. Policy/regulatory issues
   c. Institutional capacity-building for micro finance
   d. Community involvement
   e. Participation of women

In Energy for Rural Livelihoods: A framework for Sustainable Decision Making, Mulugetta et al. (2005) argue that evaluation of energy services should be against criteria including:

1. Social
2. Environmental
3. Technical (e.g., technical and service)
4. Economic and Financial
5. Institutional

3.4.1 Supply chains considerations

Developing communities generally do not have access to sufficient or regular supply chains. Technologies that require consistent operations, maintenance, or spare parts may depend on these supply chains. Thus, unsurprisingly, the lack of sustainable supply chains is an often cited reason for the failure of household energy technology in developing countries. The necessity to establish sustainable supply chains for household energy projects in developing communities is well established in the literature. Adkins, Eapen et al. (2010) describe the importance of establishing sustainable supply chains for LED lighting projects that occur in tandem with market demand for LED lighting projects. In Chapter 4 of the World Energy Assessment (UNDP, UNDESA et al., 2000), Khatib discusses how disruptions in energy supply can be caused by disruptions in long supply chains. Allderdice, Rogers et al. (2000) describe how small photovoltaic retailers in developing countries can act as the crucial link in product supply chains for rural household energy markets.

3.4.2 Economic and financial considerations

In general, the most salient factors that drive the selection of energy alternatives are economic and financial factors and criteria. Unlike other basic needs infrastructure, there is generally regular and significant recurring costs associated with access to household energy. Generally, rural communities are most constrained by access to capital or credit systems. As there is a mutually dependent relationship between access to energy and economic development (Barnes and Floor, 1996), rural communities may be unable to break cycles of deficiency in access.

3.4.3 Human resource considerations

According to the CRC Handbook of Industrial and Systems Engineering (Badiru, 2006), human resources are an essential component of any successful project and are distinct from other resources in their ability to learn, adapt, and set goals. Goldemberg, Johansson et al. (1995) state that one of the barriers to promoting dispersed energy sources in developing countries is the lack of human and organizational capacity. WEC and UN FAO (1999) state that one of the barriers to technologies for improved energy use in rural developing communities is an inadequate human resource base. McMaster and AusAid (1998) state that key lessons from the Australian Agency for International Development's (AusAid) work from 1992-1997 reveal the importance of human resource development through education and training, and the importance of retention of skilled local labour.

3.4.4 Institutional considerations

The necessity of institutional capacity for sustainable household energy projects is well documented in the literature. WEC and UN FAO (1999) state that institutional failures directly contribute to failures in rural access to energy services. According to WEC and UN FAO, successful rural access will require either public institutional capacity or alternative institutional structures (e.g., local co-operative) to support the private sector. Venema, Calamai et al. (2000) state that one of the major hurdles in implementing rural energy services on a large scale is the lack of institutional reform. Byrne, Shen et al. (1998) state that in order to take advantage of sustainable energy for rural development, policies and institutional strategies must be developed, including energy planning at different levels (i.e., central and local). Jimenez, Olson et al. (1998) claim that the barrier to renewable technology is not the technology itself, but rather the institutional aspects, and how technologies are integrated institutionally. Allderdice, Rogers et al. (2000) state that it is the institutional and financing issues that are the greatest barriers to widespread use.

Self-governance is an important community capability, because a single technology unit may rely on communal resources, especially if there are multiple technologies in a single community. It is also important, because many of the implementation programmes and policies rely on the ability of the community to self-organize and self-govern aspects of the technology. With respect to assessing the management capability of household energy, a key facet is the ability for communities to form collective self-governing entities.

3.4.5 Environmental and natural resource considerations

In general, poor communities most directly experience the impacts associated with environmental degradation. This is because these communities often rely on natural resources for their livelihood, and have no buffers or barriers to natural disasters. Many distributed household energy technologies rely on the availability of natural resources. Thus, the availability of environmental and natural resources in the community, and those required for successfully managing a technology, are important considerations.

3.4.6 Socio-cultural considerations

Goldemberg, Johansson et al. (1995) argue that the poor, in general, and poor women and girls, in particular, are often trapped in cycles of poverty and demands that lead to poor health, lack of education, and unequal participation in self-governing bodies and social or political programmes. This leads to an underdeveloped human resource base for a country. Goldemberg et al. argue that any projects or interventions that attempt to address inequalities in gender, caste, or class should be focused on improved energy services. WEC and UN FAO (1999) state that rural electrification programmes often do not account for their socio-cultural, political, and institutional contexts, which interact with economic factors to influence individuals decisions. WEC and UN FAO further argue that failing to account for such interactions leads to inequalities unaddressed in policies and programmes. Nieuwenhout, Dijk et al. (2001) state that supporting human resource development for small and medium scale enterprises helps establish solar photovoltaic distribution and servicing.

Some developing communities have entrenched inequalities between groups of individuals because of sex, age, or membership in a particular social group. The existence of such inequalities will not only likely impact the success of projects, but also impact the ability to increase service access. Similarly, a community whose members are highly involved in the community are essential for project success, in particular for household energy projects.

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CHAPTER 4: CASE STUDIES FROM INDIA

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This chapter on India starts with an overview of India's energy landscape and the policy initiatives which have a bearing on village energy provision. Individual sections for biomass, solar photovoltaic, hydro power and wind power then present the case studies followed by a cross-cutting case study, making thirteen in all. A final section draws together conclusions and recommendations from the case studies.

4.1 Introduction: Overview of India's energy landscape

Energy is a crucial input to drive economic and human growth in India, if an economic growth rate of 9-10%, achieved in recent years, is to be sustained. Basic needs are delivered to people through energy services such as water pumping, cooking food, and lighting for education (Bhide and Monroy, 2011). In order to fulfil the Millennium Development Goals set for 2015, to reduce by half the proportion of people living on less than US$1 (€0.75) a day, India needs to provide accessible, affordable, reliable, and environmentally oriented energy services (UNDP, 2010). Decentralised energy facilitates infrastructure development in the agriculture, industry, household and commercial sectors, both in rural and urban areas.(Hiremath et al 2009).

Providing universal electrification to a population of 1.2 billion (estimated to double by 2030), 22% of which are poor and 70% of the poor are from rural areas, is a herculean task. Currently, an estimated 580 million Indians live with little, or completely lack access to, electricity(Bhide and Monroy, 2011). Equitable supply of electricity remains an important challenge. Around 40% of India's population lack electricity services to support their livelihood activities: addressing this shortfall is a critical factor in the future development of India (Winrock International India, 2011b).

Currently, the electricity supplied across India is deficient in "quantity and quality", with high levels of losses in transmission and distribution (T&D) and sub-standard infrastructure (Government of India, 2008). The electricity which reaches through the centralized grid to rural areas fluctuates in voltage and is available only irregularly.

According to a study by the International Energy Agency (IEA, 2009), India overall stands at 64.5% electrified: 93.1% of urban India is electrified, while rural electrification stands at only 52.5%. According to MNRE (2009), Indian states face electricity shortages ranging from 3% to 21%. At a national level, the average shortage is about 10.3% and the shortfall on peak demand is 15.4%. By way of example, in a study done by the World Bank (2010), customers in Kolhapur district of Maharashtra were found to receive only 8-10 hours of electricity on average during the day.

Kerosene is often used as a substitute, and traditional biomass fuels such as dung and firewood account for a large portion of energy consumption. Kerosene continues to be a major source of lighting, and to generate power for irrigation and to meet the needs of small enterprises (Krishnaswamy, 2010 MNRE, 2011). In contrast, urban households generally have efficient energy sources such as electricity and Liquid Natural Gas (LNG) (Buragohain et al, 2010).

Post-Independence (achieved in 1950), rural energy provision in India was characterized by a "strong public sector presence" (Modi, 2005). In the 1970s, energy in India underwent a process of nationalization. Energy, like agriculture, has continued to be a central policy priority and India's power system is planned centrally. A large centralized power sector has the advantage of economies of scale and serves the needs of industrial and urban sectors of the economy. For example, wind power, a distributed power form of renewable energy, is developed on the basis that it is connected to the grid, adhering to the centralized energy planning policy of India (Sharma, 2007; Kuldeep, 2009).

Similarly, the provision of electricity to rural and remote areas is by and large synonymous with access to electricity through grid extension of the centralized power system (Kuldeep, 2009; Sampath et al., 1985). State governments, under the central government, are responsible for providing electricity, under the Concurrent State List[11]. State bodies have autonomous structures and organizational patterns to implement energy policy. A range of public corporations, development agencies and commercial entities are concerned with energy and renewable energy (Harriss-White et al., 2009).

State run electricity boards do not deal with remote off-grid technology projects (Harriss-White et al., 2009). And commercial utilities in fear of their long-term financial health, consider extending electricity to rural areas as an unviable option for the following reasons (Niez, 2010):

- the rural distribution system is low density, leading to high delivery costs;
- fixed costs are high and variable; and
- commercial arrangements are unsustainable.

Therefore, the stimulus for rural electrification has been the support over the years from several Government of India (GOI) run rural electricity access programmes (see later overview of rural electricity for details of programmes). Subsidies and cross- subsidies were granted for two purposes: electrification of villages, and to power irrigation pumps. However, most electricity reforms catered to maximizing crop yields.

11 Concurrent State List: (http://lawmin.nic.in/coi/contents.htm)

To fulfil its 'political goal' and speed up large-scale renewable energy efforts, a 'Power for all by 2012' objective was declared in 2001, under the REST (Rural Electricity Supply Technology) Mission. As part of this Mission, "The Village Electrification Program of the Ministry", was commenced in 2001, and since then, 2197 un-electrified villages and 594 hamlets (listed according to the 2001 census) have been provided with basic lighting under the 10th Plan mission to provide electricity to 5000 remote villages (Planning Commission, 2006).

In continuation, the Electricity Act 2003 (EA03) uniquely devised rural electrification in the form of a law to achieve "100% universal household electrification and infrastructure by 2012", chiefly via the medium of grid extensions and stand-alone systems for remote areas (including renewable and non-conventional systems), with consultation of state governments. The EA03 introduced a new entity in the system, working within the three tier Panchayati Raj System, to take on a new role to distribute electricity to rural areas (Ministry of Power, 2005). Further, the EA03 freed "stand-alone generation and distribution networks from licensing requirements" (Ministry of Power, 2006). The formulation of the subsequent National Policy on Rural Electrification, developed in consultation with state governments and commissions, was mandated to strengthen infrastructure, local distribution and bulk purchase of power and management via users' associations, Panchayat Institutions, Non-Governmental organizations (NGOs), co-operative societies, or franchisees (Ministry of Power, 2005).

The National Policy on Rural Electrification in 2005 launched the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) to electrify all un-electrified villages/hamlets and to provide household electricity connections by 2012 (Ministry of Power, 2005). Off-grid energy in the RGGVY has been addressed through the Decentralised Distributed Generation (DDG) projects for villages lacking grid connectivity (where grid connection is not cost effective or not feasible) based on renewable or conventional sources. It was planned that unconventional and conventional forms off-grid electricity generation would facilitate decentralised distributed generation along with local distribution networks. The alternative would be to install isolated lighting technologies, like solar photovoltaic, instead of standalone systems, or grid connectivity wherever possible., Apart from rural household lighting, electricity access for schools, Panchayat Bhawan's, street lights, and community buildings were also envisaged in the scheme. The State Renewable Energy Development Agencies/departments, State utilities or Central public undertakings could be responsible for implementing such projects (MNRE, 2012).

Un-electrified villages and hamlets (below 100 habitants) are covered under the flagship Remote Village Electrification Programme of the Ministry of New and Renewable Energy. The Programme endeavoured to provide electricity to all un-electrified remote census villages by 2007, and all households in remote census villages and hamlets by 2012.

Despite the policy initiatives mentioned above, a few States lag behind in access to rural electricity, in particular, Assam, Bihar, Jharkhand, Orissa, Rajasthan, Uttar Pradesh and North-East India. Krishnaswamy et al (2010) argue that poor governance is the main reason for slow implementation. Structural differences between regions are another reason for the disparity in rural electricity development (Palit and Sarangi, 2011). According to (Palit and Chaurey, 2011), renewable energy based national programmes create financial burdens on the States. Similarly, the implementation of RGGVY has also been delayed at a State level (Niez, 2010) (see later 'rural electricity policy overview' for further detail).

To the Government of India's credit, the installed grid power capacity has increased from 1.7 GW in 1950 to 187 GW in 2011 (CEA, 2011). Currently, India depends primarily on coal and oil to meet its energy demand. The primary sources of fossil energy in India include: 52.3% coal, 10.9% gas, 0.8% oil. 2.6% is from nuclear, 23.8% from hydropower, and 9.8 % from renewable energy resources as indicated in Figure 4.1 (Purohit and Purohit, 2010, see http://www.power-min.nic.in).

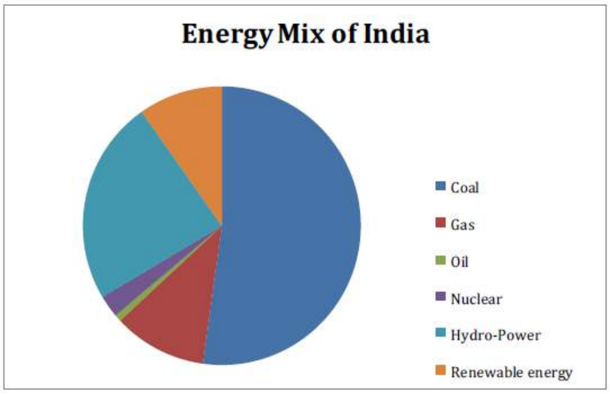

Figure 4.1: Energy mix of India in 2010 (Source: Purohit and Purohit, 2010).

However, India's current energy mix is a matter of concern. Coal is polluting and one of the biggest emitters of greenhouse gases. Also, India is heavily dependent on the import of oil, accounting for 72% of its total oil consumption in 2004-2005, and a bill of €29 billion (US$39 billion) in 2006. This is an economic burden and brings the risk of future energy insecurity. Consequently, there is a need to reduce dependence on coal and oil. Even though India's per capita consumption of energy is low in comparison to the USA, China and Japan, energy consumption is on the rise (Bhattacharya and Srivastava, 2009).

Figure 4.2 compares the annual per capita electricity consumption (in kWh) of India with other major economies in 2007, and projected for 2030 (IEA, 2009).

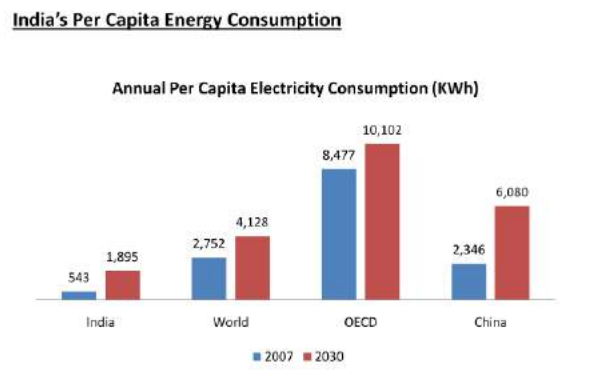

Figure 4.2: Comparison of per capita energy consumption in India and other regions (Source: IEA, 2009)

To address issues facing the power sector in India, the Government of India has set up several initiatives to develop an alternative energy path.

The Electricity Act 2003 paved the way for rapid development and reformation of the power sector. Renewable energy portfolios were given significant importance in consecutive policies (Singh et al., 2009). The Integrated Energy Policy envisages adding 800 GW of power generating capacity by 2030 (Purohit and Purohit, 2010). The provision of subsidies to provide a boost to the renewables sector was considered to be justified. As of August 2012 the grid interactive renewable power generation capacity (excluding hydropower) was 24 GW, contributing around 12% of the national electricity installed capacity of 207 GW (CEA, 2012; MNRE, 2012).

Grid connected renewables have the capacity to generate electricity at the periphery of the grid where the supply of electricity is otherwise unreliable, and to generate employment and livelihood options for the poor. It recognizes that a local renewable energy resource is "environmentally benign" and can supply electricity earlier than the centralized system. Further, solar power has been considered an important player for the future energy security of India. The National Action plan on climate change with its eight missions was launched in 2008. Two out of the eight missions - the 'National Solar Mission' and the 'Enhanced Energy Efficiency' mission - address key development and energy security requirements through several innovative schemes. They aim to attract private investors to invest in renewable energy projects (Government of India, 2008).

The National Solar Mission, designed to enhance the ecological and energy security of the nation, provides for implementation of the programme in 3 stages to reach a target of 20 GW installed capacity by 2022, the end of the 13th Five Year Plan (MNRE, 2009). The first phase, ending in March 2013, aims to install 1.1 GW of grid connected solar plants. The intention is to promote the use and development of solar energy to generate power and make it competitive with fossil fuel energy options. €12.4 billion (820 billion Indian rupees (INR)) has been allocated to the National Solar Mission by the Government of India (http://www.indiatogether.org/2010/may/byr-solar.htm). So far, there has been keen interest from private investors in large scale solar power plant. But interest for small scale solar power plants is lagging, and so far only one plant has been financed by capital markets and private equity. Similarly, Indian banks have been financing solar projects in which the State guarantees the return, and which are channelled through State-owned enterprises (Harriss-White et al, 2009).

Programmes promoting off-grid applications reaching 1 GW by 2017 and 2 GW by 2022 are also proposed. By 2017, 15 million m2 of solar thermal collector area (concentrating solar power), and 20 million m2 by 2022 are planned to be achieved. And 20 million households are planned to have installed solar lighting by the end of the 13th Five Year Plan in 2022, covered largely under the Remote Village Electrification Programme, funded by central grants (MNRE, 2010).

As of June 30, 2012, through the means of various policy schemes for installation of solar photovoltaic (PV) systems, a total of 931,262 solar lanterns, 898,048 home lights, 233,775 street lights, and 8,792 solar water pumps have been installed or distributed across various states in India. Additionally, a total capacity of 23.8 MW of off-grid, standalone solar PV power plants has been installed. These initiatives have been implemented between 2007 and 2012. The Government of India has also stressed the development of domestic solar manufacturing capabilities (Palit and Sarangi, 2011; Purohit and Purohit, 2010).

Alongside solar, other renewable energy options (in particular, biomass, micro-hydro and micro-wind) are being deployed, supported by private entrepreneurs, aid backed funding and government based funding.

The following two sub-sections consider in more detail the approach that has been taken in India to rural electrification and to decentralized power generation. Sub-section 4.1.3 then makes a comparison between off-grid and grid-connected supplies.

4.1.1 Overview of rural electrification policy in India

According to Oda and Tsujita (2011) and Andreas (2006), India has placed considerable emphasis on rural electrification as an important policy goal, both at central and state government levels, since independence. However, the focus has mainly been on increasing agricultural productivity and providing electricity for irrigation pumps, particularly so with the start of the Green Revolution. The original definition of rural electrification released by the Government of India, soon after independence, considered a village electrified, "if electricity supply was used for any purpose what-so-ever, for example, given to irrigation pumps alone." Acting on this inadequate definition, the Government of India has taken several policy initiatives to accelerate rural development programmes (Bhattacharya, 2006b).

The Ministry of Power develops rural electrification policies, monitors programmes' progress, sanctions projects and releases funds for project implementation. One such programme was the Kutir Jyoti, launched in 1988–89, which benefitted 5.8 million households at a cost of €68 million (4.5 billion INR). Under this programme, a single point connection was provided for households living below the poverty line, and the costs of internal wiring and service connection were covered under a state grant, funded by the federal government. The funds were dispersed through the Rural Electricity Corporation, and the State utilities were responsible for the execution of the programme. Similarly, the Prime Minister's village development programme (Pradhan Mantri Gamodaya Yojana) offered financing via 90% loans and 10% grants (Ministry of Power, 2003; http://powermin.nic.in; www.recindia.nic.in/). However, a number of problems led to the failure of the implementation of these programmes, despite rolling out several initiatives to provide rural electrification, including:

- Inefficient operation and management: red tape and bureaucracy slowed down the process of implementation, leading to high costs of management and operations, and low cost recovery (Bhattacharya and Jana, 2009).
- Difficulties for villages in accessing cheap loans and in repayment of loans (Modi, 2005).
- Irregularity of electricity supply, even when the connections were installed.
- Unsuccessful deployment of the 40% capital subsidy for rural electrification programmes (the Planning Commission's mid-term review of India's Tenth Plan) and the consequent financial burden on the State.

In recent years, rural electrification programmes and initiatives have accelerated and taken diverse social roles (Oda and Tsujita, 2011; Bhattacharya, 2006) as part of the "Inclusive Growth" aim of the Government of India which strives to achieve social justice along with rapid growth. The Electricity Act 2003 (EA03) focused on reforming the existing top-down policy approach of the Government of India and mandated the formulation of a National Rural Electrification policy (NREP). Hereafter, 'Rural Electrification' in India was re-defined, and certified a village as electrified only if it fulfils the following criteria (Ministry of Power, 2006):

- at least 10% of the village households are electrified;
- basic infrastructure such as a transformer and distribution lines is placed in the inhabited locality as well as the "Dalit basti Hamlet[12]"; and
- public facilities such as schools and Panchayat offices must be electrified.

Under the National Electricity Policy of 2005, the Government of India announced ambitious targets for electrification of all villages by 2007 (according to the above definition) and universal (100%) electrification of households by 2012, aiming to ensure at least 1 kWh per day per household of electricity in rural areas and availability of electricity on demand (Bhandari and Jana, 2010).

The National Rural Electrification Policy when established in 2006, gave implementation directives to the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGVVY) programme, discussed in Section 4.1 above, which aimed to provide a reliable and quality supply of electricity to all households by year 2009:

- The setup of at least one distribution transformer and distribution line in every village with feasible or existing grid access, giving priority to electricity to the "Dalit Basti".
- Villages to be selected to be covered under different schemes.
- Awareness of the scheme to be spread amongst the grassroots village consumers.
- High voltage distribution systems (HVDS) to be installed, which improve the voltage profile and provide reliable supply.

The Rural Electricity Corporation (REC) manages the plans and funds of the RGVVY programme, working between State governments, the central government and often 'central public Sector undertakings' (PSU's). Tariffs are set by the "State Electricity Regulatory Commissions' (State Nodal agencies) and are separate for different States. To develop the infrastructure of the programme, rural energy distribution franchisees have been created to handle responsible metering, revenue collection and billing for different regions. Input based franchises were introduced to procure bulk electricity from distribution utilities to distribute in their respective operational areas.

The RGGVY programme has been successful in providing 9 out of 27 Indian states with 100% village electrification, and a further 8 states have achieved 90% village electrification (according to the definition given above). Since 2005, as per its target, the programme has connected 98,000 villages to the grid, providing 17 million households with grid connections. The RGGVY (www.rggvy.gov.in/) has deemed 56% of rural household's electrified as of March 2011.The Central Electricity Authority statistic states, as of March 2011, that amongst the 641,000 villages in India, 537,947 villages have been electrified and 103,053 Indian villages require electrification. The priority states - North East States, Bihar, Jharkand, Odisha, and Uttar Pradesh - have the largest number of un-electrified villages.

The budget allocation for this was €24 billion (1600 billion INR) to 2009. The budget costs of reaching these targets have increased to €79

12 Dalit Basti is a small hut in a hamlet.

billion (5200 billion INR) as of an extended deadline of 2012 (Prayas Energy Group, 2011). However, the RGGVY has made good progress in terms of its quantitative targets, more so since 2009, and is expected to reach its targets. The responsibility of RGGVY is to erect the grid as per the targets. State organizations are responsible for its operation in their areas. There have been problems with the implementation of the RGGVY (Niez, 2010):

- States have been slow in awarding contracts for projects.
- Monitoring has been a problem at a state committee level.
- There is insufficient manpower.
- Franchisee systems have been put in place too slowly.
- There is a lack of lists of households living below the poverty line to enable targeting of electrification connections.

4.1.2 Decentralized power generation in India:

'Decentralized power generation' is the generation of electricity using locally available resources (biomass, solar, wind or mini-hydro) (MNRE, 2012). Two situations may be identified: **grid-connected** decentralized power and **off-grid**, **stand-alon**e decentralized power systems (Kaudinya et al., 2009).

Grid-connected decentralized power systems are managed by the locals and cater to local needs, but any excess electricity is fed into the grid. Another option is for decentralized stations (for example, a biomass energy power plant or a solar power plant) to be operated by a utility company. In this case, the generated electricity is usually fed into the grid and does not cater for the local needs.

In **off-grid, stand-alone decentralized power plants** power is produced independently of the grid. This approach is most suitable for the remotest areas. So far, the off-grid technology most effectively deployed has been photovoltaic installations, forming a cost-effective option. However, associated battery costs (necessary to enable demand for electricity to be met when the sun is not shining) are high, which often means that insufficient battery storage capacity is installed, resulting in the under-utilization of excess generation.

Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to grid-provided power (Kaudinya et al., 2009). Decentralized energy projects are being implemented through two separate schemes: one run by the Ministry of Power and the other by MNRE. The two schemes may be summarized as follows:

- **Ministry of Power:** The village electrification Decentralized Distributed Generation programme (DDG) was established in 2007 under the 11th plan scheme of Rural Electricity and Household Electrification, and is managed by the RGGVY of the Ministry of Power. Amendments to the Village DDG were made in 2011. A capital subsidy of €820 million (54 billion INR) has been allocated for the DDG programme included under the flagship subsidy of €38 billion (2800 billion INR) allocated to RGGVY under the 11th Plan period. Decentralized distributed generation projects are to be based on biomass, biogas, biofuels, solar, mini hydro, etc. It is expected that if a DDG funded plant generates excess electricity, then it could be fed into the grid. However, 10% of the cost of upgrading infrastructure in order to feed excess electricity into the grid has to be borne by the project developer (Ministry of Power, 2011).

- **MNRE:** In 1992, the Ministry of Non-Conventional Energy Sources (MNES) was formed by the Government of India, and was later upgraded to be the Ministry of New and Renewable Energy (MNRE) in 2006. MNRE efforts have developed, "grid interactive renewable power (wind power, biomass power, small hydro power, solar power etc.), distributed renewable power (waste to energy, biomass gasifiers, hybrid systems), rural and decentralized energy systems (solar photovoltaic, thermal programmes, home lighting systems, family type biogas plants, wind pumps), remote village electrification and other programmes such as energy parks, Akshay Urja Shops and Hybrid vehicles."

Under the rural electrification design of the MNRE, remote villages in scheduled areas are not included in the targets of the RGGVY, due to their inaccessibility. The Remote Village Electrification Program provides facilities to remote villages with a population of 100 habitants (as defined by the 2001 census). But this covers only 1.5% of the non-electrified villages in India. The programme is designed for hamlets and villages located in forest fringe areas, which are impractical to reach by grid extensions at present. Subsidies provide up to 90% of the initial installation costs of non-conventional energy systems/devices.

Such villages are generally located inside forests, Sanctuaries and National Parks, and energy access is most likely addressed by the MNRE's remote electrification programme, providing solar lighting through the National Solar Mission and biomass energy projects under the Biomass Policy of India (refer to biomass energy introduction section (4.2.1) for details). The National Solar Mission has created a franchise system under the State agencies to implement the scheme to provide solar lanterns to remote areas. The franchisees can also be NGOs.

Remote and isolated communities unlikely to be connected to grid electricity are powered through distributed/decentralized renewable energy projects (MNRE, 2012; http://www.mnre.gov.in/schemes/offgrid/). MNRE has categorized off-grid renewable energy solutions as follows:

- Biomass based heat and power projects and industrial waste to-energy projects for meeting captive needs.
- Biomass gasifiers for rural and industrial energy applications.
- Watermills/micro hydro projects for meeting electricity requirement of remote villages.
- Small wind energy and hybrid systems for mechanical and electrical applications, mainly where grid electricity is not available.
- Solar PV roof-top systems for abatement of diesel engine power generation in urban areas.
- Other decentralized systems are:
    - Family-size biogas plants.
    - Solar street lighting systems.
    - Solar lanterns and solar home lighting systems.
    - Solar water heating systems
    - Solar cookers.
    - Standalone solar/ biomass based power generators.
    - Wind pumps.
    - Micro-Hydro plant

4.1.3 Grid versus off-grid

Several studies indicate that decentralized systems have a limited socio-economic impact as compared to rural grid electrification (e.g. Ulsrud et al., 2011). However, according to Kaudinya et al (2009), the electricity currently delivered to rural regions through grid supply tends to be expensive, leading to a rise in social inequality and a reduced standard of living. For example, a survey conducted for eight States (Haryana, Jharkand, Orissa, Kerela, Gujarat, Uttarakhand, Karnataka and Maharashtra) in the report 'Shifting of Goal Posts' by Vasudha Foundation (Krishnaswamy, 2010) reveals that the rural consumer pays more for the electricity than the urban consumer in Jharkand, Orissa, Kerela, Maharashtra and Haryana. For example, in Jharkand, rural consumers end up paying 8 times more than the urban consumers for their electricity service. Similarly, in Odisha, on paper the cost of electricity to rural consumers is as low as 45 € cents (30 INR) per month for a 15kWh electricity service. The difference is in the average cost of service per kWh to rural consumers at 2 INR per kWh, against a tariff of 1.40 INR per kWh paid by an urban consumer.

Centralized systems intended to provide cheap electricity to rural areas, in reality provide erratic, unreliable, and frequently expensive electricity, by the time it trickles down to the rural poor. Large investments are made in extending the grid to transmit electricity generated in fossil-fired stations. And "the cost of coal and copper - ingredients of conventional grid power — are soaring. Meanwhile, the price of solar panels and LEDs - the ingredients of distributed renewable power - are racing down even faster" (Pope, 2012).

In India it is estimated that 30% - 40% of rural, and 6% of urban, households are dependent on kerosene as their primary source of household lighting (Bhandari and Jana, 2010). Buying kerosene can account for 25-30% of a family's income: "The poor do not use kerosene because it is cheap — they are kept poor in significant part because they must rely on expensive, dirty kerosene."(Pope, 2012).

This amounts to an estimated 340 million potential users for solar lanterns. An emphasis on solar lanterns could save the poor an annual expenditure of €5.5 billion (360 billion INR) and the Indian Government €14 billion (930 billion INR) in subsidy relief to the Public Distribution System for kerosene. Carbon-wise, it could avoid 10 million tonnes of carbon dioxide emissions annually, which would give a Clean Development Mechanism (CDM) benefit of €1.4 billion (90 billion INR) annually. However, the current National Solar Mission policy aims for only 20 million solar lighting systems to be provided to the rural population (Byravan, 2012)

Prayas Energy Group recommend off-grid solutions as a stop gap measure to achieve rural electrification (Prayas Energy Group, 2011).However, off-grid energy in India is also often perceived and treated as a secondary form of electricity, not 'real electricity'. It consequently often does not receive the emphasis it deserves. Targets for the provision of decentralized energy in current policies are very low. The grid-connected decentralized renewable energy projects have been developed purely for commercial purposes. However these projects don't necessarily cater to local rural electricity needs.

The Government of India has so far adopted a grid electricity-centric approach, has this has frequently been unable to reach rural areas with an effective electricity service. The study of India has therefore considered decentralized electricity models that complement initiatives to provide electricity through grid extension. Key challenges include:

- How to provide 100% village electrification rather than the 10% which qualifies a village to be considered 'electrified' according to the definition of the Government of India?
- Integrating off-grid solutions with grid electricity, and providing good, quality and reliable electricity to the end rural consumer.
- Developing holistic solutions to economically develop an area, for example provide income generation, education, empowerment and other such solutions to lift people out of poverty.

This study focuses on proven off-grid scalable business models that can be replicated in other rural or remote areas of India. It highlights the technology, financial models, processes and approach, challenges and lessons learnt through each case study, to serve as a practitioners guide before implementing off-grid projects in the future. More so, this study is an attempt to have the voices of several stakeholders heard to bring about an overall change in their sector.

4.1.4 Case studies introduction

Thirteen case studies have been examined in order to illustrate and explore the challenges and opportunities associated with village energy development in India. They are presented in four sections - on biomass energy (Section 4.2), solar energy (4.3), hydropower (4.4), and wind power (4.5) – together with a cross-cutting study (4.6):

Biomass Energy

- Case Study 1: Husk Power Systems
- Case Study 2: DESI Power
- Case Study 3: Appropriate Rural Technology Institute (ARTI).

Solar Photovoltaic (PV)

- Case Study 4: Selco Solar
- Case Study 5: Barefoot College
- Case Study 6: Mera Gao
- Case Study 7: ONergy
- Case Study 8: Pragati Pratisthan
- Case Study 9: Tata BP Solar
- Case Study 10: Simpa Networks

Hydro power

- Case Study 11: Prakruti Hydro Laboratories

Wind power

- Case Study 12

Cross-cutting Study

- SPEED: Case Study 13

For each of the four energy technology categories an introductory overview precedes the presentation of the individual case studies. A final section (4.7) looks across the case studies to present an overall analysis and conclusions. The cases studies have been undertaken through a review of the literature and information available on websites (references are listed at the end of the chapter, and website links provided in the text), together with a series of interviews: interviewees are listed at the end of the chapter.

4.2 Biomass Energy

4.2.1 Introduction

Bio-energy is a renewable energy resource derived from organic matter such as agricultural crops and wastes, forest residues, and wood wastes. Solid biomass, biogas and liquid bio-fuels are three distinct forms of energy extracted from biomass. The deployment of bio-energy technology in India has so far been primarily for cooking (biogas and improved cook stoves) and for decentralized power (biomass gasifiers for power generation).

India generates a vast amount of biomass material through its agricultural & agro-industrial operations: Government-sponsored studies have estimated such biomass production at over 540 million tonnes per year. Principal agriculture residues include rice husk, rice straw, bagasse, sugar cane tops and leaves, trash, groundnut shells, cotton stalks, mustard stalks, etc. About 70-75% of these residues are used as fodder, as fuel for domestic cooking and for other economic purposes, leaving behind 120 – 150 million tonnes of surplus agriculture and agro industrial residues per year which could be made available for power generation. Biomass energy has been taken up more and more as an option for providing decentralized electricity. It has the advantage of providing electricity at consumption points, and the option of feeding excess electricity to the grid if a connection is available (WII, 2011).

India is considered to have a biomass power potential of about 21,000 MW. Around 16,000 MW of power can be derived from agricultural and forestry residues, excluding energy plantations in waste land. Another, 5000 MW of power could be produced, if operations of sugar mills were to switch over to modern techniques of co-generation.

Although the aggregate installed capacity of the independent biomass power generators is about 1000 MW, the current capacity utilization has been only 50%. Most of the biomass power plants in the different States face imminent shut down on grounds of viability leading to loss of employment of labour, both direct and indirect, apart from impacting the revenue streams of the farmers and intermediaries in the rural sector.

Under the MNRE, the National Bio-energy Mission is to establish a roadmap to develop biomass energy markets commercially, by utilizing agro-residues and plantations dedicated to providing fuel. The proposed road map sets out two phases: 12th Plan (2012-17) Phase 1, and 13th Plan (2017-22), Phase 2. Policy and regulatory interventions to develop (primarily) grid connected de-centralized biomass electricity systems are to be the focus of phase 1. A target of 20,000 MW of biomass power, primarily grid-connected, is planned to be installed by 2022. Off-grid schemes as part of this are estimated to contribute 225 MW by 2017 and 350 MW by 2022. This is planned to be achieved through the establishment of rural energy supply companies (WII, 2011).

Three options are discussed below:

- decentralized power based on biomass gasifiers;
- improved cook stoves; and
- biogas energy.

4.2.2 Decentralized power based on biomass gasifiers

During the biomass gasification process, biomass is converted to combustible gas (producer gas) in a reactor (gasifier) under controlled conditions. The combustible/producer gas has a calorific value of 4.5-5.0 MJ/cubic metre, and is cooled and cleaned before it undergoes combustion in an internal combustion engine to generate power. Small scale (10-25 kW) and medium scale (up to 2 MW) systems are available.

A biomass gasifier-based power project consists of a biomass preparation unit, biomass gasifier, gas cooling and cleaning system, internal combustion engine (suitable for operation either in dual fuel mode with diesel as pilot fuel and producer gas as main fuel, or on 100% producer gas), electric generator and electricity distribution system. Figure 4.3 presents a schematic diagram of a typical biomass gasifier-based power project (Nouni et al, 2007).

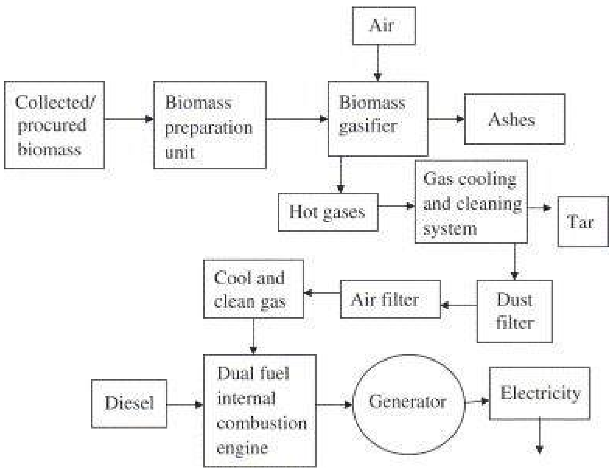

Figure 4.3: Schematic diagram of a typical biomass gasifier-based power project (Source: Nouni et al, 2007)

Biomass is cut to the required size, and fed into the biomass gasifier where it undergoes drying, pyrolysis, and reduction reactions in a limited supply of air to produce a combustible mixture of carbon monoxide, hydrogen and methane (together with some 'diluents', notably carbon dioxide and nitrogen, and tar and ash) (Nouni et al 2007). Tar and ash are removed in the gas cooling and cleaning unit of the gasifier system as they would otherwise adversely affect the operation and performance of the engine.

In the dual fuel mode of operation of the engine, diesel or bio-diesel can be used as pilot fuel and producer gas is used as the main fuel. When the engine is operated on 100% producer gas appropriate provision has to be made for initiating combustion. Use of locally produced bio-diesel as pilot fuel can completely eliminate dependence on fossil fuel based diesel, especially in remote locations where transportation of diesel may be difficult. Electricity generated is distributed to the consumers through a local mini-grid (Nouni et al, 2007).

There are a number of technical challenges posed by this technology which require further R&D (WII, 2011):

- high maintenance and running costs;
- incomplete fuel conversion (typically around 85%);
- problems with tar contamination;
- low calorific value of the syngas impacting on engine performance; and
- poor scalability of gasifier systems.

The Government of India, through MNRE (and MNES before), has supported the development of indigenous biomass gasifier technologies for two decades, resulting in the development of two models. Huskpower Systems Ltd has evolved a single fuel biomass gasifier which is currently manufactured locally and has proved successful. The application of this technology is explored in the case study of Husk Power (http://www.huskpowersystems.com).

One of the key challenges for the successful functioning of biomass energy plants has been the lack of a secure year-round supply of biomass feedstock. Proposed approaches to address this problem have included (WII, 2011):

- that there should be a minimum distance of 75 km between two biomass energy plants to ensure viability of both the projects, and to avoid escalation of biomass prices due to competing demands for biomass feedstock for the plants;
- a benchmark capacity of 7.5 MW should be set to make it convenient to procure biomass;
- management of feed stocks from plantations for existing biomass power plants should be improved; and
- a national tariff policy should be designed to set prices for biomass feedstock for the power plants.

4.2.3 Improved cook stoves

There are two types of improved cook stoves: fixed mud chulhas (with chimney) and portable metal chulhas (without chimney).

Figure 4.4: Fixed mud chulhas (with chimney)

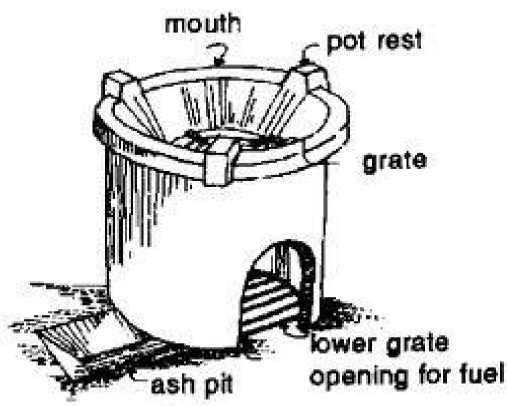

Figure 4.5: Portable metal chulhas (without chimney)

Different models and designs have evolved across India under these two broad categories. The cost of chulhas as specified under the National Policy on Improved Cook Stoves varies from €1.5 – 4.5 (100–300 INR). Under this policy, a direct cash subsidy of 50-70% of the cost is given by the Government, depending on the region and social status of its households. There is a large infrastructure in place and technical backup units undertake R&D and provide training to support state programmes (Kishore and Ramana, 2002). The MNRE recently announced a series of pilot projects to be implemented under the National Biomass Cook-Stoves Initiative, to improve the efficiency of stoves in households (WRI, 2012 and http://www.worldwatch.org/node/6328).

From the 2011 Census, 72.3% of India's households depend on biomass: firewood, cow dung cake, crop residue, etc. On average, 40 minutes is spent each day collecting wood for cooking and heating. The aim of the National Programme on improved cook stoves launched in 1983 was to implement efficient use of biomass fuels, reduce the pressure on natural resources, improve health effects by eliminating fumes released from traditional cook stoves used for indoor cooking, and eliminate the drudgery of collecting firewood, often performed by women. Since the start of this programme, 80 different types of cook stoves have been launched. A total of 35.2 million cook stoves had been installed by 2006, though it has been recorded that many have subsequently become disused. The technology has been evolving since 1983 and several designs have been developed to meet rural needs. 6.45 million households were estimated to use the cook stoves by 2000, which is a considerable achievement.

Challenges faced in this sector have been:

- absence of quality control;
- lack of support and maintenance post-construction; and
- lack of accountability for poor performance in respect of budget and meeting targets.

Subsidies provided by the Government of India were a deterrent to the development of this programme, as the sector came to be reliant on subsidies and focused just on meeting the technology specifications issued by the Government of India. Therefore innovation to meet consumers' preferences, and customization, slowed down considerably. Further, below the poverty line households often cannot afford the cook stoves (Bhattacharya and Jana, 2009).

4.2.4 Biogas energy

Biogas technology developments started as early as the 1920s in India, and the first unit of the 'floating drum biogas digester' design (known as the Khadi and Village Industry Commission Design) was constructed in 1950. A 'fixed dome digester' by the name of Janatabio-digester was developed in 1975 and a National Programme for Biogas Development was launched in 1981-1982.

The technology gained momentum around this time due to the subsidies for the technology introduced in the market. By the 1990s, the technology was well established in India and even though subsidies were cut, the technology remained in the market. Installed biogas plants can be used for several applications, such as cooking, heating, etc. (Bhattacharya and Jana, 2009).

A typical family-type floating -drum biogas digester uses cow-dung as the raw material, and the cow-dung digestate is then used as manure for agricultural purposes (Bhattacharya and Jana, 2009). Different types of digesters have been developed with improved technology. The ARTI Biogas technology is one success story which is presented as a case study in this section.

4.2.5 Introduction to biomass energy case studies

Three case studies are presented for bio-energy. The first two, on **Husk Power** and **DESI**

Power, explore the use of biomass gasification for power generation. The third, considers the activities of the Appropriate Rural Technology Institute (ARTI) which has developed and deployed technologies for improved cook stoves and biogas energy, as well as biomass gasification for power generation.

4.2.6 Case Study 1: Husk Power Systems

Background Overview

Referred to as a "silent revolution", power plants installed by Husk Power Systems have been used to electrify 22 villages and to empower the lives of 50,000 villagers in the rice belt of Bihar, India (the State produces 4.7 million tonnes of rice annually). Annual per capita electricity consumption in the State of Bihar is much lower than the national average (75 kWh compared to 613 kWh), and the State has a priority status in the RGGVY scheme with over 18,000 non-electrified villages scheduled to be connected to a regional grid by 2012. The Special Task force set up by the Government of India in 2007 pinpointed the potential for 200 MW of biomass-based power projects in Bihar. Husk Power Systems is one of several social entrepreneurs that have consequently implemented projects in the State, and it provides an example of an economically viable off-grid energy option.

Husk Power Systems was established in 2007 with the goal of providing affordable, quality, reliable, and sustainably produced electricity by using waste rice husks to generate electricity for off-grid villages. The social enterprise is based on the concept of providing electricity through efficient gasification or combustion that is, 'reliable, renewable and rural'.

Rice husks are a waste residue from processed rice production from paddy fields, and constitute a large quantity of biomass (1.4 million tonnes each year in Bihar) which can be utilized for generating energy in efficient gasification or combustion systems. Husk Power Systems utilize the waste rice husk to generate electricity for off-grid villages using 'build, own and operate' 35-100 kW mini power plants. Figure 4.6 maps the evolution of Husk Power Systems'.

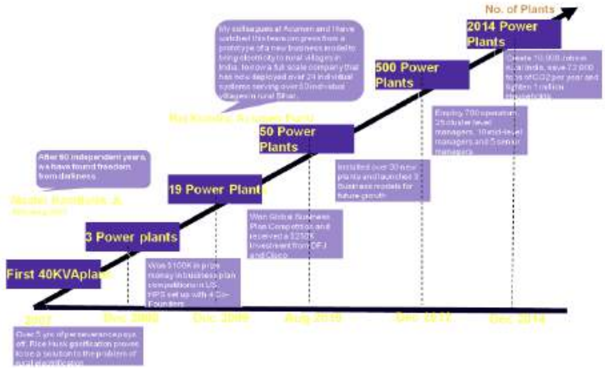

Figure 4.6: Evolution of Husk power Systems. (Source: http://www.huskpowersystems.com)

Technology Genre

Husk Power Systems utilize a proven technology, a gasifier based system in which biomass is converted to a combustible gas which drives an engine to generate up to 200 kW of power, and which operates in 'single fuel mode' without diesel. Rice husk is an amorphous low density fuel producing a gas which is high in tar content. Consequently, the engine has to be regularly cleaned so that its operation is not hampered by the tar content of the gas. (www.huskpower-systems. com).

Further, low cost local materials are used in the power plant's construction in place of the usual materials, brick and concrete, bringing down the power plant's costs. Similarly, locally manufactured gasifiers and gas engines are used. Currently 22 plants are operating in 3 clusters, and 30 more installations are in the pipeline.

Key characteristics of the technology used by Husk Power Systems include:

- multi-fuel gasifiers which can use a range of feedstocks such as rice husk, wheat husk, mustard stems, corn cobs, wood chips etc.;

- unique gasifier design which allows for easy disposal of biomass char, lack of which results in tar formation;
- a low cost system to monitor plant performance via the internet; and
- pre-paid meters, costing around € 6 (400 INR) per consumer, which enable electricity to be sold like mobile phone talk-times where consumers get their meter charged with the amount of money they have and the meter automatically disconnects the supply after the credit is exhausted.

Business Model

The business model adopted by Husk Power Systems is demand driven, and electricity is provided to people (on a 'pay-for-use' basis) only where they would like a connection and there is a demand for electricity that currently is not met. The scale up business model of Husk Power Systems is as follows:

HPS:	Franchisee partner responsible for:
• provides technology and equipment	• site selection and doing preliminary due diligence
• trains the team	• identifying manpower for plant operations
• provides maintenance and repair support	• obtaining local regulatory approvals
• facilitates monetization of the by-product char	• day to day operations including husk procurement, cash collection
• supports issuance and sale of carbon credits	• payment of maintenance fees to HPS
• facilitates processing of relevant subsidy applications	• site selection and doing preliminary due diligence;

Process and approach

In order to gauge the demand, survey teams approach each household to quantify their electricity needs. Before a system is installed, a group of 250 households need to agree to be connected. A charge of 100-125 INR (1.5-1.9 €) is collected per household each month to light up two fluorescent lamps and a mobile charging station for a daily supply of eight hours of electricity. This charge goes towards expenditure on the local grid distribution system, which accounts for 5% of the total infrastructure investment (which also includes for example, the power plant shed and biomass storage space). Figure 4.7 illustrates a step by step process and approach of electricity generation from rice husk.

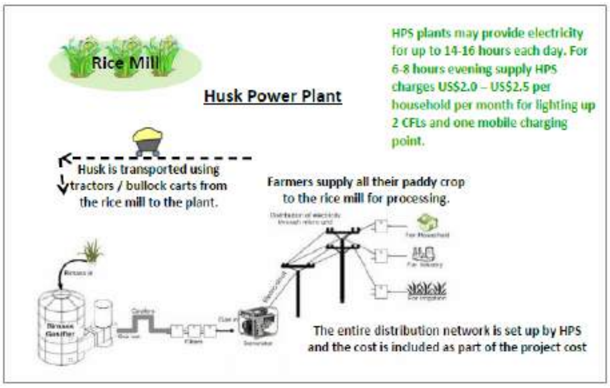

Figure 4.7: Husk Power Systems: electricity generation from rice husk. (Source: Husk Power Systems)

Generating employment: operation and maintenance

Husk Power Systems retains ownership of the decentralized systems that they install in the villages. In order to run the power plant, one operator and one husk loader are appointed to every power plant to operate the plant and carry out routine maintenance. Training is imparted to the staff in Patna, Bihar for a period of two months and they are then sent on a field training programme on site. In addition, two more people are associated with the power plants; one handles feedstock management, ensuring the supply of raw material, and another is the appointed electrician for the cluster of villages. The staff members are trained in an established institutionalized structure following standard procedures, practices, and operation and maintenance drills covering power plant commissioning and operation.

Economics of power generation/ Pricing Model:

In order to supply 6-12 hours of electricity per day to 500 households, 300kg of rice husk raw material is used to generate 40 kW of power. An average fixed 6-8 hours of electricity is supplied to both domestic and commercial users. Raw material is purchased at 1 INR per tonne (1.5 € cents) from the rice mills (DA, 2011).

The promoters have adopted a differential pricing system which provides for different electricity charges. A household is expected to pay a fixed monthly fee of 45 INR (68 € cents) for an installed compact fluorescent lamp (CFL) of 15 W, or a package of two 15 W CFL's and mobile recharge can be purchased for a monthly fee of 80 INR (1.21 €). Similarly, prices are prepared for fans and other electricity connections depending on the wattage of the product. A low cost pre-installed meter system regulates flow of the electricity and enables checks to be made that any theft of electricity is less than 5%. There is a willingness to pay amongst the villagers since the schemes bring them access to reliable and quality electricity.

In order to make a project financially sustainable, an average revenue of 20,000 to 40,000 INR (300-600 €) per month (it fluctuates seasonally) needs to be collected. Even the residue - the semi charred and charred husk - is used in households for cooking purposes and the other product - rice husk ash - is sold to cement companies. This ensures a better return for the investors.

Outcomes:

Husk Power Systems has supplied affordable electricity to rural people, created employment and enabled enterprise development. For every power plant, 3 employed personnel include a lineman/electrician (doubling up as a bill collector) and a husk loader.

Challenges of scaling up the project

Power theft: Power theft was a key challenge faced by Husk Power Systems. However, they switched to power distribution at 480 volts AC which deterred thieves, and installed a household metering box to regulate the consumption of each household.

Starting rice husk mills: Initially the existing rice husk mills raised the price of the rice husk biomass feedstock. To deal with this problem, Husk Power Systems started their own rice husk mills and created their own supply chain network of rice husk feed stock to run the power plants.

Way forward

Husk Power Systems expects to meet a target of around 3,000 operational plants by the year 2017 in over 10,000 villages.

4.2.7 Case Study 2: DESI Power

Background Overview

Decentralised Energy Systems India Private Ltd. (DESI Power), established in 1996, set up the first biomass gasification based power plant in Orchha, Madhya Pradesh, to supply electricity to a local handmade paper factory. The plant is still running (Personal Communication, Mr Hari Sharan, Co-Founder DESI Power, 2012). It subsequently identified powerless Bahabari village, in the State of Bihar, situated at the foothills of the Himalayas, as a candidate site for setting up a 50 kW biomass gasification based power plant utilizing rice husk briquettes, abundant as a raw material in the neighbouring villages (MNRE, 2011). Figure 4.8 illustrates the collection of briquettes used as raw material for the gasifier.

By 2004 the provision of electricity transformed the village, and household power connections worked on the basis of a fixed monthly rental. DESI Power works on the concept of, "EmPower Partnerships for Rural Development". Greater investments in micro-enterprises utilizing electricity led to increased agricultural productivity and the setting up of agro-processing industries. The power plant and micro-industries provide regular jobs and an additional farm income, increasing the village inhabitants' access to energy services, health services, clean drinking water and education (MNRE, 2011).

Figure 4.8: Desi Power provides off-grid electricity to villages using biomass as fuel. (Source: Gopalan, 2011)

Partners

DESI Power was set up to create jobs in villages with locally generated electricity based on renewable energy. Efficient use of biomass to generate and provide electricity was considered as the most viable route to start the programme. It is a joint venture social enterprise between DASAG Engineering and Development Alternatives. After installing its first village power plant in 2001 in Araria District, 6 other pilot projects were set up with funding from the Dutch Government and Shell Foundation. Further, a flagship Village Empower Partnership Programme was launched for 100 villages in 2006 to be completed by 2012, with a target of 5.15 MW total installed capacity (in reality, the programme has fallen far short of this target as discussed later). This project was validated as a Clean Development Mechanism (CDM) project by Det Norske Veritas (DNV) for an advance sale of CDM credits (IDFC, 2011).

Process and approach

DESI Power provides decentralized electricity to its markets through the following process (MNRE, 2011):

First, the setting up of 'Independent Rural Power Producers' to provide energy services to villages and semi-urban areas. A local partner is identified to develop local industry through better access to energy services, for example, rice mills, water pumps, etc. The local partner could be a village Panchayat, NGO, cooperative or a company. DESI power ensures the supply of affordable electricity through the joint venture, and local partners ensure feedstock management for the power plant and buy the electricity at a pre-decided price.

For example, initially, DESI power couldn't find a local partner in Bahabari to implement the project. To overcome this problem, the cooperative

Figure 4.9: Processing of biomass feedstock by village level personnel. (Source: Gopalan, 2011)

Baharbari Udyogic Vikas Swaavalambi Shakari Samiti was set up. Subsequently, partnerships have usually been made with the villagers through the cooperative set up or by identifying local NGO partners. Currently the cooperative has 19 members and owns water pumps and paddy mills. Figure 4.9 below illustrates a village level member of the cooperative processing biomass feedstock.

Capacity building and training events are held, with a focus on women. Local level personnel are trained for the operation and maintenance of the power plants at the Indian Institute of Science at Bangalore and in DESI Power's own premises. A team of 3-4 run one biomass power plant (MNRE, 2011). Figure 4.10 below illustrates a staff member monitoring the biomass power plant.

Figure 4.10: Local youths have been trained to operate and maintain the biomass power plant. (Source: Gopalan, 2011)

Electricity supply is through well-insulated underground cables and a meter measures the end user's consumption of electricity. Gasifier feedstock is sourced from a broad-base of options by DESI Power staff as a key factor to enable the reliable running of the power plant. For example, in Baharbari, locally available Ipomoea (known as Besharam) combined with hardwood was used as a feedstock. Demand for biomass as a feedstock in Baharbari made the cooperative identify the residue of maize as a feedstock alongside a locally available leguminous species called Dhencha, used by villagers to make backyard walls. Dhencha proves to have a good calorific value and nitrogen fixing properties if grown in a cycle of four months. Villagers were encouraged to grow this crop. Similarly, such feedstocks were identified for the village and an annual feedstock calendar was prepared to meet the biomass needs through the year.

Second, the setting up of dedicated power plants to provide electricity to small scale industries and mobile phone network towers which were otherwise dependent on unreliable grid electricity or diesel generators to run their businesses. For example, Zero mile decentralized gasifiers with installed capacities of 125 kW and 150 kW of connected load, were set up in the District Araria in 2008 as suppliers of electricity in competition with the grid supply in the area.

Business Model

The DESI Power business model is based on providing electricity through the setting up of renewable energy power plants, catering to the existing demand of households, and creating demand by setting up new micro-enterprises. These micro-enterprises are promoted and set up by the local cooperative / NGO partner (e.g. Baharibari Odhyogik Vikash Sahkari Saimiti). Their electricity needs are serviced through mini-grids. Power plants are set-up in accordance with the anticipated long-term needs, growth and economic development of the area (IDFC, 2011).

One of the main differences between DESI Power and Husk Power is the end goal of services provided to the customers. DESI power provides a combination of electricity and energy services in order to enhance the holistic development of the village, whereas Husk Power concentrates only on the provision of electricity for lighting purposes.

Pricing Model

Prices are set according to consumer types. For example, a price of 7-15 INR (10-23 € cents) per kWh is charged to households and micro-enterprises (IDFC, 2011) and electricity for water pumping is charged at 50 INR (75 € cents) per hour. Revenue streams vary with seasonal demand.

Key lessons learned (Sharan and Jhirad, 2011)

- In order to finalize a project, a survey needs to be conducted assessing the total load requirements of the community, or existing micro-enterprises to prevent over-sizing or under-utilizing the plant.
- Training to the local people at a community level should be a priority.
- In order to ensure annual availability of biomass, renewable energy generator operators should ensure an annual biomass raw material value chain is in place.
- Smart generation and load management should be ensured to match variability in consumption levels. Agreement of O&M (after sale service and spare parts) should be an essential part of the supply contract with the equipment suppliers.

Challenges of scaling up the project

- **Lack of demand for micro-enterprises:** The projected holistic development and creation of demand for micro-enterprises hasn't materialized on the ground level. Against the planned 100 plants by 2012, only 3 had been established by the end of 2011 (with a total capacity of 372 kW). One of the main reasons for this shortfall is the lack of capital support for micro-enterprises. To rectify this problem, DESI Power has signed a memorandum of understanding with the State Bank of India enabling villagers to get loans to start their small enterprises. Training is planned to be provided by DESI Power to entrepreneurs to run their businesses successfully in order to pay off their loan (IDFC, 2011).
- Currently, under the Rajeev Gandhi Grameen Vidyutikaran Rozgar (Ministry of Power, 2005) rural electrification policy of the Government of India, the aim is to extend the central grid to every village. The mandate of the RGGVY is the setting up of the grid whose functioning is overseen by the State agencies. However, the grid doesn't necessarily provide a reliable supply of electricity of adequate quality. In this scenario, the money spent by the RRGVY is not utilized efficiently to provide rural electrification. If the funds allocated under RGGVY were extended to creating more micro-enterprises, the Village Empower Partnership Programme for 100 villages could have probably been more successful and the business model of DESI Power could thereby have a better success rate (Personal communication, Mr Ashok Das, Managing Director, DESI Power, 2011).
- **Fuel supply:** Scaling up of projects requires secure biomass production and availability throughout the year. Biomass availability is a pre-requisite for setting up a decentralized system and plantations could be grown solely for use as gasifier feedstock. However, costs needs to be monitored carefully (IDFC, 2011). In order to standardize the local cost of biomass, it is essential to connect with the local operators and gain their trust. Partnerships with local people need to evolve in the case of an external company penetrating an area to ensure sufficiently low costs of biomass (Personal communication, Mr Ashok Das, 2011). DESI Power is currently in the process of determining different business models.
- **Capacity Building:** There is a general lack of skilled manpower to run the gasifier units and trained staff members often leave for better prospects after working for a while. Also, better project management skills are essential to ensure the effective operation and maintenance of the plants and to generate maximum value from their operation (Personal communication, Mr Ashok Das, 2011).

- **Low revenues on the business model:** DESI Power has a stake in every power plant they set up, and has the initial responsibility of financing the power plant, setting up the local infrastructure and training local operators to monitor the plant. Returns on the current business model are low and the overheads are large, particularly in respect of monitoring the on-going operation of the power plants. Therefore the business model needs to be tweaked to gain profitability and better revenue returns (Personal communication, Mr Ashok Das, 2011).
- **Financing:** Notwithstanding attractive subsidy schemes introduced by the Indian Government as discussed at the start of this chapter, and even if the project proves to be financially viable, the scale of DESI Power projects tends not to be attractive to traditional financial institutions. Scaling up the business model is constrained by "cost effective debt and equity instruments". Similarly, revenue could be generated from the Clean Development Mechanism (CDM), but this has so far proved to be unreliable (IDFC, 2011). However, recent discussions with rural development banks indicate an increased willingness to provide funds for village enterprises such as dairy farms and energy services for cold storage, clean cooking energy supply, water supply and agro-processing. Interest has also been shown by industrial companies wanting to enter the rural markets, and in fact the first such investment has already been made in a DESI Power plant.
- **Lack of financial mechanisms to reach scale:** Currently, financial loans available to end users have a high interest rate. Low cost financing schemes need to be established: for example, reducing the interest rate from 12% to 6% could make a major difference to the financial viability of a project. The loan interest rates should cater to a segment of society as an affordable and accessible financial service. This would solve two problems faced by DESI Power. Firstly, micro-enterprises would now have cheap loans to start different enterprises and the demand for electricity would go up, thus taking the power plant to its anticipated scale and generation of electricity. Secondly, the availability of low cost financing to end users would be an incentive to expand and start more power plants (Personal communication, Mr Ashok Das, 2011).

Outcomes

Sustainable energy based job creation and village development has been the key outcome of DESI Power projects. Additionally, availability of electricity has improved delivery of education to village level schools, empowered women by providing them a new source of income and spurred local development of new businesses. (Personal Communication, Mr Hari Sharan, Managing Director, 2012)

Way Forward

DESI Power is currently in the process of implementing pilot projects adopting the SPEED model discussed later in this Chapter as case study 13.

4.2.8 Case Study 3: Appropriate Rural Technology Institute (ARTI)

Introduction

The 'Appropriate Rural Technology Institute' (ARTI) has been a registered society NGO[13], since 1983 for the application of science and technology. ARTI has a focus on agriculture and biomass/ bio-energy projects and has partnered with several organizations to implement their in-house technologies, for example cook stoves, biogas plants, and biomass to electricity gasifiers. ARTI runs a training institute which has created 150 full-time entrepreneurs earning their livelihood from businesses in cook stoves. Similarly, 80 en-

13 Societies are membership organizations registered for charitable purposes, managed by a governing council or a managing committee, governed by the Societies Registration Act 1860, adapted by various states. Unlike trusts, societies may be dissolved. (http://www.ngosindia.com/resources/ngo_registration1.php) trepreneurs run a business using the technology of charcoal making developed by ARTI. Other adopted vocations by ARTI-trained entrepreneurs include installation of ARTI bio-gas plants, plant nursery businesses etc. Recently, ARTI has been working on a remote rural electrification project in the village of Madap-Thakarwadi, Taluka14Khalapur, in the District Raigad. The funding of ARTI is either donor-led or through the sale of the technologies.

Experiences with three of ARTI's technologies are described: provision of biogas, electricity generation from biomass gasification, and cook stoves.

Biogas

Figure 4.11: ARTI Biogasifier (Source: ARTI, 2012)

14 A subdivision of a district; a group of several villages organized for revenue purposes. (http://dictionary.reference.com/browse/taluk)

One of the key problems of the traditional biogas technology developed for large scale implementation was the use of cattle dung as a feedstock. Methane has a calorific value of 4600 kJ/kg, and for a system to have a high output of methane, the input would need to have a correspondingly high calorific value. Manure, as compared to food waste, has a low calorific value, resulting in the production of low quality biogas in which the methane content is diluted by other gases. The current biogas technology in widespread use ferments 40 kg of cow-dung for 40 days, and requires daily topping up of feedstock and disposal of slurry. ARTI, in 2003, developed a new biogas technology using high calorific value feedstock comprised of starchy and sugary material. From every ton of such feedstock, 250kg of methane (dry weight basis) is produced, and this reaction is much quicker, taking just 1 day to complete.

For a household biogas cooking system, this 1 day reaction is enough to provide a family with enough biogas to cook all meals. The feedstock components of the new biogas plants include waste grain, oil cake, seeds of any plant species, inedible or over-ripe fruits, and even flour swept from the floors of flour mills can be utilized. This new technology caters to lower levels of biogas use than the previous technology, reducing the size of the digester and consequently the cost of the system. The ARTI biogas plant costs 10,000 – 12,000 INR (€150-180).

The gas holder of the ARTI biogas plant has a capacity of 1000 litres, enough to cook two meals for a family. Every day 2 kg of feedstock has to be fed to the biogas plant. The effluent slurry by-product is 10 litres every day, and the methane flows along an inlet pipe fixed to a gas holder in the consumer's household. In order to build the biogas plant (two plastic water tanks) the top of each drum is cut open to accommodate the smaller drum to nest in the larger drum. The outer drum serves as a gas holder and the inner drum serves as the digester. The gas inlet pipe is fitted to the inner drum connecting to the gas holder in the household kitchen (ARTI, 2012). Figure 4.12 illustrates the mass balance of the ARTI biogas process.

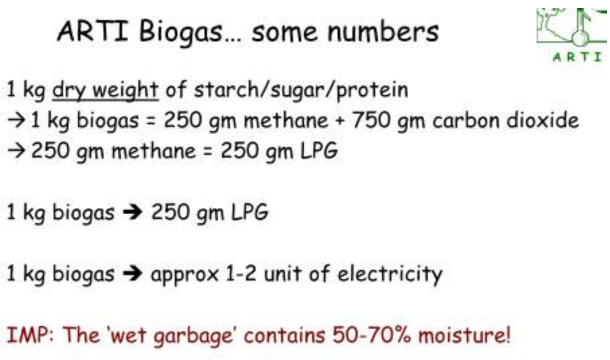

Figure 4.12: The ARTI Biogas process in numbers. (Source: www.arti-india.org/)

Figure 4.14: Manually carrying the biomass gasifier to the remote village located on a hill. (Source: www.arti-india.org/)

Biomass to Electricity Gasifiers

ARTI has installed an 11kW system in Madap-Thakarwadi, Taluka. Khalapur, District Raigad comprising a wood gasifier (using local 'nirgunda' trees) and a dual-fuel engine and generator using wood-derived gas and diesel as its feedstock (see figure 4.13). The project falls under the 'Remote Village Electrification' programme of the Government of India.

Figure 4.13: Biomass Gasifier set up in Madap-Thakarwadi, Taluka. Khalapur, District Raigad (Source: ARTI, 2012)

For this project the villagers manually and collectively carried the machinery along a steep narrow footpath through a forest to their village situated on a hill.

An electricity distribution line (mini-grid) of 17 poles was erected, distributing electricity to 100 households and a flour mill, for a total investment of 350,000 INR (€5000). In each household, 2 CFL lamps have been installed ranging from 20-30 watts. Every evening the gasifier is started and the electricity supply ends at 12 pm. In return for the electricity and service, each household contributes 100 INR (€1.5) each month and biomass as feedstock for the gasifier.

Further, ARTI cook stoves have been installed in each household instead of the traditional chulas. A kitchen performance test showed that replacing the traditional chulas with the ARTI cook stoves (costing 500 INR (€7.6) each), would save 3-4 kg of wood per family per day, which can instead be utilized in running the biomass to electricity gasifier technology to generate electricity. In order to run the gasifier system, 100-120 kg of firewood is required on a daily basis to meet minimum requirements. Currently, the village has enough collected to use 300-400 kg of firewood every day to generate electricity for 6-7 hours by running the gasifier.

However, firewood is a short term solution to generating electricity. Therefore, three or four different types of plant species have been planted on 3 acres of land over 2 years. After 2 years, the plant species will be cut as grown fire-wood and stocked to be utilized throughout the year in the gasifier ARTI is in discussion with the village committee to appoint villagers to run the gasifier as a commercial activity, charging each family for the electricity services. The revenue thus collected will pay for the salaries of the staff running the gasifier, collecting firewood from the plantation, and operating and maintaining the electricity system.

The project arose from a visit by Mr Deshmukh, ARTI President, to the village, and subsequent meetings and discussions with the Panachayat (village governing body) and villagers, building their trust in him to deliver their energy needs. The funding is through the Department of Science and Technology, following a proposal submitted by ARTI. The funds are however limited, and have enabled only a percentage of the 100 household target to be given electricity. Within a year of the project starting, funds have to be raised to enable the scheme to be enlarged so that additional households can be connected. The project has also received financial support from the charity Give2Asia (U.S.A.)

ARTI's portfolio of cook stove technologies includes the following:

- Improved Laxmi stove kit (includes fuel chamber grate, chimney chamber and two chimney holders)
- Improved Laxmi stove mould (for minimum 250 stoves)
- Sarai Cooking System (available in two sizes: Medium and Large)
- Vivek Sawdust Stove

Cook stoves technology

Figure 4.15: ARTI technologies (ARTI, 2012) (Source: www.arti-india.org/)

Figure 4.16: The uses of improved cookstoves. (Source: www.arti-india.org/)

Process and approach

- The ARTI cook stoves evolved through a feed-back process concerned with understanding the requirements of rural customers. Different kinds of cook stoves using biomass were developed by ARTI. ARTI cook stoves can be single- or multi-pot: single-pot stoves have a lower efficiency than multi-pot stoves. Development of ARTI cook stoves began in 1981 with evaluation of the efficiency of initial models of cook stoves. Ideas from booklets from The Energy Resource Institute TERI[15] surveys of cook stoves, and R & D activities in universities, led to the development of several models of cook stoves.

- The Institute took these ideas forward by implementing a village project, funded through a Government scheme in 1983 – the National Programme on improved cook stoves - to support the development and deployment of cook stoves (Kishore and Ramana, 2002). Initially, they installed 250 cook stoves in a village, and then extended the initiative to other villages. ARTI was then appointed as a technical backup support partner to implement the national programme on cook stoves in Maharashtra and Goa in 1986. After which, a series of cook stoves were developed to match different cultural and regional conditions.

Key learning points

- Several models were researched and created, and ARTI's expertise developed through their use. The traditional cook stove was the focus and its development was based on feedback from users. For example, the metallic chimney in one of the first cook stoves that were installed was replaced with a cement chimney. Further, in another area visited, a working housewife demanded a single pot cook stove since she was unable to operate two at the same time.
- Similarly, in the Konkan areas, cook stoves installed were initially not used by the women of the house, since their traditional chula played an extremely important role in their life. In the rainy season, the traditional chula emanated smoke which kept insects away from the house. So while, the smokeless ARTI chulas had solved the indoor smoke problem, this wasn't a good solution for a household in the monsoon to keep insects away, especially in small huts made from thatched coconut leaves. It was also not effective, since in the monsoons, they could no longer dry clothes in the heat of the chula. Therefore a grate was designed for the cook stove to serve all purposes, burning clean biomass, and creating enough smoke and heat to sustain the women's needs.
- The design of the cook stove further evolved with feedback from another lady, who wanted a particular type of cook stove that accommodated the way she wore her sari. A Guajarati lady wears her sari from the left side and would have difficulty in lifting the hot vessels from right to left. Therefore she preferred the more efficient first pot of the cook stove to be on the left side, rather than the right side.
- Initially the height of the cook stove developed by ARTI was 12 inches, 3 inches more than the height of the traditional cook-stove/chula of 9 inches. As a result, the women complained of pain in the hands to deal with the height of the new cooks stove as installed by ARTI. Their vessels were heavy and lifting them was a problem.

Iterative feedback was crucial to develop the technology, and diffusion of the technology was extremely important as well. Therefore a mould was developed to replicate the design. The interesting point of the mould is that different kinds of cook stoves can be made on the same mould.

In order to use the mould to make cook stoves, ARTI consulted with potters for the best clay to be used. As suggested by them, ant clay mixed with donkey dung and river clay would make the best mixture for a sturdy cook stove, giving strength to the structure. Another experiment was to make cook stoves out of cement and metal. Also, portable cook stoves were developed. With new players in the market, ARTI has kept up with new designs for cook stoves and has adapted them, becoming one of the market leaders. In order to diffuse the technology all these factors developed simultaneously.

15 TERI: The Energy Resource Institute, www.teri.in

Business Model

In order to reach villages, ARTI distributes leaflets, and holds gatherings and meetings with the housewives and the Panchayat to discuss the drawbacks of traditional cook stoves, and to explain how ARTI cook stoves could improve their lives, especially in the context of the health of women. If they agree to take the cook stove, ARTI chooses 4-5 members to implement the project for them and use their product. With success stories, more families come and ask for their product. At village level, ARTI creates entrepreneurs who establish businesses based on the installation of the cook stoves in each household.

The main strategy of ARTI is to develop and standardize the technology, and to train the entrepreneurs in its fabrication, installation and use. ARTI believes in giving the local artisans a business opportunity to develop the cook stoves for their village and to function as artisans and entrepreneurs to supply the cook stoves to the other village members. This model works very well, since not only is this additional income for them, but they are trained to develop a new skill. The entrepreneurs are called to the training centre run by ARTI, where they are trained to build, operate and disseminate the technology. The training includes how to make a mould out of local resources for the cook stove, and aims to help them develop their own format to sell and install the cook stove. They have a holistic training programme at the training centre which involves charcoal making, cook stove making, bio-gas plant making and other such programmes.

ARTI's local partners promote its technologies and approach local people to be trained. They are able to develop lucrative business opportunities by adopting ARTI's technology and installing it for interested customers in their local areas.

Challenges

- **Low awareness of the technology:** In a recent school visit by Mr Deshmukh in Satara district, 99% of the school children gave the feedback that their mothers used the traditional cook stoves. However, in an awareness talk, Mr Deshmukh explained to them the importance of the improved cook stove, keeping in mind the health factor of the fumes for their mothers who cook food for them on traditional chulas and work in enclosed areas of their small houses.

- **Financing:** Affordability is a major problem: traditional cook stoves cost 50 INR (75 € cents) and people living below the poverty line (70% of households in Maharashtra) cannot afford the ARTI cook stove, whose cost ranges from 150– 500 INR (€2.3–7.6). For such households, corporate social responsibility finances have been diverted towards doing projects for a few villages in partnership with ARTI. Micro finance and self-help groups have been developed and tried out, however they haven't been very successful in implementing these projects, and establishing a self-sustaining business model. The cook stoves do not generate sufficient income for the self-help group in relation to the amount of effort they put into the diffusion of the technology. They have other activities which would give them more revenue.

- **Manpower limitation:** Working as an NGO has a limitation since ARTI is unable to pay high salaries to proficient educated professionals. Currently, they have a product design professional, Jed Farlow, from Design Impact, an independent organization based out of Boston, who is working on re-designing the Sarai cook stove technology to serve several consumer audiences.

Way forward

Currently, ARTI is looking to upgrade the design of their cook stoves and come up with a new model for the Sarai cooker to cater for large scale cooking applications. It is also doing an improved cook stoves project and a gasifier electricity project in Mayouganj tribal district, Orissa, for the below poverty line local people who earn a living out of making plates and cups out of leaves from Sal trees.

4.3 Solar Photovoltaic (PV)

4.3.1 Introduction

Solar photovoltaic technology has been adopted as one of the first renewable energy technologies to meet basic rural electricity needs. Even though decentralized PV systems at domestic and village level provide relatively small amounts of power, their socio-economic and cultural impacts are large. Electricity to villages provided by dedicated PV systems has improved the quality of education and health services. It has boosted local village economies by sustaining livelihood activities dependent on electricity such as small shops, computer kiosks etc. PV plants have also been installed for customers accustomed to receiving un-reliable grid connected electricity.

Figure 4.17: "Many villages in India are not connected with the electricity grid. The lucky ones have solar power modules." (PV Magazine, "Empowering Rural India", Issue4, 2010) Photo: Christina Kamp

Over the years, funding organizations, microfinance institutions, social enterprises, and NGOs have developed innovative financial and institutional mechanisms to disseminate PV technology. For example, fee-for-service delivery models developed by private sector enterprises, consumer customized PV technology products, and consumer credit sales through microfinance institutions have facilitated the diffusion of PV technology into rural markets. Even so, it is strategically important to develop more innovative and scalable business models for large scale diffusion of PV technology (Chaurey and Kandpal, 2010).

India's off-grid solar photovoltaic (PV) market has three major segments: captive power plants (where the majority of generation is consumed at the source), telecom towers, and rural electrification. The market potential for these PV segments has created an off-grid solar market in India forecasted to install more than 1 GW per year by 2016.

In the off-grid rural solar energy space, there are four key options for solar PV-based rural electricity solutions:

- **Solar photovoltaic lights:** with integrated power generation capacity. These are portable lanterns and street lights.

- **Solar home systems (SHS):** are standalone systems which provide comfortable illumination levels in a room, a small hut or house, and a small amount of plug-in power. The systems consists of one or more compact fluorescent tubes (Indian term-tubelight) or lamps (Indian term-CFL bulb), together with a connection for low power demand appliances. They are designed to work for 3-7 hours a day.

The cost varies according to the components of the system and the use of each individual customer, which may be some combination of CFLs, a connection to power a television set or small fan, and a combined mobile charger and night lamp, etc. The lowest price of a SHS which provides 3-4 hours of light is around €45 (3000 INR) (without an operation and maintenance service) (Chaurey and Kandpal, 2010). However, quality SHS products customized to the needs of individual customers provided by private enterprises like Selco and Tata BP Solar have a price range of €90-180 (6000 - 12,000 INR) reflecting the costs of the product, reaching rural customers, logistics, arranging financial loans, etc. Government support programmes are available for users, eligibility being determined according to the guidelines issued by the Jawaharlal Nehru Solar Mission.

- **Solar mini-grids:** Solar photovoltaic power plants generate electricity and provide electricity to users through a local grid, typically with a capacity of 1 kW to 25 kW, and supply alternating current (AC) power to customers. They are implemented in remote areas which the grid cannot reach. Supply of electricity from the solar power plant is more convenient to households than a SHS since someone else operates the power plant which provides a reliable supply of electricity.

Solar mini-grids, depending on their size, can supply electricity for domestic power, commercial activities (e.g. shops, video centres, computer aided communication kiosks, and small grinders), and community requirements such as drinking water supply, street lighting and vaccine refrigeration (Chaurey and Kandpal, 2010). Schools, offices and other institutions are also potential customers. One, or a few, operators with relevant training operate and maintain the power supply system on behalf of the customers (Ulstrud et al, 2011).

- **Solar Photovoltaic pumping systems:** These are installed in remote areas. However there has been much debate about the price of the pumping system and the Government of India recently launched a technical research programme to bring down the price of the systems (Personal communication, MNRE 2012).

4.3.2 Energy policy for PV

Solar energy in India has recently received a boost through the Jawaharlal Nehru Solar Mission (JNSM), announced under the National Action Plan of Climate Change. The aim is to promote the use and development of solar energy to generate power and make it competitive with fossil fuel energy options. The Government of India has charged the JNSM with the mission of providing an enabling framework to bring down the cost of solar energy technology through large scale expansion (Purohit and Purohit, 2010; MNRE, 2008). The National Solar Mission is implemented through a capital/refinance scheme launched through the National Bank for Agriculture and Rural Development - NABARD, to provide financial incentives (in the form of capital subsidy and interest subsidy on loans granted by financial institutions (commercial and regional banks eligible to receive finance from NABARD)), and to promote commercial marketing of off-grid solar (photovoltaic and thermal) decentralized applications (home lighting, water heaters and irrigation pumps) .

The schemes provide 40% capital subsidy and a 5% interest loan subsidy per annum for the installation of solar devices by tenders. In special category states, the capital subsidy to be provided is 90% of the benchmark cost decided by the MNRE. MNRE, consulting IREDA and NABARD, finalized 11 model projects which will provide the basis for future financial support.

The JNSM has two flagship off-grid solar PV programmes:

- Programmes promoting off-grid applications reaching 1000 MW by 2017 and 2000 MW by 2022.

  Under the policy specifically, off-grid Solar PV installations would have a capacity of 100 kW to 250 kW per site. Mini-grids pertaining to off-grid Solar PV installations would have a capacity of 250 kW.

According to the Integrated Energy Policy, 2005 of the Planning Commission, implementing subsidies should link "incentives to outcomes". For example, a capital subsidy should be linked to an outcome. A capital subsidy of €2.3 (150 INR)/watt is provided for community solar PV plants with micro-grid/ local distribution networks. A 90% installation capital subsidy is provided for in special category states such as North East India, Sikkim, Himachal Pradesh, and Uttarakhand, Lakshadweep, Andaman and Nicobar Islands. An interest subsidy of 5% is also available on soft loans.

- 20 million off-grid solar lighting systems will be deployed in rural areas by 2022.

  The National Solar Mission solar lanterns off-grid agenda relies on the Remote Village Electrification (RVE) programme of the MNRE. RVE is run on the basis of the Census of un-electrified remote villages carried out by the Rural Electrification Corporation in 2007. Under this programme villages left out under the RGGVY are identified for electrification.

  The Remote Village Electrification programme (RVE) is responsible for electrifying un-electrified remote villages with a population of less than 100 inhabitants. The RVE programme is implemented in the states by state-notified implementing agencies (SNAs), which receive 90% capital subsidies from the MNRE. A remote village or hamlet will be considered electrified if at least 10% of the households are provided with a lighting facility. Under the RVE programme, the electrification process entails choosing the most appropriate energy technologies through the identification of locally available energy resources. However, in the case where these solutions are not feasible and the only means of electrification is through the use of isolated lighting systems such as solar PV, the NSM's distribution of lighting systems and off-grid solar home lighting comes into picture.

  Currently, there is no clear mandate as to which villages will have solar stand alone and home lighting systems, and villages where other appropriate technology options would be chosen. In some cases, villages having abundant biomass are being provided with solar systems leaving their biomass potential un-utilized. These solar energy systems could otherwise be used in places which do not have other renewable energy sources such as Biomass.

The following case studies are presented for solar PV:

- Case Study 4: Selco Solar
- Case Study 5: Barefoot College
- Case Study 6: Mera Gao
- Case Study 7: ONergy
- Case Study 8: Pragati Prathisthan
- Case Study 9: Tata BP Solar
- Case Study 10: Simpa Networks.

4.3.3 Case Study 4: Selco Solar (The Solar Electric Light Company)

Introduction Overview

Selco Solar has been a pioneering social enterprise since 1995 and provides access to energy solutions to underserved households and businesses. Households are provided with a complete customized package with energy generation and use equipment, operation and management service and standardized, affordable financing packages. Selco Solar employs 200 employees across 32 energy service centres in Karnataka and Gujarat, and has provided 140,000 solar systems to customers since 1995. The customer segment by default is low income (2000- 5000 INR (30-75 €) a month).

Selco creates appropriate financing models to provide affordable technology and finance to their customers. Currently one of the main challenges faced by Selco Solar is making the transition from a solar energy service to an energy service provider through innovative products, financing, and linkages. Figure 4.18 below shows Selco's customized PV hut installation.

Figure 4.18: Raising a family living in a small hut out of darkness. (Source: Mukherji, 2010; http://cases.growinginclusivemarkets.org/documents/81)

For example, Neelbagh School is an under-privileged school in a remote location in rural Karnataka with 100 resident students (50 girls and 50 boys) and 14 staff members staying on the campus, and 150 day school children attending from the vicinity of the school. They are connected to the power grid, receiving "3 hours of 1 phase per day" and "2 hours of 3 phase per day". The monthly cost of the grid supply is 3000 INR (45 €). Diesel generators were used as back up at a cost of 53,000 INR (800 €)/year. The diesel generator undergoes voltage fluctuations causing erratic electricity supply in the classrooms, disrupting class hours and the noise of the generator disturbed the students. Due to the low brightness of lights, students were forced to study in the daylight and generator usage was minimized on the grounds of cost.

Selco installed a 100% DC system generating 1.5 kW with a 3 day back up lead acid battery running LED (light-emitting diode) lights for 4-12 hours daily. The use of the generator was eliminated saving 53,000 INR (800 €) per year.

Technology Genre

Selco utilizes solar photovoltaic (PV) modules to provide several energy services: electrical lighting systems, water pumping, computing, communications, entertainment, and to run small business appliances. The technology is customized to meet the needs of individual consumers, and financing arrangements are put in place to enable the provision of solar electricity to customers with no access to energy services.

Partners

Selco partners with community-based technical, financial, and not-for-profit organizations and with volunteers. Collective skills from each entity are integrated to identify new customer segments and energy supply-demand related problems, and consequently to identify project development needs and collaborative innovative solutions.

Financing Mechanism

Selco's main presence is in Karnataka, hub to Syndicate Bank, Karnataka Bank, Corporation Bank, Canara Bank and Vijaya Bank. Despite the presence of these institutions, financing solar energy products continues to pose problems. The guidelines of the Reserve Bank of India require a down payment of 15-25% for providing loans against solar products to poor families. The interest rates are too high for the poor families to avail themselves of loans and they therefore fall under the "unaffordable category".

Business Model

Selco adopts a two-pronged approach of providing "door-step service and door – step financing" to cater for the needs of the end-user, which may be met through simple innovation or technical-financial solutions. Selco has evolved flexible financial packages so that end users can access mainstream financial systems depending on their cash flow. A bottom-up approach is adopted to create customized products to meet the expectations of the end-user. Aftersales service is provided by regional service centres.

Two specific examples of Selco initiatives are the 'Community Credit system partnership' and the 'Light for Education model'.

1) Community Credit system partnership

Two villages in Bihar, Munger District are far away from the grid and kerosene was the main source of their lighting. Every month, each family purchased around 5 litres of kerosene, the first 2 from the Public Distribution System and the remaining from an irregular source. An electricity supplier used to charge 60 INR (90 € cents) a month for the provision of electricity for one light bulb per family. However, the supply ceased. There are power poles in the village, but they are bereft of grid electricity whose supply is very erratic in remote areas of Bihar. Each family owns mobile phones, which they recharge every second day at a cost of 5 INR (7.5 € cents) in the nearest Block Headquarters which has both grid electricity and a generator.

The main income generation activity of women in the village is leaf collection every alternate day in the nearby forests and making plates out of them. Essentially half of the month is spent collecting leaves and the other half making plates. Each woman makes around 100 plates per day, selling them for 35 INR (53 € cents) (increasing to 50 INR (75 € cents) during the marriage season). Women make plates for 3-4 hours every afternoon and when demand is high, they continue their work into the evening by the light of a kerosene lamp.

Technology specifications and Financial Model

SEWA Bharat provided an interest-free loan to the Self Help Group at a village level to purchase and install a system for each household. The design and installation was done by Selco. The Self Help Group through its corpus collects 90 INR (1.36 €) from every end user each month, on a hire purchase agreement for 54 months. The Self Help Group pays back the loan on a monthly basis to SEWA Bharat. One and a half month's collection of funds from the end users goes to the running cost of the Self Help Group as an annual service charge. At the end of 54 months and the payment of the loan for each household system, the ownership of systems is handed to individual end users.

Selco provides customized solar home lighting systems (LED) and electricity for 6-8 hours per day, alongside a facility for charging mobile phones. The entire system costs 7000 INR (106 €) per household. Subsidies from MNREGA funds, channelled through SEWA Bharat, reduce the price of the system to be paid by each household to 4320 INR (65 €). In order to maintain individual systems on a long term basis, local youths have been trained to maintain systems and get their salary partially from SEWA Bharat and Selco service revenue. The business model has been successful in installing systems in 57 homes, and the record of repayments has been excellent. The model is now being scaled up with some systems being financed by the Bihar Kshetriya Grameen Bank, where SEWA Bharat now plays a facilitative role in processing documents for SHG loans and ensuring collection and maintenance.

Outcomes

- Opportunities for lower income groups and a better quality of life are outcomes of greater access to alternative energy sources. Affordable electricity has increased the productive working hours of the communities. Entrepreneurs have an incentive to invest in small scale businesses which provide energy services, and they have tie ups with the local formal financial institutions for cash flow options such as loans.

- Income generation has doubled: with the installation of Selco's energy system, women finish the collection of leaves in the morning, finish their household work during the day, and make leaf plates in the evening using solar lights. This system has changed their lifestyle and increased the productivity of their work, thus doubling their income. During the marriage season when there is heavy demand for their product, they are now able to extend the duration of their working hours.
- Savings have increased: every household saved 10-15 INR (15-22 € cents) daily on mobile phone charging. Similarly, income spent on kerosene reduced drastically.
- Education: The children in both the villages have benefited greatly since they have developed a habit of studying in the evening.
- Women Empowerment: with the success of the Self Help Group acting as an energy service enterprise, it now has a surplus income. Women in the village as part of the Self Help Group have greater decision making power with their increase in income.

2) Light for Education Model:

In several rural parts of Karnataka, villages are either off the grid or have access to unreliable grid electricity, and so there is no reliable light for children to do their homework in the evening. Kerosene lamps or candles provide dim light, unsuitable for studying, and emit unhealthy smoke, an irritant to the eye. Using kerosene lamps, students are unable to concentrate on their studies for more than 30 minutes. It is one of the most common excuses given by students to teachers for incomplete homework. Safety of the child is another issue due to fire accidents. Figure 4.19 illustrates a study lamp to replace kerosene lamps.

The model consist of three important components, a centralized solar charging system (installed in the school), pocket size battery and LED study lamp. Each student carries a personal pocket size light weight battery to school every day in the morning. The battery is charged in their school by a centralized solar charging system and the students carry the charged battery back home at the end of the school day. In the evening, when it is time to study, the students can connect the battery, easily attachable or detachable to a LED study lamp (placed at home where students study at night), with a connecting plug. A completely charged battery provides light for 3 hours a day with 2 days autonomy.

Figure 4.19: Light - hi-power LED's of approximately 0.5W total power consumption. (Source: Selco).

Figure 4.20: A child studying at night using a hi-power LED study lamp of approximately 0.5W total power consumption. (Source: Selco)

Technology specifications:

A typical setup will comprise of 2 sub-systems – study lights and charging station.

Study Lights: LFE programme provides study lamps to students, with the following technical specifications:

- Light - Two hi-power LED's of approximately 0.5W total power consumption
- Detachable Battery pack - 2700 mAh NiMH batteries. This can give a backup of 8-9 hours, and can be charged on alternate days.

Figure 4.21 below presents a typical battery charging station for the children. Their detachable batteries are charged during the 8-9 hours of day they are at school.

Figure 4.21: Solar central charging station for detachable batteries. (Source: Selco)

The LFE programme provides solar central charging stations at schools with the following technical specifications:

- Polycrystalline silicon solar PV module: 30W
- Lead acid tubular battery: 30 Ah
- Charge regulator: 5 A
- Charging points: 12
- Wiring and casing

Figure 4.22 PV panels placed on the school's roof to provide a facility at the solar central charging stations for detachable batteries. (Source: Selco).

Financial Model

The base cost per student in the LFE model works out to around 1700 INR (€26) (all inclusive). This cost may vary depending on remoteness of the location, number of lights supplied and other factors.

Outcomes

- In order to avail themselves of electricity for their households, the children will attend school to charge their batteries at the centralized solar system.
- It is an independent solar charging system which does not require grid electricity.
- It is cost-effective since it reduces the high expense of providing individual solar panels for students attending school.
- Technically, the central system has a higher performance than individual solar panels, especially during rainy weather.

Key challenges faced by Selco Solar

Impacted by agricultural cycles for community payment collection: One of the main challenges has been with collection of payments from their rural customers. Selco collects payments from communities at the end of the month. However, cash flow is often a problem. Each farmer has a different cash flow according to the crops he/she grows and their income is seasonal. Therefore Selco Solar had to design appropriate financing models for their customers and adopt agricultural financing mechanisms similar to the designs of NABARD (which reflect the seasonal cash flow patterns of the farmers). They have a default rate of less than 10% as a result.

A technology specification for off-grid technology is detrimental to innovation: The NSM has been detrimental to the growth of Selco Solar sales in the bottom of the pyramid. One of the key features of Selco has been to customize technology for the needs of rural customers to meet their specific requirements. However, by following pricing benchmarks as set by the NSM, Selco Solar has to abide by technology specifications of the 11 model projects in order to access subsidies. Setting technology specifications and the cost of component modules limits the extent of customization for individual customers.

In order to provide a quality product to the customer the enterprise has to build a favorable ecosystem. However, the ecosystem needs to be built gradually and for long term sustainability. The NSM dictates "what to provide the customer, what to use, what to charge the customer and how much warranty to be provided, to avail of the subsidy. It is techno-centric and environment centric." Instead, the service provider needs to understand the specification of the customer and then fix a price and as a social enterprise focused on serving the under-served, the prices offered will be fair.

For example: The benchmark cost is set according to each technology specification. Focusing on one of the technology models, a 10 watt solar panel has been priced at 3000 INR (€45); now reduced to 2700 INR and reducing over time. The energy service provider of this panel has to provide a 5 year warranty and 7 watt CFL lamp along with the product, to avail itself of the 40% capital subsidy and 5% interest subsidy. If the technology specification and cost benchmark are not adhered to, the service provider is unable to access the subsidy for the customer. Costs of solar system products as calculated for the NSM are set extremely low and exclude overhead costs of penetrating rural markets, sustained operation and maintenance, and financial facilitation of loans for their rural customers.

Financial loans: Banks have had to align with the NSM to continue providing loans for solar systems sold by Selco Solar to rural customers. Subsidy approval delays from NABARD continue to be problematic in ensuring timely energy access for rural customers.

4.3.4 Case Study 5: Barefoot College

The Barefoot College is a Non-Governmental Organisation, established in 1972, with the objective of making communities self-sufficient and sustainable through 'barefoot solutions' in solar energy, education, health care, water, rural handicrafts, communication, people's action, wasteland development and women's empowerment. It operates out of Tilonia Gram Panchayat of Kishangarh Block in the Ajmer District of Rajasthan.

The College practices the belief that for successful implementation of rural development activity, it must be owned and managed by, and based on, the village that it serves. Therefore all barefoot activities - economic, social and political - are sustained by the barefoot professionals, a network of rural men and women, irrespective of age, barely literate, with no hope of getting the lowest government job, who are trained to fill in day and night job roles such as school teachers, solar engineers, computer instructors, phone operators, artisans, masons, health workers, midwives etc. (www.barefootcollege.org/).

The Barefoot College has a pioneering solar electrification programme in rural, non-electrified and remote villages replicated across 750 villages in 16 states of India and 20 other underdeveloped countries. Its approach is innovative, aiming to achieve a people-centric, participatory development model capitalizing on local skills, rather than bringing in external experts in fabricating, installing, repairing and maintaining. Clean energy and electricity access has been provided to nearly 200,000 people, and collective efforts have benefited 896,000 men, women and children, worldwide. (www.barefootcollege.org/).

"With little guidance, encouragement and space to grow and exhibit their talent and abilities, people who have been considered 'very ordinary' and written off by society, are doing extraordinary things that defy description". Bunker Roy, Founder Barefoot College.

Business Model

Villages which are remote and are not electrified are considered for solar electrification. A beginner-level orientation event is held for community members to help them appreciate the benefit of solar lighting, and a village environment energy committee (VEEC) is formed with key representatives from the village. The role of the VEEC is to introduce the community members to the benefits of solar units and instil responsibility and ownership for future implementation of projects. A village level consultation is held between the community members and the VEEC, to map the needs, willingness, and aspirations of village community members. Households interested in owning solar lighting units are identified.

Two choices of solar lighting units are given: Fixed Home Lighting Systems and Solar Lanterns. The village community accordingly assigns responsibilities to implement household level lighting. The process of installation begins with training in leadership qualities from the College to community members with a low economic status. They are trained as barefoot solar engineers to set up rural electronic workshops in their village to install, repair, and maintain solar lighting units in their village. The VECC ensures that the Barefoot Solar entrepreneurs implement their monthly work and maintain and repair the systems installed (Development Alternatives, 2011).

Pricing mechanism

A monthly contribution is collected from the households expressing an interest to own solar lighting systems, irrespective of the economic status of the households. This is to instil a sense of ownership amongst all the households to take care of the system. However, the monthly fee is determined according to the income of the household and its monthly expenditure on candles, kerosene, torch batteries and wood (Development Alternatives, 2011).

Challenges Overcome

Local politicians, influential families, cultural and social beliefs play a dominant role in communities, thus proving a major challenge. Every family was given space to have their say on social issues to nullify the dominance of the influential forces in the village. The consequent development of new livelihood opportunities at a village level, like repair work, marble work, etc., has checked migration of villagers to cities in pursuit of work and income generation (Development Alternatives, 2011).

Outcomes

The College is the epicentre of solving several community problems such as providing drinking water, education of women, health and sanitation, rural employment, income generation, and electricity, as well as building social awareness and conservation of ecological systems (Development Alternatives, 2011).

More than 50,000 children in India are attending Barefoot night schools after sunset (as they work at home and herd livestock during the day). As of May 2010, 480 people had been trained as Barefoot Solar Engineers, of whom 230 are women.

These Barefoot Solar Engineers have fabricated, installed, repaired and maintained nearly 16,000 fixed solar units and 10,000 solar lanterns across 16 states of India and 20 of the least developed countries like Afghanistan, Bhutan, Cameroon and Kenya etc.

Figure 4.23: Barefoot College has been scaled up across India and other countries. (www.barefootcollege.org/)

Women who used to spend hours fetching water and collecting fuel wood can now spend quality time doing other productive work thanks to the installation of nearly 16,000 solar units and construction of more than 1500 rain water harvesting structures (Development Alternatives, 2011).

4.3.5 Case Study 6: Mera Gao (My Village)

Mera Gao is a social enterprise serving off-grid customers in Uttar Pradesh. It builds and operates solar power plants, battery storage and micro-grids which provide "high quality, dependable and mobile charging services." It works as a rural utility company, providing services tailored to the specific needs and income levels of off-grid consumers. As a result of providing dependable, quality electricity, children are able to finish their homework at night, adults have an additional income and indoor air quality has improved substantially. In a business as usual scenario, women were exposed to kerosene fumes working indoors.

Figure 4.24: Kerosene lamps used by households. (Source: www.meragaopower.com)

Similarly, the health effects extend to children, who are at risk of accidentally drinking kerosene, getting burnt or inhaling harmful fumes. Mera Gao has installed its system in three villages, and by the end of 2012 wants to reach out to fifteen villages.

Technology & Business Model

Figure 4.25: Solar Panels placed in the middle of the village. (Source: www.meragaopower.com)

Renewable Power Generation: Mera Gao's design uses solar panels to generate power. Because of the low energy design of the connected technologies, four panels are sufficient to power an entire village of 100 households with quality lighting and mobile phone charging. These panels are installed on the roofs of existing households, thus eliminating the need for land.

Battery Bank: Power is generated during the day but consumed at night. To bridge this gap, a battery bank large enough to provide two days' back up is installed inside the same house that the panels are installed on. Mera Gao's design only requires four batteries for an entire village, thus reducing the footprint of the battery cabinet in the household.

Power Distribution: Power is distributed over a short distance from the battery banks to the village and then to households within the village. Low voltage electricity is distributed according to a set schedule agreed by the village and Mera Gao.

Light-Emitting Diodes (LED): By utilizing LED lights, Mera Gao's system is energy efficient. This is the key to reducing power generation and storage equipment. Each household is provided with two or four LED lights. These lights provide better light through more light points and for longer duration each night than customers are able to get through kerosene.

Figure 4.26: Micro-grid electricity connection for each household. (Source: www.meragaopower.com)

Pricing Mechanism

Mera Gao is a commercial scalable utility company, not a product company. It provides services to the end consumer by installing a range of solar panels, batteries, cables, lights and mobile phone chargers. Based on the utility company model, Mera Gao owns the system and provides a service at a range of fixed monthly prices, thus giving a choice to the consumer. If the consumer is not happy with the service, they can disconnect the service. Therefore there is not too much of a risk for the customer. For a service comprising 2 lights and one mobile phone charger for a household, a monthly charge of 120 INR (1.8 €) is made for the electricity and operation and maintenance service. These prices are lower than the average grid electricity rates. The micro-grid supplies electricity which is reliable, affordable and of quality.

The system belongs to Mera Gao, and it is the responsibility of the company to make sure that electricity reaches the houses. If something goes wrong, Mera Gao undertakes and pays for, the repair, taking the worry from the customers.

Process and approach

Mera Gao partners with local NGOs to identify villages where their solar system can be installed in the middle of a village. An informal interaction, demonstration and a Q&A session is held with the villagers. No matter how poor the villages they prefer quality electricity service and value for their money. The villages are fairly close together and they are currently paying for a poor electricity service, and they would rather pay for good service and value for their money. "Pay less for better and this is a pretty easy decision for them, they express their willingness for cheaper and better, they don't have to give an upfront commitment. It doesn't require too much salesmanship to convince the people. Demonstrate in one village and then word of mouth gets automatic customers."

Solar micro-grids typically have a 75% take up rate from households, whereas it is often only 25% for stand-alone solar systems for individual households: "It is harder to convince people to own the home lighting system than connect to a readymade service which is cheap and affordable."

Challenges

Payment collections: Mera Gao is experimenting with microfinance models. Currently, they have a monthly payment collection model. Fixed schedule visits by local group members are organized to collect money from each household for the Mera Gao electricity service. Collecting small amounts of money from each household can prove both cost effective and challenging. Mera Gao has to create a local infrastructure to collect monthly payments: mobile banking systems have not yet reached these parts of India and Eko bank is limited to Delhi and Bihar (Personal communication, Nikhil Jainsinghania, Director, Mera Gao, 2012).

Suppliers of products: Bad products and services from solar product companies (solar panels, wires, cables, batteries etc.) meant that it took Mera Gao a year to reach a point where 90% of the suppliers could be trusted. Currently, they import the solar panels from China and the products are of high quality. More importantly, they get to the enterprise in a stipulated time period. The tie up with the Chinese company has worked out extremely well, with efficient supply of products within a week.

Initially through Indiamart.com Mera Gao found a list of companies and tied up with a few of them. However, not only were there delays, but some of them were unprofessional and inefficient. There is a lack of reliable information on off-grid energy products in the market. For example, there is a lack of popular websites, guides or portals which rate the quality of the products of solar companies. The manufacturing and supply base of solar systems needs to be improved to better cater to a consumer market which needs higher quality, and more reliable products (Personal communication, Nikhil Jainsinghania, 2012).

Dealing with the Uttar Pradesh government's policies and regulations: Currently, the suppliers supply their products to Mera Gao, who in turn take the products to the project sites. Transporting the products across the Uttar Pradesh border has proved to be challenging. The Uttar Pradesh State government has implemented rules and regulations which determine what gets in and out of the State. Essentially, anything which enters Uttar Pradesh needs pre-approval. This has proved to be a substantial administrative burden adding unnecessary costs to implement projects on the ground.

With reference to Palit and Chaurey (2011), Uttar Pradesh has one of the largest populations without access to, or receiving only erratic supplies of, electricity. Therefore it could prove beneficial for the State government to support a possible solution by encouraging the scaling up of the Mera Gao model. Mera Gao did look into importing the products directly into Uttar Pradesh, but it proved to be a costlier option (Personal communication, Nikhil Jainsinghania, 2012).

The lack of specialized electricians and technicians: Mera Gao often hires local electricians and technicians who follow a step by step manual to undertake installation and maintenance. However, they are often unable to detect specialized problems with the solar systems and to troubleshoot problems when providing individual customer service. "We need electricians who are well enough trained that they can do diagnostics and trouble shooting. Unfortunately solar engineers are not easy to find. It is a challenge especially for small enterprises, since we have to deal with several other problems at the same time." (Personal communication, Nikhil Jainsinghania, Director, Mera Gao, 2012).

Working with NGOs can prove to be difficult: Social enterprises seek commercial returns by providing electricity to rural areas, but NGOs are often not aligned with the commercial aspects of providing electricity services to rural households. Paying representatives of NGOs to go out in the field and engage with community members can use up 30% of monthly operating expenses. Therefore, Mera Gao started dealing with the community engagement process themselves and found customers for their product in one demonstration and question and answer discussion.

Technical challenges: Technology developments and scalable business models are needed to deliver lower capital and operating costs. A conducive environment is extremely important for the scalability of the technology. It will build the confidence of investors and will bring easier access to commercial finance.

From the experience of Mera Gao, the micro-grid sector is relatively unexplored in India. Skills are yet to be built in achieving efficient micro-grids, and future investments in the micro-grid sector are critical. To make their micro-grid more competitive, Mera Goa switched from copper to aluminium wire, sourced better quality and lower cost light solutions from China, and optimized their distribution voltage at 24 Volts (Personal communication, Nikhil Jainsinghania, 2012).

Power theft: Within a village, the solar PV panels are installed in the middle of the village and distribution lines of 24 V run all across the village. People then pay for a connection to one of the distribution lines. But someone not connected could make an illegal connection from the distribution lines, especially to charge mobile phones. Therefore a mobile charging service was installed in each household in addition to the lighting systems. According to Mera Gao, installing an individual household meter would have been a better solution; however the challenge is the initial cost of the meter. Currently, the installation cost per household is 1500 INR (€23), and a meter costs an additional 700 INR (€11), increasing project costs for Mera Gao (Personal communication, Nikhil Jainsinghania, 2012).

Grid tariff vs. off—grid tariff of electricity: If the village is grid connected, each household has to pay a flat rate of a certain amount per month for the electricity connection and electricity supplied, irrespective of the quality of electricity. Rural households prefer to pay for a good quality, guaranteed electricity connection rather than the grid electricity installations established by the State. However, Mera Gao would need to apply for a license to provide alternative electricity supply in villages connected to the state grid. There is an opportunity of providing a service to a market, however, procuring licenses is time consuming and Mera Gao is short on manpower (Personal communication, Nikhil Jainsinghania, 2012).

Government subsidies: Mera Gao is eligible to apply for project-based subsidies but it is a time consuming procedure which can delay the projects. Procedures should be streamlined. Also, the visibility of subsidy schemes to small enterprises is poor and needs to be improved

Financing: Accessing commercial guaranteed loans from organizations like NABARD has been difficult. It is important to create a sustained relationship with commercial banks: this can be challenging for a small enterprise.

Lack of investment in social enterprise startups: The Mera Gao business model has been shown to be low risk and capable of being successfully scaled up. The company is currently procuring a second round of funding to expand its business and set up several more solar micro-grid systems in other villages of Uttar Pradesh. "Investors want to see bigger, better and faster", therefore Mera Gao has designed a business model keeping scalability in mind, but acquiring donor funding has been hard. Software and IT based start-ups in comparison have access to fast loans since they have a guaranteed market.

Way Forward

Mera Gao plans to expand from three to fifteen villages by the end of 2012.

4.3.6 Case Study 7: ONergy, (Punam Energy Pvt.Ltd)

Introduction

ONergy, a social enterprise established in 2009, aims to touch 1 million lives by 2015, through its energy solutions in place of fossil fuels like kerosene and diesel. Across rural India complete energy solutions are provided to meet the energy needs, resources and aspirations of rural communities, including those living below the poverty line. OEnergy creates an effective ecosystem which connects technology, grassroots organizations and finance to distribute and service appropriate renewable energy technology. ONergy provides quality and affordable sustainable energy technologies through its proprietary model; training micro entrepreneurs at their self-initiated Renewable Energy Centres (RECs) called Shakti Kendras (Hindi translation, energy centres).

The initial focus of ONergy is East India, which is home to 35% of India's total rural population who live below the poverty line. The area of operation is mainly in off-grid areas or in grid-connected rural areas where power cuts frequently last over 4 hours. ONergy is currently concentrating on 2 districts in West Bengal - South and North Paraganas - where three renewable energy centres are presently functioning. Each Renewable Energy Centre's (RECs / Shakti Kendras) aim is to penetrate 5 to 10% of the villages within 4 districts. However, they also have pilot projects in Orissa and around India. The end consumer targeted has a household expenditure of 2000 – 8000 INR (€30-120) a month, out of which the kerosene expenditure is estimated to be 150-200 INR (€2.3-3.0) per month. Other monthly expenditures include, mobile charging (50-60 INR: 75-90 € cents), battery charging (120-240 INR: €1.8-3.6), cooking fuel (60-150 INR: €0.9-2.3) and diesel (> 500 INR: 7.6 €).

Technology Genre

Figure 4.27 explains the different technology categories offered to rural customers by ONergy in accordance to their income brackets.

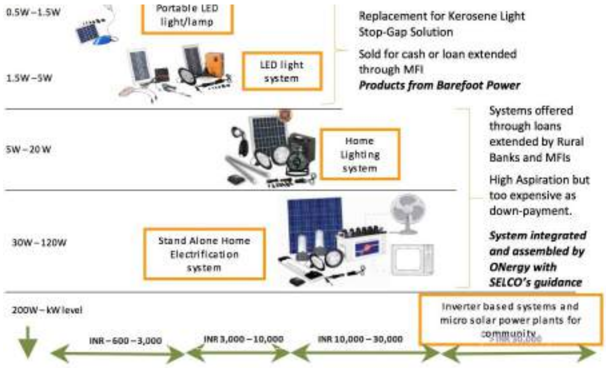

Figure 4.27 ONergy categories of technology for different income level rural customers. (Source: www.onergy.in)

Small Solar Light Products (0.5W–10W): Basic and portable low-cost solar lighting products. Satisfies the need for affordable and reliable solar lighting solutions

Solar Home Electrification Systems (20–120W+): Generate sufficient power for 10-20 hours of light per day to power multiple lights and electrical applications (fans, TVs etc.) Systems offered through loans extended by Rural Banks and Micro-Finance Institutions.

New products under development: Solar Water Heating Systems, Solar TV and Computers, Water Purification

Smokeless Cook Stoves: (promoted by TIDE) - two pan low cost stoves for domestic cooking in households that are smokeless, compact, durable, low-cost and compatible with a wide range of solid biomass and are 25-30% more efficient. They can be easily adapted and modified according to local needs, ensuring that the cooking solution is both feasible and viable. They are bundled with solar systems and offered to existing customers through a network of self-help groups trained to make the stoves.

Partners

ONergy's renewable energy centres are set up in partnership with NGO's and microfinance institutions. ONergy has applied for support under the solar mission of the Government of India and is awaiting approval for subsidies sanctioned to them. They have also been closely in touch with West Bengal Renewable Energy Development Agency (WBREDA: www.breda.org) to participate in the hot water systems tender and other schemes. Also, their proposal was selected for the MNRE-UNDP Ace Project (http://www.undp.org.in /sites/default/files/Note-Format-for-mnre.doc)

Financing Mechanism

ONergy partners with both banks and microfinance institutions (MFIs), to provide tailored, innovative financing solutions to customers keeping in mind their financial situation. Two main mechanisms are used depending on the power use of the system:

- 0.5-5 W: sold for cash or loan extended through MFI
- >5 W: systems offered through loans extended by rural banks and MFIs

Figure 4.28 presents a step by step schematic of ONergy's business model.

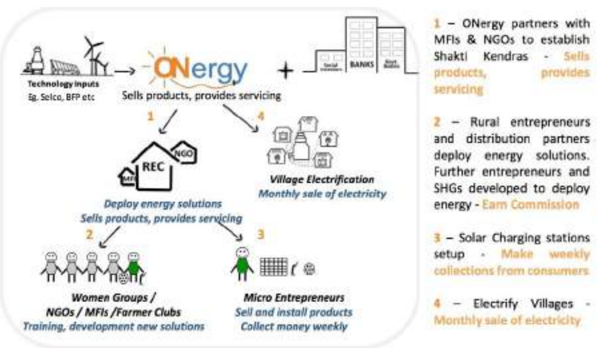

Figure 4.28: Business Model of ONergy (Source: www.onergy.in)

Renewable energy centers (RECs or Shakti Kendras) provide a network of decentralized, trained rural entrepreneurs. OEnergy works closely with self-help groups empowering them through technical training in the Shakti Kendras. This builds strong servicing infrastructures for access to sustainable clean energy services. Prompt service and training are provided by trained entrepreneurs who install energy services and attend to customer complaints.

ONergy is working towards bridging the gap between technology and end consumers by working closely with rural entrepreneurs and self-help groups, giving them extensive technical training to provide energy services and products to rural consumers.

In every new location identified, ONergy partners with the local NGO /micro-finance organizations, to set up a local infrastructure. Essentially, on a long term basis, the local partner needs to be motivated enough to carry out the project. OEnergy manages the distribution, service network, infrastructure and local goodwill/knowledge of the partner.

ONergy establishes field staff in different RECs/ Shakti Kendras who report to the central team. The central technical staff members are trained to conduct training courses across different Shakti Kendras, and they travel between project sites to attend to operations and maintenance. Technical training courses are necessary to create strong servicing infrastructures for sustainable access to clean energy. Entrepreneurs are trained to install, and provide prompt servicing, for ONergy's installed solutions in 6 districts (Howrah in Calcutta etc.) and train customers to use their product.

The curriculum to run the Shakti Kendras was originally developed by the founders of ONergy. They have recently partnered with an organization from the Netherlands to further develop the staff training curriculum. Similarly, they have had trainers from France and other countries to further develop the model.

Key challenges

One of the key challenges Onergy has faced is with trained staff. They currently have a good team to run the organization. However, in rural areas, a working culture to run a Shakti Kendra has been challenging to implement. In order to work in Shakti Kendra's the locals needed to accustom themselves to a different work discipline. Farmers in West Bengal for example, are seasonally employed on their farms and have a laid-back life. Therefore settling into a 9 to 5 typical pattern of working is new to their culture. Partnering with local organisations was key to looking for the right personnel in the initial pilot project phase.

Lack of Awareness of renewable energy products: Products haven't penetrated the market, they are relatively expensive, and many are only available in major centres such as Calcutta. Even if rural customers were to buy a solar system from a shop in Calcutta, they wouldn't receive a support and maintenance service.

Financing has been one of the other major issues. As a social enterprise, ONergy has to spend a lot of its time in connecting and coordinating with banks, getting loans, doing paperwork, collecting repayments from customers etc. The need for proof of land ownership or some kind of collateral makes the process slower, even though it is important. And the profit margin on each product is relatively low for all the effort put into selling one product to one rural customer. For the Bank it is additional time-consuming work to process several small loans. ONergy has to collect the loan money for re-payment of the loans sanctioned by the National Bank for Agriculture and Rural Development (NABARD). ONergy has been helping its customers through the process of getting loans from the bank, through paperwork, etc.

Tax has to be paid on different components of the solar power system which makes it more costly. Appropriately designed tax breaks could be beneficial in making systems more economically attractive.

Way Forward

ONergy is looking to expand its offices in Orissa and other parts of the country.

4.3.7 Case Study 8: Pragati Pratisthan

Introduction

Pragati Pratisthan began its activities in 1972, aiming to improve the standards of primary school education and start slum improvement activities in Thane city. However, their activities expanded to providing medical services in rural areas of Thane district, education to the disabled, rain-water harvesting, women empowerment programmes, energy conservation, self-empowerment nutrition programmes for children, and agro-development.

A residential school for the disabled (deaf & mute) was started in 1985 in Jawahar, Maharashtra, recognized by the State Government, and currently housing 41 boys & 14 girls from different districts (tehsils[16]) and ranging from lower primary school to 4th grade primary school. Their aim is to make the disabled self-sufficient, and training is provided for various activities such as cashew nut processing, Warli art, etc.

The rural electrification programme has been a relatively new initiative of Pragati Prathisthan and was started two years ago. It started off with a few village pilots of one bulb solar PV installations supported by donations from Rotary Club 3140. Subsequently, a renewable energy centre

16 Tehsil: A state is divided into districts and districts are sub-divided into sub-districts called Taluka or Tehsil. The Panchayat Samiti is the sub-set administrative local government body at the Taluka or Tehsil level. Taluka or Tehsil are different names adopted as per language in different States. (http://en.wikipedia.org/wiki/Administrative_divisions_of_India) was set up for the operation and maintenance of renewable energy solar sets. The solar sets comprise for each household one PV panel and bulb installation with a mobile night lamp and mobile phone charger attached to it. According to Sunandai Tai (one of the co-founders of Pragathi Prathisthan), solar energy solutions made the most sense, with ample sun in the Jawahar district. In the renewable energy centre a few handpicked teachers from the deaf and mute centre were trained to assemble, repair and install solar PV sets. A team of six people is currently responsible for installing further PV systems in the villages.

Partners/ Financing Mechanism

In general, funding has been through donations and Pragati Pratisthan's in-house funds. Sunanada Tai has been a key proponent of the rural electrification programme of Pragati Prathisthan, undertaken in partnership with Rotary District 3140, through a programme called 'Rotary Pride'. For the rural electrification programme, funding has been mainly through individual donors and private institutions, rather than from government schemes.

"There are so many villages in Maharashtra and if there were enough donations, then the other villages could be electrified as well, however, it is not so easy to collect so many donations." Sunanda Tai, Co-Founder of Pragathi Prathisthan.

Technology

The components of the solar systems are sent from Thane to the solar centre. Pragati Prathisthan has a tie up with a firm to supply components to them at cost price (paid for through donor funding). The components are 90% domestically manufactured. They had initially been imported from China as a home lighting system. However the system didn't last and gave out often within a week, so a decision was made to source components domestically.

Figure 4.29: Pragati Prathisthan technology and training centre (Photo: Ruchi Jain)

The components are assembled in the solar centre and different products are made every day. Around 50 solar systems are made every day by 6 workers. In each village served by the programme, street lights and individual household systems are installed. Solar street lights work on timers and automatically switch on only in the evening.

A household system is assembled in the solar centre and consists of one CFL lamp in the form of a tube (tube light) a mobile night lamp with a charger, and a 5 W PV panel. It costs 4200 INR (64 €). Each solar panel can be used to provide electricity for around 15 years. The current system has been adapted to respond to users' feedback on their requirements.

Figure 4.30: Housewife under solar system, Asara Gaon, Jawahar Tehsil (Photo: Ruchi Jain)

In schools, a tube light is installed in each classroom providing enough light for 20-50 children. Such PV-based lighting systems typically cost

24000 INR (360 €) for a school. All the solar systems run through a remote control. They have been made to meet the specification of the children and their lighting needs, and are classroom specific. Pragati Prathisthan also recently had a concentrated solar cooker donated to them and are trying out cooking everyday meals on it.

Figure 4.31: Solar lantern and PV based lighting system for school (Photo: Ruchi Jain)

Process and approach

A teacher in the school for the deaf and mute who was interested in electrical work started working on these PV-base lighting systems and was duly appointed as unit head. Currently, as unit head, he trains people in assembling solar systems, operations, repair and maintenance of the system. He is a Bachelor in Arts in Geography and has a diploma in electronics from the Information Technology Institute (www.iti.gov.eg/). *The solar unit of Pragati Prathisthan employs 6-7 people. They are each paid 6000* INR (90€) per month.

The unit trains and guides them to work in the field and they get jobs either in the unit or elsewhere. For example, in Hajiali, Mumbai they train other disabled people. Before working in this unit, they were either employed elsewhere or were studying; a few studied only till 10th grade. Even illiterate children, young people and adults can receive training and work in this unit or where they get an opportunity. The centre has trained 320 local solar systems operations and maintenance people for 160 villages.

The staff members work to provide electricity to villages without electricity. Initially, they meet with the Panchayat (village governing body) to inform the villagers of their scheme. If the village agrees, they run the process of establishing a system to provide electricity forward.

Business Model

Once the village has given the go ahead to install solar electricity systems in every household, a survey is conducted to understand the lighting needs of the village and its households. For example, the rural village of Asara Gaon, barely has 6 households, and doesn't have too many lighting requirements. "On approaching Asara Gaon, the children ran helter skelter and the women chatted away in the small courtyard, lit by a single powerful solar street lamp."They are currently living in below poverty line conditions and have

Figure 4.32: The children of Asara Gaon, Jawahar Tehsil (Photo: Ruchi Jain)

Figure 4.33: Solar Street Lamp (Photo: Ruchi Jain)

been allocated non-cultivable land by the Government of India. As compensation for the five acres of land they held before, and in exchange for their cultural way of life, they were given 300,000 INR (4500 €) and their land was taken away and submerged for the building of the Narmada dam. Sunanda Tai directed her field staff to install a solar system in each house.The costs

Figure 4.34: Sunanda Tai, Co-Founder, Pragati Prathisthan with children of Asara Gaon, Jawahar Tehsil (Photo: Ruchi Jain)

of the system for each household are essentially covered by the donors to the programme, but a nominal amount of 500INR (7.5 €) is collected from each household in return for the system. This contribution is for the travel cost of the field staff, the operation and maintenance of the system, and to inculcate a sense of ownership of their solar systems. Prior to work commencing, the first 50% of the payment is collected from each household, and when the work is complete, they are asked for the balance.

In each village, two people are trained to operate and maintain the system and household installations. They have back up from the central unit.

Key technology Learning

The solar lighting system was experimented with over a period of time. Initially the villagers without electricity used their lights overnight which overheated the battery and shortened its life. The villagers in a feedback session explained that they needed a light switched on throughout the night to keep mice away from their grain and from inside their houses. They also preferred to charge their mobile phones at night. The mobile night lamp with the mobile charger was therefore designed to fulfil dual purposes. Alongside a tube light installed in their houses, the mobile night lamp works very well for going to the toilet in the night, for security reasons, for keeping mice away, as a lamp for children to study and as a mobile charger.

Challenges

In a donor led project the insecurity of finance is a major challenge: sometimes donors promise finance and they don't give the money on time. This creates a problem for Pragati Pratisthan given that the installation of a solar system may have begun. They have to arrange for bridging loans until external funding arrives.

Not enough demand for solar systems and not enough work: "If we teach them how to make solar systems, we are sustaining them with an income. We first give training to the deaf and mute since they are part of the school. However, even if outside students come and learn in the units, then who will give them work? We can teach as many as possible, however there needs to be a demand for solar systems by the people in order to employ more people in the unit." (Personal Communication, Sunanda Tai, Co-Founder, Pragati Prathisthan, 2012).

Currently, the workers in the solar unit don't have enough work. They have already finished installing electricity in all the villages in and around Jawahar Tehsil. They have to work throughout the year, so for opportunity and to put their skills to use, they will have to go to Mumbai. Building society staircases is where solar lights could be installed. That is where their future income will come from since they have established contacts and tie ups in Mumbai who demand their systems for this particular application. They could target grid connected villages, however, they don't give money and are not necessarily interested. "That is why we only target villages where they haven't received electricity for 60 years after independence." (Personal Communication, Sunanda Tai, 2012).

Way forward

Currently Pragati Pratisthan is working on a scheme for 500 households in Dhanu, since Jawahar Teshil with 160 villages and 3000 households has been completely electrified.

4.3.8 Case Study 9: TATA BP SOLAR

Introduction

Tata BP solar is one of the leading corporate organizations in the off-grid rural energy space in India. They have 20 years off-grid rural electrification experience, bringing solar systems to villages to light households, provide irrigation, enable rural banking solar solutions, etc. They are one of the very few 100 % solar companies.

As a large company, they designed their marketing strategy in 2009, segmenting their market into three vertical sectors and catering to them in three different forms, illustrated in Figure 4.35.

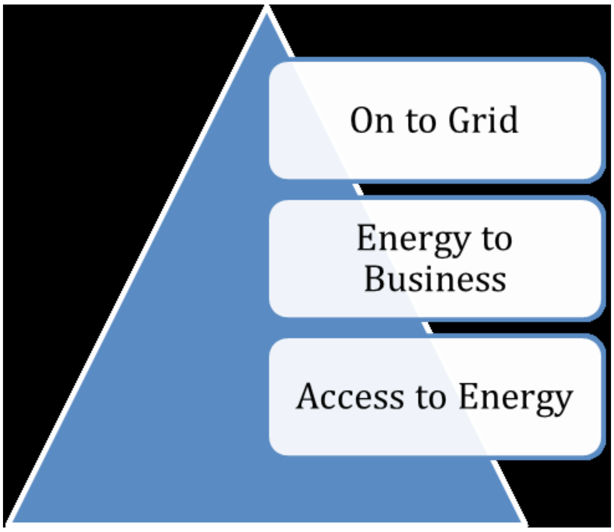

Figure 4.35: Three vertical sectors of marketing strategy of TATA BP Solar (Personal Communication, Mr Anjan Ghosh, Marketing Manager, TATA BP Solar, 2012)

Tata BP Solar's 'access to energy programme' is mainly meant for rural electrification in areas with no electricity or unreliable grid electricity. The main driver is to reach out to rural customers and provide affordable products. They have so far supplied thousands of home lighting systems to rural areas, and they have created infrastructure and networks to achieve successful implementation of their products.

Technology

Figure 4.36 showcases some of off-grid solar energy products of TATA BP Solar.

Figure 4.36: (Left corner) A solar PV installation in Ladakh; (Right corner) A fan lamp PV set; (Middle) A solar lamp PV set. (Source: TATA BP Solar)

Financing Mechanism

Tata BP Solar uses traditional banking mechanisms to grant loans to their rural customers to buy its products. Since its rural customers are unable to give upfront payments for its products, loans have to be arranged for them via local rural banks. Each public sector bank of Indian has a mandate to open rural sector bank branches. For example Grameena banks are allotted places to open their branches, providing financial facilities to farmers. The mandate for the staff of the banks is to be understanding towards the social needs of the customers. Chairmen of these banks are senior bank managers.

Process and approach

Tata BP Solar has the advantage of established networks and local partners, who help disseminate their products at a local level. Reaching rural markets is not easy and quality staff is a key requirement. Tata BP Solar has considerable experience and has built teams to penetrate the rural market, since providing off-grid products are necessary, given the un-reliability of the grid electricity supplied to the rural population. Capacity building and staff recruitment is done at a local level, and entrepreneurs are created though channel partners.

Business Model

A tie up with a local bank branch is made and loan melas (fairs) are arranged and organized to disseminate information, finance and technology through this channel. Figure 4.37, is a typical TATA BP Solar stall to sell products to their customers.

For example, in a particular case, the chairman of the regional rural bank, Aryavart Gramin Bank (289 branches operating in 6 districts in Uttar Pradesh), NK Joshi collaborated with Tata BP Solar to provide high quality home lighting systems at affordable rates to villages with no access to grid electricity in Uttar Pradesh. As a result, 80,000 solar home lighting systems were installed in 400,000 villages and there has been a consequent saving of 850,000 litres of kerosene annually. This initiative bagged the Ashden award for Mr N.K Joshi. Similarly, several such initiatives are led by Tata BP Solar with tie ups with rural banks. Especially with this initiative receiving an award, the money received by N.K Josh was re-invested in expanding the programme to other rural areas. Similarly, Chairmen of other banks contacted Tata BP Solar to implement such programmes in their rural regions as an incentive to receive recognition in exchange for the cumbersome administration work in processing small loans and government subsidies and opening outlets for access to loan schemes for solar systems.

Figure 4.37: TATA BP Solar stall to sell their products to customers. (Source: TATA BP Solar)

A loan mela has been an effective way of selling solar systems to customers. Tata BP Solar, in a particular instance in Bihar sold 5000 home lights in the first month as a result of the success of the programme with Mr N.K Joshi, Chairman of Aryavart Gramin Bank.

An MOU is signed with the local regional bank, to decide on a price consistent with the government's policy and with the prices charged by local players in the market. In several cases, banks requested TATA BP Solar to decrease their price as stated in the MOU's between them, for their products. Their products proved to be highly priced in comparison to other products in the market. However, TATA BP solar took a stand on maintaining their price range for the quality of their product and service. The company considered it important to maintain quality throughout its supply chain: supply of the product, creating awareness, taking orders, building confidence in the customers, training, local service, providing spare parts through operations and maintenance and collecting individual feedback.

In the situation where there are several players in the market, and its product is more expensive than other solar home lighting systems, TATA BP Solar suggested to the bank that it issue a market rate price list of the available solar home lighting systems in the market. The customer would buy a product in accordance with the market rate price list, and choose a solar lighting system of his/her choice. This would also ensure a fair chance for all private players in the market and for customers to decide their choice of product. Often, customers with one purchase of a basic solar lighting system would climb the aspiration pyramid and demand 40 Watts of solar PV systems which could power 3-4 plug points in their house. This would enable an inverter to run on solar power and appliances like television sets.

Inspired by the success of Tata BP Solar, the Government of India encouraged more banks to take similar initiatives. The role of the Government is crucial to drive large scale implementation of projects.

Key Challenges

Creating a touch point in a rural area which is affordable and sustaining it is one of the biggest challenges for a corporate. Once the touch point is made, training events are held and local capabilities are built up.

The basic challenge is to sell a solar lighting system to a poor person who is unable to provide up-front payment for the solar system and hence wants to pay back the cost over a period of time. A traditional bank and a corporate would want a fool-proof risk mitigation solution to make sure they have a return on their investment. In this scenario, hiking up interest rates on a loan is not the best solution. On the contrary, attractive cheap interest rate loans designed for the rural borrowers would enable an easier financial pay back for them. In Tata BP Solar's experience, rural borrowers are more reliable than sophisticated borrowers, since they are rooted to one place, living in an area for a long time and are unlikely to move their abode. In comparison, the sophisticated borrowers move around all the time. Therefore payback is not as risky as it is sometimes estimated to be, since the rural borrower is permanent and is in dire need of a quality electricity solution. There needs to be a risk absorption policy, and trust between the traditional financial systems and dealers.

There are several challenges for a corporate to access rural areas and for the staff to deal with those problems: logistics, affordable finance, finance transaction paperwork, literacy of the customers, dealing with local traders, etc. This amounts to a big investment to reach rural markets which is not completely quantifiable in terms of return on investment (ROI).

Currently, high interest loans are issued by the banks. However, low interest rates would attract a better market for their products. Low interest rates could be substituted instead of subsidies provided currently, and they would enable customers to pay for their product and work towards re-paying their full loan.

Way Forward

In 6-7 years Tata BP Solar is expecting to penetrate further into the rural market to build a larger customer base.

4.3.9 Case Study 10: Simpa Networks

Introduction

Simpa Networks introduced a "progressive purchase" pricing model to sell households energy systems. Payments for the solar home system are based on a pre-paid system according to usage and may be made via mobile phones. Once the payment for the home solar system is complete, it unlocks and delivers free electricity for 10 years (http://simpanetworks.com/).

Technology:

A field tested core technology has been developed by Simpa Networks to regulate the receipt of payments for each customer. The 'Progressive Purchase Technology', on which a patent is pending, combines the elements shown in Figure 4.38 to deliver energy access to rural customers.

Figure 4.38: Elements of Simpa Networks payments model. (Source: Simpa Networks)

Business and Pricing Model

In the "Progressive Purchase" pricing model a series of payments are made by the consumer, enabling the solar home system to unlock each time, for a paid amount of energy consumption (kWh). Once that energy has been used the system is temporarily disabled until another payment comes through. Eventually, when sufficient payments have been made, the product is permanently unlocked.

"The Progressive Purchase™ pricing model is enabled by the **Simpa Regulator**, a tamper-proof, system-integrated microcontroller and user interface that regulates the function of our solar home systems based on proof of payments, and the **Simpa Revenue Management System**, a centralized software solution in the "cloud", accessible via SMS gateway and over the internet, for payment processing and accounts settlement." (http://simpanetworks.com/)

Way Forward

Currently several pilot projects are being tried out by Simpa Networks.

4.4 Hydro power

4.4.1 Overview of Small Hydro & Watermill Hydro in India

Hydro power in India is segmented into large hydro power plants, small hydro and watermill hydro projects. Specifically, hydro projects with a capacity of up to 25 MW are specified as Small Hydro Projects (MNRE, 2012). The mandate to develop these projects has been given to the MNRE, and large scale hydro projects (i.e. schemes with a capacity greater than 25 MW) are handled by the Ministry of Power. Small hydro is further classified into the following:

- Micro Hydro: (Up to 100 kW) With the advance of micro-hydro technology, it has been possible to harness hydroelectric power with a 2 meter drop in elevation of the water that is used to drive the turbine. The gestation period of installing a micro-hydro plant is around 3 years.
- Mini hydro projects: (100 kW – 2 MW) can be constructed in canal drops, dam-toe, return canals of thermal power plants and small rivers flowing through villages. The area required for construction is small since the system has to be installed on an existing water source. They can be installed in off-grid communities to fulfil local industry electricity needs, or may feed excess electricity into the grid if a connection is available.
- Small Hydro plants: (2 MW - 25 MW) Electricity generated by small hydro plants can be

used to electrify whole communities though the establishment of micro-grids.

The flow of water changes seasonally in run-off river flows. As a result, during dry seasons, the micro-hydro/mini-hydro projects have to be supplemented with diesel generation of electricity. However, in individual cases the technology functions are different. For example, in the case of Madhya Pradesh, with perennial supply of water from the thermal power plant, the hydro electricity generation is constant; therefore the power cuts are few. During summer, water level is maintained, the river is allowed to flow and the water intake is more, therefore the power generation remains high. In contrast, with excess availability of water during rainy seasons, the water level is maintained by flap gates.

Figure 4.39: Micro-Hydro. (Source: http://www.energynext.in/india-needs-to-utilise-the-shp-potential-to-overcome-power-crisis/)

The choice of turbine for a location depends on the water flow of the region. Depending on the flow of the water, the hydraulic turbines are designed as dam base, canal flow, run-off river and hill region turbines. Small hydro turbines are in several shapes and sizes and are adapted for different regions. For example, for low head installations, hydraulic turbines vary according to their generating capacity and the speed of the turbine. Turbines are then classified according to the speed of the turbine (Adhau, 2007):

1. Low specific speed and high head turbine (Pelton)
2. Medium specific speed and medium head turbine (Francis)
3. High specific speed and low head turbine (Kaplan and Propeller)

Watermill Hydro projects

The Himalayas have a traditional method of tapping hydro-energy from hill streams and rivers through gharats (watermills). These devices have been in decline until recently, but there have been efforts to revive the technology. For example, in the NandaDevi Biosphere reserve, the adopted watermill technology is based on local designs. It has been evolved using local resources, and has low capital and maintenance costs. It utilizes the mechanical power from streams to grind grain. The grain is ground slowly to maintain its nutritional value. The gharats are set up on the banks of perennial streams in close proximity to villages. The distance to the village is determined in accordance with the safety of the slope gradient. The water from the streams is diverted to sites allocated for a mill-house, situated and built next to waterfalls at a height of 3-6m from the waterfall channel. A long wooden chute works as a nozzle, carved from the trunk of a large tree and is lowered down into the open channel. The water gushes into the wooden chute with high force and strikes the blades causing the flour mill wheel and wooden shaft to rotate and grind grain. The output power of the gharat ranges up to 1.5 kW, and the mill is able to grind up to 10 kg of flour per hour (depending on the flow of water and the type of grains) (Sharma et al, 2008).

Gharats are owned and run by individuals, but are considered as community assets. The owners collect the cost of grinding the grain through a barter system, whereby the individual owner subtracts 1/10th of the grain in exchange for providing the grinding service. The owners of the Gharats are often marginal farmers who sell other products to meet community needs at their mills. The water mill also plays an important social role, acting as a meeting point.

Figure 4.40: The working of a typical Gharat (Source: www.hesco.com/)

Recognizing the potential of these systems, and in order to revive the traditional technology, a UNDP-GEF project designed two upgraded versions of the water-mills, one for mechanical output and another one for mechanical and electrical outputs (developed by Alternate Hydro Energy Centre (AHEC), Roorkee). The MNRE, has also provided financial support of €560 (750 US $) or 75% of the actual cost for the mechanical model watermill and €1120 (1500 US $) for the electrical and mechanical version of the watermill. As of now 150 Gharata have completed upgrading in Uttarakhand.

Government Policy

The MNRE aims to develop 7000 MW of small hydro plants by the end of 12th plan period which runs from 2012 to 2017. The current focus is on increasing the reliability of established projects and decreasing the capital cost of equipment in remote areas. A list of 5,415 potential sites amounting to an aggregate capacity of 14,000 MW has been identified. Several projects have been installed in the Himalayan region and in mountainous regions on account of streams and river run -offs.

The subsidy scheme is for micro-hydro projects up to 100 kW capacity. The scheme provides grants (Central Financial Assistance) for micro-hydro projects and upgrading watermills. The emphasis is also on building capacity related to the execution of micro -hydro and watermill projects. The following table 4.1 gives a breakdown of the grants available to micro-hydro.

Central Financial Assistance for Watermills and Micro Hydro Projects

Watermills:		
	Category of Watermill	Amount of Central finance assistance
1.	Mechanical output only	€520
2.	a) Electrical Output (up to 5 kW) or, b) Both mechanical and electrical output (up to 5 kW)	€1640
Micro Hydro Projects up to 100 kW capacity:		
	Areas	
1.	International Border Districts (excluding Arunachal Pradesh (AP))	€1490
2.	North Eastern and special category states other than AP.	€1190
3.	Other States, other than AP	€595

Table 4.1: grants available to micro hydro

A minimum of 10%-20% of the project cost should be met by the project owners in the special category States and North Eastern States.

In addition to the grants, an incentive of €53 (3500 INR) is provided per mechanical watermill and €152 (10,000 INR) per electrical watermill. Further a 1% subsidy, or €380 (25,000 INR) as a minimum subsidy for each micro hydro project, is provided to the State Nodal Agency as a service charge if they are the owners of the micro hydro projects for the communities. In the case of a micro-hydro project being implemented both by the State Nodal Agency and a NGO, the ratio of the cost of the project shared amongst the parties is 30:70. The responsibility to implement state-wise projects is given to State nodal agencies, local bodies, NGOs, cooperatives and individuals.

4.4.2 Case Study 11: Prakruti Hydro laboratories

Introduction

Nisarga Environment Technologies is a renewable energy systems company delivering micro-hydro systems and efficient cook stoves to rural and remote areas. They have installed micro-hydro systems in 2000 sites in Karanataka, Uttar Kannada, Dakshin Kannada, Chipmanglur, Hosan and Coorg. The parent company is Prakruti Hydro Laboratories, Bangalore founded by Sampath Kumar and D. R. Muralidhar and they run daughter dealerships:

1. Nisarga Environment Technologies, Shimoga (central hills of Karnataka),
2. Karavalli Renewable Energy, Belthangady (southern hills of Karnataka),
3. Canara Renewable Energy, Sirsi (northern hills of Karnataka).

The company's turnover was 3.7 million INR (56,000 €) in 2009, and 6.8 million INR (103,000 €) in 2010 (close to 100% growth). In 2011 they planned to become a Private Limited Company, and were in the process of putting together equity from friends and relative networks.

Technology

Three main types of system are used, the first two having been developed by Prakruti Hydro Laboratories:

1. A 1 kW micro-hydro system operating on 10-60 m head and 4-60 l/s flow rate
2. Pico Cross-Flow Units suitable for situations with low to medium head water sources and high flows
3. A Pico Pelton Unit system which is a stock product usable from 10 m to 100 m head, and providing a power output of 200 W to 10 kW in standard configurations (see Figure 4.41). This is an integral turbine generator unit. The standard system comes with an electronic load controller panel and associated dump loads.

Figure 4.41: Pico Pelton Unit system (Source: http://www.indiamart.com/prakrutihydrolabs/)

Example: Sridhar Bhatt, a farmer, operates the micro-hydro system, by turning a small valve wheel connected to a bright blue box, and the stream water is ushered over the valve and fills up into the box. The turbine inside the box begins to rotate from the pressure of the stream and the needle on the pressure gauge rises to ten. The water comes from a diverted section of the stream from a high point of the hilly land, and falls onto the turbine from a ten meter drop, generating up to 1 kW of electricity, which is then directed to Sridhar's house through a single set of wires to operate 30 lighting points. Figure 4.42 gives a glimpse into Sridhar Bhatt's house electrified through micro-hydro.

Figure 4.42: Sridhar Bhatt's family in his house electrified through micro-hydro. (Source: Boyle and Krishnamurthy, 2011; http://www.greenpeace.org/india/Global/india/report/2011/Taking%20Charge.pdf)

The water re-joins the stream at a lower section after passing through the turbine. During summer, due to decreased flow of water, Sridhar switches on the system only for five-six hours in the morning and evening. An electric load governor outside the house regulates the flow of electricity, ensuring no change in voltage during its use. Figure 4.43 shows the stream which passes Sridhar Bhatt's house.

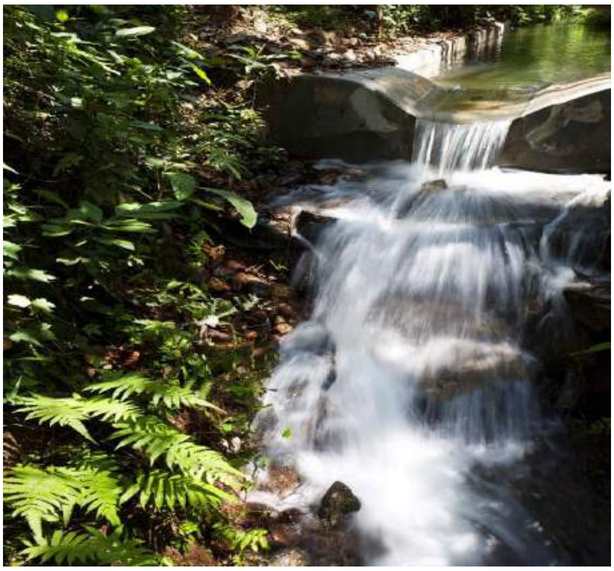

Figure 4.43: Flow of stream water diverted to Sridhar Bhatt's house to generate micro-hydro electricity. (Source: Boyle and Krishnamurthy, 2011; http://www.greenpeace.org/india/Global/india/report/2011/Taking%20Charge.pdf)

Financing Mechanism

For every project, loans are disbursed by banks, typically amounting to 90,000 INR (1360 €) at 16% interest for a fixed period of up to 1 year, with no early repayment fees. A fixed membership fee of 525 INR (8 €) is paid to the cooperative bank by the customer when the loan is taken out. Similarly, a loan documentation fee of 2,900 INR (44 €) is charged to customers. Per household products costs can be broken down as follows:

- Wiring and basic end use devices: 15,000 INR (227 €)
- Customer Civil works and piping: 20,000 – 60,000 INR (300-900 €)
- Customer Electromechanical equipment (turbine, generator, load controller):91,750 INR (1390 €).

Figure 4.44 shows a typical scene of bank officials dealing with micro-hydro schemes and loans with the members of the community (Boyle and Krishnamurthy, 2011)

Figure 4.44: Members of community dealing with bank officials for micro-hydro loans. (Source: Boyle and Krishnamurthy, 2011; http://www.greenpeace.org/india/Global/india/report/2011/Taking%20Charge.pdf)

A subsidy of 110,000 INR (1670 €) is paid by Karanataka Renewable Energy Limited (KREDL) for every project under the "Upgradation/Development of Water Mills" scheme after completion of installation. The paperwork to get the subsidy from the MNRE was proving to be a burden to Prakruti's operation and sustaining relationships for the day to day transactions with the KREDL was distracting their engineers. Therefore Prakruti devised a smart solution, "to multiply to conquer". An employee, Ravi S. Gownder, who had spent the most amount of time dealing with KREDL, branched out into his own dealership firm, focusing on "the delivery of the product, consumer financing and post-installation services". This enabled a more effective delivery of the product supply chain.

Business Model

In the case of Sridhar Bhatt, the transaction between Prakruti Hydro Laboratories and Sirdhar Bhatt is a purely commercial transaction to meet the needs of the household. His farm is in Chembu in Kodugu district, Karnataka, and his Panchayat (like several other Panchayats) of 5000 people (around 950 households) is mostly un-electrified. The population comprises of under-privileged (dalit)[17] and tribal people, 40% and 20% of which respectively are landless labourers.

Farmers (with an average landholding of three to five acres) grow rubber, cocoa, bananas, areca, and a little bit of cashew and paddy rice. The farmers with land have sought to invest in individual micro hydro systems. However, as a Panchayat, they had applied for grid connectivity through the Rajeev Gandhi Grameen Vidutikarna Yojana (RGGVY) scheme twelve years ago. Four years ago they had been informed that they would receive grid based electricity through the RGGVY scheme. However, electricity has failed to reach them even now and villagers mostly use kerosene for lighting needs. Community taxes are used to supply water to individual houses and government funds are used to run schools and provide housing for the poor. A lot of money is spent on gutters and making of roads. Therefore finance is a big problem for building micro hydro systems, whether for the community or for individual households.

Those with access to land and resources have been able to install their private micro-hydro system. "It's all word to mouth": one successful installation, has prodded other households to install a system. "No conscious effort was made to emanate awareness for our system." Each individual installation is provided with an operation and maintenance service, even beyond the guarantee period, which is an extra cost to the company, but ensures the delivery of a quality product in its long-term lifecycle.

The critical aspects of the business model include:

- Bundling finance and financial services for end users (in particular, bridging loans and access to subsidies) is critical to drive the uptake of decentralized renewable energy.
- Post-sale maintenance services must be available to sustain decentralized renewable energy.
- Sustainable supply and delivery chains effectively place renewable energy products where they are needed - and create local employment.

Challenges: (Personal Communication, D. R. Muralidhar, Nisarga Environment Technologies, 2012)

- The overheads of the business are very high and it takes 4-5 years to fully payback one installed system.
- Financing is a big issue, since potential customers don't have access to cheap loans. There are no bank mechanisms for micro-hydro projects as a priority lending sector.
- There may be inappropriate applications of the technology leading to potential problems. Sometimes customers cut corners, for example hiring their own labour which could

17 Dalits: India's under-privileged, oppressed and outcast population. The term "Dalit" means "those who have been broken and ground down by those above them in the social hierarchy in a deliberate and active way." http://www.dalitnetwork.org/go?/dfn/who_are_the_dalit/C64 potentially lead to long-term problems with the system.

- Consideration needs to be given to how projects can become viable in the absence of subsidies. A development that could help to meet this challenge would be to make the micro-hydro systems into income generation activities. Instead of the subsidy, if the grid was made to accept the excess power generated from the micro-hydro systems, and an income could consequently be created from the sale of power, this could help to make projects financially viable on a long term basis. Currently the grid can accept electricity only up to a certain range. Therefore a solution would be needed to be worked out to establish a way of collecting the excess electricity from the micro-hydro systems to feed to the grid.
- Similarly, a micro-grid could be created to transfer power between households and/or villages which have micro-hydro systems and those that don't. A practical challenge would be the repair of grids in hilly areas which is difficult.

Way Forward

Prakruti is in the process of developing grid-interactive small hydro models of higher capacity (up to 0.5 MW).

4.5 Wind power: Case study 12

In India, wind energy capacity has generally been grid connected, and the installed capacity amounted to 13 GW in 2010. While such wind energy capacity, typically employing relatively large wind turbines, has been growing steadily since 1995, there has been very little deployment of small wind turbines, working off-grid, ranging between 150 and 200 kW.

However, there are now several designs of small wind turbines in the market, and there are a few installations such as in Goa, Maharashtra, etc. The cost of generating electricity is around 27-33 € cents (18-22 INR) per kWh. The Centre for Wind Energy Technology (CWET) has been testing five small wind turbines (ranging in capacity from 1.4 to 5.1 kW) at the Wind Turbine Research Station, Kayathar (to meet the requirements of the standards IES -61 400-2 and IEC 61400-12-1 prior to commercial deployment). The results of the research conducted by the Centre for Wind Energy Technology are to be discussed with the Small Wind Energy System (SWES) Empanelment Committee set up by the MNRE (CWET, 2011).

Electricity from small-wind turbines has several applications: for example, lighting, water heating, mobile phone charging, and heating households with the installation of a heat pump. They may be connected to the grid and export excess electricity generation into the grid but typically no payment is made for any exported units. Small wind turbines have low maintenance requirements.(http://www.fortiswindenergy.com/faq). Figure 4.45 and 4.46 are two examples of small-wind indigenous technology developed by Auroville Systems and CWET.

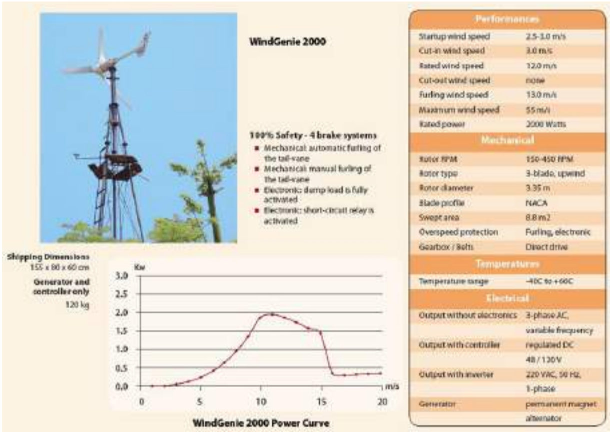

Figure 4.45: Small-Wind technology developed by Auroville Systems (Source: http://www.aurovillewindsystems.com/Auroville_Wind_Systems_Genie%202000.htm)

Figure 4.46: Small Wind installation at Centre for Wind Energy Technologies.

Government Policy

In April 2010, the MNRE, launched a small wind energy and hybrid systems programme implemented by the State Nodal Agencies. A key role of the small wind turbines supported by this programme will be to provide the motive power for water pumping. Water pumping windmills typically cost around €1200 (80,000 INR), and wind-solar hybrid systems around €4000 (250,000 INR) per kW (MNRE, 2010).

Financial support is provided as 50% of the "ex-works cost of water pumping windmills." Similarly, for hybrid systems a subsidy of €1500 (100,000 INR) per kW is provided for projects implemented by government bodies, NGOs, charitable trusts and R&D organizations. So far, a cumulative capacity of 608 kW of wind-solar hybrid systems and 1180 kW of water pumping windmills have been installed (MNRE, 2010).

A new empanelment procedure has been introduced by the MNRE for the 12 manufacturers of aero generators/water pumping windmills listed under the policy framework. The empanelment procedure is mandatory and has been set up to ensure that the turbines meet international standards (MNRE, 2010b).

Challenges

(Personal Communication, 2012, Dr. S. Gomathinayagam, Executive Director, Center of Wind Energy Technologies (CWET), www.cwet.tn.nic.in/)

- Reliability and quality assurance: Several installed small-wind projects are under-performing and there is a lack of confidence in the existing machinery. Similarly, there is a lack of certification or quality assurance of the product.
- Cost: The current small-wind installations are dependent on subsidies to make projects financially viable. Generating costs are high and unattractive for investors unless a feed-in tariff policy designed specifically for small-wind energy is available.
- Research and development: Currently, the small-wind technology used in India has been adopted from the European models and wind conditions. India needs its own R & D efforts in this field to adapt designs to lower wind speeds and to develop indigenous technology.
- Information on installations: The Government of India is connected to several manufactures of small-wind technology in India, but is not aware of all the installations of projects in remote areas of the country. There is a general lack of documentation and literature about this field, and case studies of small wind installations have not been documented.
- Operation and maintenance: small wind turbines are currently promoted by small enterprises and family owned businesses which are inadequately staffed to properly support the operation and maintenance of the turbines.

Way forward

(Personal Communication, 2012, Dr. S. Gomathinayagam, Executive Director, Center of Wind Energy Technologies (CWET))

In order to address these challenges, the following initiatives are required:

- More standardization and certification, together with more routine performance testing.
- Reduction of cost through R&D, and domestic volume production.
- Training of an operation and maintenance task force to assist small business enterprises.
- Introduction of feed-in tariffs for export of electricity to the grid.
- Need for a policy framework which promotes large scale domestic manufacturing of small-wind turbines and early adoption of the technology.

4.6 Cross-cutting Study: SPEED: Case Study 13

Introduction

Smart Power for Environmentally sound Economic Development (SPEED) has been designed "to identify and showcase scalable business models and implementation plans" and trigger economic development through energy access solutions in areas with under-privileged inhabitants. Alternatives to diesel driven pumps and lighting generators are sought for the telecom industry and farmers. The aim is to facilitate an ecosystem of multiple stakeholders.

The aim of SPEED is to create ground-level demonstrations to provide clean energy services in areas which do not have access to electricity, encompassing a broad range of stakeholders, and mobilizing finance and donor funding. Poor revenue streams make rural energy projects financially unsustainable and a difficult proposition for investors, suppliers of energy services and financiers. And revenue streams cannot be guaranteed unless, and until, there is a high rural demand for electricity. This is because of the lack of rural scale economic activities. Under these circumstances, the success of village level economic activities is vital to cultivate future rural demand for electricity. Simultaneously, electricity is needed to sustain micro- economic development programmes.

A key element of the design to reach scale is to engage private enterprises and capital to augment efforts of governments, development finance institutions and economic activities undertaken through the involvement of local entrepreneurs and consumers from rural communities.

"The theory of change of SPEED is to leverage anchor loads to be the leading driver of rural electrification, thereby stimulating the cycle of rural economic development that in turn would support long-term rural electrification."

Business Model

The business model of the SPEED project is best explained through the theory of change shown schematically in Figure 4.47.

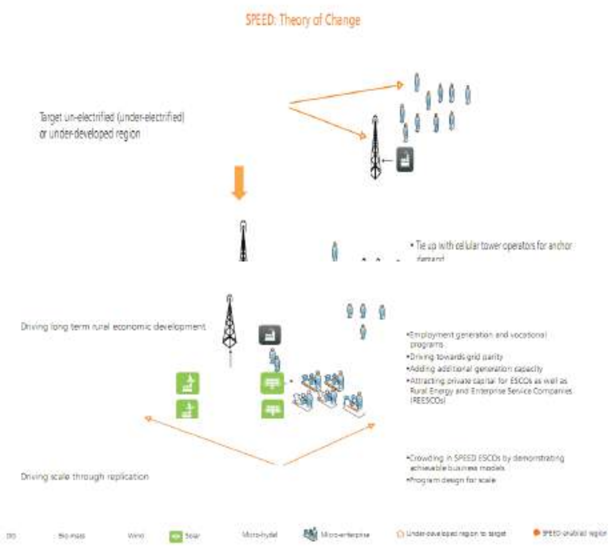

Figure 4.47: SPEED Theory of Change. (Source: Sharan and Jhirad, 2011)

The step by step design for scale proposed by SPEED includes:

1. In order to solve the problem of lack of demand of electricity for micro-enterprise development, SPEED ensures base demand by tying up with an anchor load for electricity

consumption, in the form of cell phone towers and other existing loads. A tie up with the cell-tower anchor load will ensure a guaranteed revenue stream and maintain a plant load factor that makes the power plant viable.

2. Simultaneously, it promotes the setup of new local enterprises and use of energy services, to reach an "economic electricity generation threshold." The new micro-enterprises are supplied with electricity to hasten their economic development.
3. Previous rural electrification projects have had NGO, public or quasi-public formats focusing on initial investments which often results in ineffective long term operation and maintenance. In the SPEED model, a private enterprise is engaged with to create a comprehensive ESCO (Energy Service Company) leveraging long-term private investment and sustained operations and maintenance.
4. Since up-front capital has always been one of the biggest challenges faced by decentralized off-grid projects, SPEED will catalyze investments by creating investable frameworks, both at a programme and project level to attract private third parties to fund and invest in projects.
5. So far, rural electrification has targeted household electrification and meeting their lighting needs, however, "community empowerment and income enhancement" has been focused on as a key tenet, by generating micro-enterprises in areas thus served.
6. Payment collection and power theft have been key challenges faced by several off-grid rural energy projects due to lack of community involvement and availability of trained competent local staff. This has hit the operational viability of several projects. The SPEED model engages with communities and village level organizations to create a win- win configuration. Villagers are trained to take responsibility for operations and maintenance, and to support the setup of their own micro-enterprises. The increase in local economic activity, and the ability to pay for the power, enables interesting payment mechanisms and pay back capacity for the tariff charged for the energy service. It is anticipated that peer pressure will reduce power theft.

Financing mechanism

SPEED is a concept based design and it will take some time to implement since it is based on research and synergy of different stakeholders in the pilot phase. It is not dependent on Government programmes. Figure 4.48 has listed a few potential sources of funding for partnerships and investments.

Potential sources of financing

Source of Financing	Type	Area of Financing / Investment
Private philanthropy	Grants	• Research & analysis • Capacity building of lead actors • Monitoring & evaluation
Social investment funds (social venture, impact investing, program-related investments)	Patient capital (equity/debt)	• Developers of SPEED pilot projects • Suppliers of pro-poor technologies and solutions for SPEED pilots
Carbon funds	Carbon-related investments or transactions	• Reduction in greenhouse gas emissions from SPEED pilots
Venture capital	Growth stage commercial equity/debt investment	• Businesses with proven commercial growth potential

Figure 4.48: Potential sources of funding. (Sharan and Jhirad, 2011)

4.7 Conclusions and recommendations from case studies

The thirteen case studies have been very instructive in illustrating the challenges and opportunities associated with progressing village level energy in India. This section draws out conclusions and recommendations from them. Some key initial points are:

- An integrated approach needs to be taken to developing the overall energy 'package', including both energy supply and use, and making a reality of the opportunities provided by new, more efficient energy use technologies such as LED lighting in conjunction with substantial reductions in the cost of technologies such as solar photovoltaics which can provide power at an appropriate scale.

- Effective involvement of local partners is important, both in the initial stages to build local confidence and support, and once energy systems are installed, to ensure their sustainability through reliable operation and maintenance. Such local partnering and involvement provides villagers with employment and business opportunities, but requires attention to, and investment in, training as a sufficiency of skilled people can be a rate limiting factor in the deployment of village energy schemes.
- Villages and villagers need to have a strong sense of 'ownership' of energy initiatives, but different models of actual ownership of the energy generation and use equipment have been found to work: ranging from households just paying for the energy they use through to households and villages having a significant stake in the energy supply and use equipment.
- Affordability for households, and viability for energy supply businesses, always present challenges and various innovative approaches have been used, such as pay-as-you-go and payment by instalments, to squeeze economic schemes out of difficult financial contexts. Appropriately designed subsidies can be a 'make or break' factor.
- The reliability of energy supply is valued by customers – and can be a key advantage of local generation over a marginal grid connection – and important to the sustained economic viability of energy schemes. To achieve such reliability, suppliers of equipment of appropriate quality need to be identified, careful attention given to the design of schemes, and effective arrangements put in place for the operation and maintenance of equipment.
- A consistent theme of many of the case studies is the benefit that a reliable supply of electricity can bring in respect of educational opportunities, not just for village children, but for adults too. This arises from the provision of efficient electric lighting instead of (at best) kerosene lamps so that students can read when the sun goes down, and the powering of computers and tablets together with access to the web, and the step-change in educational opportunities that such connection brings.
- The story of cook stoves is that attention needs to be given to designing stoves to be sensitive to the cultural context in order to ensure their sustained use. If adopted, they can provide substantial health benefits through reduction in indoor air pollution, more sustainable harvesting of biomass as less is needed, and opportunities to re-direct labour to more productive activities as less time needs to be spent gathering fuel.

Off-grid rural energy in India is attracting funding and attention. Appropriate rural technology options have been proven and are available. However, the scaling up of business models faces several challenges. Many are still in the pilot phase. For example, Desi Power has devised a pilot project adopting a model presented in the SPEED case study. These options are not yet mainstream and projects are more or less limited to remote areas.

Off-grid energy is clubbed under decentralized energy in India. It is viewed by the Government of India as an interim step until the grid reaches the area. If the grid reaches the area and provides an alternative service to customers, investment and effort in off-grid projects may prove to be nugatory. This doesn't instil confidence in private investors to fund private entrepreneurs to develop off-grid energy systems. Further it doesn't necessarily motivate banks to extend financial loans to such projects.

Identifying the best energy mix for India needs to explore both grid-connected and off-grid energy options. Key considerations are:

- The need to achieve 100%, good, quality and reliable village electrification rather than the 10% which qualifies a village to be considered 'electrified' according to the definition of the Government of India.
- Energy access, social equity and climate change should be given equal importance. Holistic solutions are needed to develop an area's economy, for example providing income generation, education, empowerment and other such solutions to lift people out of poverty.
- Access to electricity is a crucial step towards economic development of rural areas. The priorities of economic development should be integrated into the design, implementation and impact assessment of rural electricity programmes.
- Priority should be given to achieving a long-term, subsidy free, financially stable energy environment.

The following findings and recommendations from the study aim to provide a pathway to address these issues.

Better integration of off-grid and grid-connected initiatives: When a village has a grid connection, or one is in prospect, locally generated electricity should be appropriately integrated with that provided through the grid to maximise the quality, reach and value of electricity provided to the people of the village. The situation should be avoided where the two sources of electricity are seen to be in competition, or where the establishment of, or prospect of establishing, a grid connection threatens the viability of local generation schemes.

A feed-in tariff for locally generated electricity may play a key role in enabling such transitions, and ensuring the continuing viability of local generation projects which may otherwise fail, or not even get off the ground. Several countries (for example, UK, Germany, and Spain) have been successful in implementing effective feed-in tariff energy policies, and their experience should provide a useful starting point for the Government of India to develop an appropriate scheme of its own.

Currently, as per the amendment to the Decentralised Distributed Generation (DDG) guidelines 2011, a private developer can feed in excess electricity to the newly set up grid. However, the extra cost of making the connection is to be borne by the private entrepreneur, which is as much as 10% of the project cost and can be prohibitive. The allocation of this cost should be reconsidered. In terms of electricity tariffs, the cost of producing electricity is often more than the return for feeding electricity into the grid.

Currently, 280 DDG projects have been planned but they are not necessarily grid interactive. However, projects need to be evaluated for this future possibility (Ministry of Power, 2011)

The need for ambitious off-grid energy targets: Some off-grid energy targets have been set for remote areas: for example, under the National Solar Mission, 20 million solar lanterns are to be distributed through State-run franchises. A few interviewees suggested that the targets for off-grid standalone solar systems could be more ambitious. It is recommended that initiatives under the grid connectivity scheme to meet the energy needs of villages should also include the distribution of solar lanterns or solar home lighting systems to help fulfil the goal of providing 100% village electrification. Similarly, micro/mini-grids can co-exist with the installed grid in rural areas.

Better sharing of information: Rural customers are often unaware of appropriate rural technologies. Innovative schemes exist on paper and in 'pockets' of NGO and social enterprise programmes, but it was consistently observed that there was a lack of awareness of off-grid electrification options in rural areas. There are several Government support programmes which are potential sources of financial support to projects, but entrepreneurs often don't know about them. Different wings of the Government ministry run their own rural electrification schemes and they are often not aligned. It is recommended that policy makers should be empowered with social media skill sets in order to reach out to the wider audience, possibly through increased involvement of young people. For example, policy announcements could be made on an MNRE twitter and Facebook page: new opportunities provided by information technology can play an important role in bridging the information gap between policy makers and stakeholders.

It has also been recommended by aid agencies that the Government maintain a single point organization contact at a grassroots level for better information sharing and implementation of off-grid energy projects.

Lack of information on good quality products in the market: There is a lack of reliable information on off-grid energy products in the market. For example, there is a lack of popular websites, guides or portals which rate the quality and reliability of the products of solar companies.

Need for retail network for renewable energy off-grid technologies: In order to increase access to solar technology, the Government of India initiated the setup of Aditya Solar shops. However, there are not enough of them. For example, villagers from remote areas of Sundarbans, are able to access solar household lighting systems only in Calcutta. And at retail outlets in Calcutta, they are unable to afford the upfront payment for the solar lighting systems.

Improving access to affordable financing: Financing of schemes is a problem, both because interest rates are too high, and because venture capital tends not to be given to concept-based social enterprises (there are lots of pilot projects, but approaches aren't considered proven). Such lending as does occur tends to be very solar-centric, and Government agencies and banks are selective in the scale of off-grid projects that they fund. There should be more emphasis on lending to other off-grid energy solutions, such as micro-wind and micro-hydro, and on funding all viable scales of off-grid projects. Entrepreneurs assume that it is difficult to access financing from banks and often have little confidence in private financial institutions. In part, this is due to an information gap between financial support programmes and entrepreneurs, which needs to be addressed.

Tedious paperwork for the bank: Even where banks are willing to extend loans, processing the paperwork is often a time consuming process.

It is recommended that institutional capacity for making loans to rural renewable energy projects is enhanced and that processes are streamlined. For example, NABARD is in charge of disbursing funds to the local and regional banks, but it is primarily set up to make agricultural loans, and the solar financing institution system is fairly new. Therefore the Indian Renewable Energy Development Agency Ltd, (IREDA[18]) could play a role in subsidy funds disbursement, relieving NABARD of the institutional cost of solar financing.

Several entrepreneurial businesses were found to face challenges in reaching out to banks and government institutions to make initial connections, build relationships and sustain them over a period of time. At the same time they must ensure that their distribution, operation and maintenance activities continue efficiently. Such small and medium enterprises (SMEs) are often short staffed, and paperwork has been a major impediment and time consuming process.

18 *IREDA is a Public Limited Government Company established in 1987, under the administrative control of* Ministry of New and Renewable Energy (MNRE) *to promote, develop and extend financial assistance for renewable energy and energy efficiency/ conservation projects with the motto :* " Energy for Ever" www.ireda.gov.in/

From the case studies, Prakruti (Micro–hydro SME) devised a smart business model solution to create enterprise branches. One branch looks after the innovation, manufacturing and technology building. Another branch oversees the execution of projects which involves follow ups with the bank, government institutions, approaching customers and distribution of the technology.

Accessing government subsidies: Private entrepreneurs are often unable to access subsidies due to a policy-entrepreneur gap. Even if they do, subsidies often reach them after the project has been sanctioned and is being implemented. Initially the entrepreneur has to raise finance by himself and this can prove challenging without a subsidy. Even though subsidies of 90% of the project cost may be provided, entrepreneurs have found it difficult in the past to raise the remaining 10% of financing as loans from banks. There is a mis-match of cash flow to implement the project and the subsidy doesn't pay for up-front project expenses. However, the Government has to incorporate risk mitigation in its procedures for sanctioning subsidies. Innovative approaches are needed to resolve this tension, potentially including two-stage subsidies which are able to cover the developer's up-front costs

Need for better evaluation and information dissemination: The Government is yet to extensively evaluate and monitor existing off-grid success stories in different pockets of India. This will help it build confidence in this sector and cater to the needs of future development of this sector through a feedback process. Government officials are often given a positive picture by project developers on their project visits. Thus, they are unable to evaluate projects, potentially deriving false conclusions about the design of future initiatives from what is presented to them. Similarly, the Government lacks information on why off-grid business models have sometimes failed to be scaled up in other parts of the country. More systematic evaluation and synthesis of experience should be undertaken in order to develop a more accurate picture of progress and causes, so that future policies are better informed.

There is an urgent need for an official off-grid network which enables private entrepreneurs and NGOs to have constructive dialogues and to share information about funding opportunities, suppliers, factors in project success/failure etc. For example, the micro-finance network boosted the sector by bringing key stakeholders together and developing uniform standards to re-structure the sector. The off-grid network will create benchmarks for off-grid rural energy project developers.

Need for capacity building: There are not enough trained people to support the deployment of renewable technologies: e.g. electricians/technicians trained in problem diagnostics for micro-hydro, solar and biomass technologies. Government-led training schemes are needed which will substantially enhance the capacity of rural populations to design, install, operate and maintain renewable energy systems.

In entrepreneur-led off-grid projects, it has been observed that the entrepreneur is the sole driver of the project and often lacks expertise in one or another thing. Hiring new expertise can be challenging and expensive.

Building a favourable ecosystem to sell the product: In order to provide a quality product to the customer the enterprise has to build a favourable ecosystem. However, the ecosystem needs to be built gradually and be sustainable in the long term. A key need, often not currently met, is for entrepreneurs and social enterprises to be able to charge prices that cover their costs together with an adequate profit margin. Benchmark costs, set by policy makers, potentially have a role but would need to be based on rigorous cost estimates and appropriately reflect the experience of the existing players in the market.

The development side of decentralized energy hasn't been emphasized enough. The benefits of off-grid energy solutions impact health, education, and livelihood income generation programmes. Developing the decentralized energy sector adds value for every Ministry of the Government of India. A directive should be issued to each Ministry highlighting the benefits of localised solar power initiatives. For example, Selco's 'light for education' model targets education, rural development and environmental development simultaneously. Similarly, Panchayats have been issued with a computer for each village, but reliable electricity is not available for the computers to work. In this context, the solar energy policy needs to be an integrated development based policy. Another example is that to realize the educational benefits of Aakask tablets, reliable quality electricity is key.

Photo: Ruchi Jain

Photo: Ruchi Jain

4.8 References for Chapter 4

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4.9 Interviewee List:

No	Name	Organization	Designation
1	Aparna Khandelwal	Ckinetics	SPEED
2	Jyoti Deka	Ckinetics	SPEED
3	Sunanda Patwardhan	Pragati Prathisthan	Co-Founder
4	Dr Debajit Palit	TERI	Project Manager & Senior Researcher
5	Mr Rahul Sharma	TERI	Researcher
6	Mr Karl Segschneider	GIZ	Senior Advisor, RESRA
7	Jessica Singh	GIZ	
8	Utparn Dubey	Development Alternatives	TARA - Technology Action for Rural Advancement,
10	Dr Hari Sharan,	DESI Power	Co-Founder
11	Dr Ashok Das	Desi Power/SUN Moksha	Managing Director
12	Mr VK Jain	Biomass Energy, MNRE	Director, MNRE
13	Dr Ahmad Raza	Decentralised PV,MNRE	Director, MNRE
14	Nikhil Jainsinghania	Mera Gao	Director
15	Mr Anjan Ghosh	Tata BP Solar	Marketing Director
16	Mr Neeraj Sharma	Rural Electricity Corporation, RGGVY	
17	Mr Prasanta Biswal	Selco Solar	
18	Miss Surabhi	Selco Solar	
19	Siddharth Pathak	Greenpeace India	Political Officer Climate and energy
20	Srinivas Krishnaswamy	Vasudha Foundation	Co-Founder
21	Mike Macharg	Simpa Networks	Co-Founder
22	Mr Deshmukh	ARTI	Director
24	Dr . S. Gomathinayagam,	CWET	Director
25	D. R. Muralidhar	Prakruti Hydro Labs	Co-Founder
26	Vinay Jaju	ONergy	Co-Founder
27	Ekta Kothari Jaju	ONergy	Co-Founder

Chapter 5: Case studies from Tanzania & Ghana

Author: Meghan Bailey

5.1 Introduction

Over 90% of sub-Saharan Africa's energy consumption is derived from firewood and wood charcoal. The vast majority of Tanzania's and Ghana's wood fuel is extracted from indigenous trees by the sub-continent's poorest rural communities, which depend on environmentally unsustainable secondary livelihoods such as charcoal production as a last resort to generate income. Loss of forest cover leads to higher rates of soil erosion and the risk of desertification, which then threaten communities' primary agricultural livelihoods. This further increases the need for alternative means of income generation.

For rural subsistence-oriented communities, environmental degradation and poverty are inextricably linked. Extreme poverty forces families to unsustainably extract what resources they can from the environment, yet these families are equally dependent on their environment for survival. This has created a cycle of communities destroying their most important resource in an effort to ensure a livelihood and provide for their minimal energy needs. This dangerous phenomenon is most prevalent in rural communities, leaving their small amounts of income at risk in combination with high transportation and communication costs which isolate the typical resident from most markets.

The *Poor People's Energy Outlook 2012*, published by Practical Action (see Practical Action, 2011) offers some compelling findings on sub-Saharan Africa vis-à-vis developing nations as a whole:

"[M]ore than half of people in developing countries cook with solid fuels, with more than three-quarters doing so in sub-Saharan Africa. While in developing countries as a whole, around a quarter use some kind of improved cookstove, less than 10 per cent of those using biomass in sub-Saharan Africa use an improved stove. In total, 37 per cent of people in developing countries have access to 'modern fuels', such as electricity, liquid, and gas, but only 17 per cent in sub-Saharan Africa" (p65).

The global discrepancies in energy services are clear, with sub-Saharan African countries the most disadvantaged.

Population growth is currently outpacing new energy connections, meaning that each day the proportion of sub-Saharan Africans without access grows (Practical Action, 2011). Lack of energy access in rural areas also provides a strong disincentive for skilled professionals such as teachers and clinicians to return to their home communities after receiving education elsewhere or for skilled professionals to immigrate. The precise impacts of rural-to-urban migration and 'brain drain' as a result of energy scarcity alone are difficult to calculate, but the loss is systemic and jeopardizes the viability of rural communities across the sub-continent.

For the millions of sub-Saharan Africans that are currently located far from their national grids, decentralized energy generation is a more viable option – certainly for the short term and perhaps in the long term as well (Joint Research Centre, 2011). Lighting Africa (2010) reports that as a result of blackouts, nearly 30% of those that are connected to established grids could be considered 'under-electrified'. Further, there are 200 million Africans in possession of mobile phones who must rely on off-grid energy to charge them – often at great expense in proportion to their daily income (PPEO, 2011).

Discussing informal settlements (commonly known as slum areas or shanty towns in much of sub-Saharan Africa) is beyond the scope of this review, but it is noteworthy that many of the challenges faced by rural subsistence-oriented communities are comparable – lack of land tenure, insecurity, ambiguous legality and government jurisdiction in informal settlements create conditions that mirror their rural counterparts' conditions of isolation, transport hurdles and credit scarcity. All are conditions which make these communities particularly hard to serve, as a result of which decentralised options may remain the most viable and adaptive options to energy scarcity and fuel poverty.

Fuel poverty is one of several interdependent and mutually reinforcing conditions of poverty and morbidity within rural communities in sub Saharan Africa. Scarcity of energy is inextricably linked with environmental degradation which has cast-on effects for water security and food production. Projects to address energy scarcity and fuel poverty are problematized by the same short-comings experienced by a wide variety of poverty reduction efforts, which are largely tackled by international and community-based charitable organisations with greater or lesser efficacy. Such efforts, and the energy sector as a whole on the sub-continent, are further disadvantaged by a severe shortage of a technical expertise within the physical sciences and other complementary disciplines. These cross-cutting points are essential to highlight before considering the suitability and efficacy of any given energy intervention in sub Saharan Africa.

5.1.1 Traditional Biomass Consumption

Ghana and Tanzania's voracious demand for fuel wood has created a significant market opportunity, which could be capitalised on by the use of decentralized renewable energy. The vast majority of fuel wood is harvested illegally from protected indigenous trees, and hence charcoal is produced at a small-, rather than, large-, scale. The market is therefore extremely decentralised and characterised by a very high level of inefficiency, substantially driving up unit costs. Despite many areas' susceptibility to desertification in both Tanzania and Ghana, a massive informal supply chain of wood products from local indigenous trees has developed between rural, peri-urban and urban areas. Some data are available on charcoal consumption in neighbouring Kenya – the annual consumption of charcoal in Kenya's coastal province alone is estimated at €130 million ($173 million). The sale of charcoal from felled local indigenous trees is unsustainable and illegal in both Ghana and Tanzania, but lack of alternatives for fuel and income generation combined with poor enforcement mechanisms continue to make the sale and consumption of illegal charcoal commonplace.

5.1.2 Energy and water security

The provision of safe and reliable water supplies remains a major challenge throughout sub-Saharan Africa. Progress towards water security is stunted by energy scarcity – from both limiting boiling time of drinking water to economize on fuel and by limiting possible technologies for pumping and filtration (as well as the tools to service the infrastructure) to manual designs. The track record of rural water systems is particularly poor, with an estimated 30-50% of them in disrepair or otherwise non-functional (Baumann, 2005; Harvey and Reed, 2006). According to the World Health Organization, 53 percent of rural residents in sub-Saharan Africa are without sufficient and safe drinking water, in comparison to 17 percent of urban and peri-urban residents (WHO, 2000). Sufficient water access is defined by the United Nations Children's Fund as the "...[p]roportion of population with access to an improved drinking water source in a dwelling or located within a convenient distance from the user's dwelling"(UNICEF, 2006). Rural areas have historically been the hardest to serve within water provision strategies and the uptake rates and sustainability of service delivery reflect this challenge.

To meet the Millennium Development Goal (MDG) target to cut the proportion of people without access to water in half by 2015, water provision projects will need to be considerably scaled-up and the issue of sustainability, aggressively addressed (Harvey, 2008). Climate change and other global environmental changes add to the uncertainty of future water provision. With much of sub-Saharan Africa expected to become warmer and dryer (Thornton et al., 2009), the risk of drought and water scarcity is immense. The design and delivery of water provision programmes will need to keep pace with an increasingly unstable set of environmental conditions and natural assets.

5.1.3 Scale of energy service delivery: households vs. communities

Unlike in high-income countries where energy services are generally managed by public entities or through private-public partnerships at a large scale, rural energy supply services in much of sub-Saharan Africa are managed locally, if the service is available at all. Communities and households have been the favoured units of many energy project implementation designs and subsequently, major actors in their management and operation, for a number of reasons. Harvey and Reed (2006) outline three fundamental drivers that have been instrumental in shaping current mainstream community-based management schemes since the divergence from centralized management by national governments beginning in the 1980s:

1. “Poor service delivery and performance by government institutions.
2. Suitability to the project approaches adopted by non-governmental organizations (NGOs) and donors.
3. Western cultural idealization of communities in low-income countries.”

Multiple studies have shown that local ownership alone does not automatically translate into a sense of collective responsibility within a given community, nor does it necessarily provide incentive for willingness-to-pay for up-keep costs (see Harvey and Reed, 2006, p.370). Both energy and water projects implemented at the community-level rather than at the household level, more so than other sorts of poverty relief interventions, are particularly prone to artificial groupings of project beneficiaries. The community is generally a set of households within a geographic area that a given energy supply can realistically serve, regardless of the heterogeneity in ethnicity, religion and socio-economic status that might exist within those boundaries. As such, assumptions about solidarity and capacity to coordinate and mobilize internal resources are often faulty (Harvey and Reed, 2006, p.368); they exemplify the tendency to project cultural idealism on so-called collective societies, and in doing so, oversimplify the characteristics of project beneficiaries. This provides a partial explanation for the poor track record of community-level rural energy provision, a problem which needs addressing.

Historically, the most resilient unit of human populations to environmental change is the household (Netting, 1993). Anthropological studies suggest that households have a strong track record of buffering a wide variety of disturbances because of their unique ability to reorganise themselves (Thornton and Manasfi, 2010). Harvey and Reed (2006) note that service delivery at the household level, rather than the community level, holds much promise because of a deeper sense of ownership and personal investment. Decentralised energy technologies are inherently well-placed to meet household level needs in comparison to other projects for poverty relief and development. Engaging beneficiaries at multi-scales (household, community-level and so forth) is one potential method of reducing vulnerability of such programmes and creating greater energy resilience.

One of the characteristics of community and household level focused energy supplies that is desirable for both government and aid agencies is the ability to phase-out, or maintain lower levels of, involvement – or in the case of social enterprises, maintain lower levels of support. The stated goal is to build local capacity to run services autonomously or with very little external support. Building local capacity to maintain services in the long term is the primary strategy to foster sustainability of community-based rural energy projects, whereby international NGOs can phase out their direct involvement and communities do not need to rely on national governments with a poor track record of project maintenance and servicing. It also lends itself well to development funding cycles, which tend to be shorter term. This is a striking contrast to the service design of energy supplies in high-income countries.

The push to engage beneficiaries at the local level has, over time, given rise to a host of local social structures for both representation and active management. However, studies suggest that projects have a higher rate of success if managed by a pre-existing community group, as opposed to a group formulated by external actors for a specific project (see Harvey and Reed, 2006, p.369).

5.1.4 Energy Research Capacity Building

The landscape of village level energy provision assistance in Africa is changing, with an increased focus on developing highly skilled Africans that are better placed to design, service, monitor and lobby for, appropriate energy generation. The International Science Programme (ISP) of Uppsala University is a case in point, which is beginning to scale up partnerships with higher education institutions in both Tanzania and Kenya for training in the physical sciences (see http://www.isp.uu.se/).

Reliance on foreign consultants for technical services drives up project costs for implementation and maintenance, and denies would-be scientists the opportunity to play an active role in their country's development. 'Brain drain' of the few skilled professionals also strains the system – either by poaching trained Africans or by bringing the highest potential African students to study abroad, where they may choose to stay and build a life outside of Africa. Current academic institutions also tend to have large proportions of staff nearing the age of retirement, meaning the situation will worsen if not addressed aggressively.

ISP identified several barriers to graduate and post-graduate training in sub-Saharan African educational institutions. Inadequate primary and secondary education is a common problem, whereby students may need to take preparatory courses before beginning their main courses. Many post-secondary institutions lack text books, demonstration equipment etc. that is imperative for instruction. Funding is often not the only prohibitive barrier. Students at the University of Legon, Ghana reported being unable to purchase books from online outlets such as amazon.com, even with cash in-hand, because Ghana is considered a 'high fraud zone' by distributors. Equipment often has prohibitively high up-front costs and those that are able to import the machines necessary often struggle to source the labour to service them.

The ISP has been directly supporting research groups in Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Tanzania, Zambia and Zimbabwe. However, they are currently undergoing an institutional shift and aligning fiscal supports with the Swedish International Development Agency's (SIDA) priority development funding programme area. As such, funding support will be phased out of Ghana and Nigeria and ISP will place a stronger focus on southern and eastern Africa. The trend away from western Africa for both programming and research is common in the field of international development for a multitude of reasons, including limited trade links and poor tracks records of progress/success in the harder-to-serve region of West Africa.

Other networks for academics have also begun to take shape; researchers in Africa have started to network, consolidate funding proposals and collaborate on research projects. The African Network for Solar Energy (ANSOLE) is a prime example, which meets annually in-person and has an online presence bringing together academics from across the continent as well as collaborators from developed nations. They are focusing on research areas in which they are better placed to have a strategic advantage to push research forward such as solar thermal energy and organic solar cells, rather than more established specialties such as photovoltaic technologies, concentrating solar power and solar fuels research (e.g. artificial photosynthesis) in which significant research contributions from less established institutions are less realistic. The network has been instrumental in connecting high potential students with doctoral studentships between nations – a key strategy to improve access of sub-Saharan African students, in particular to more established research institutions in North Africa. A formal student exchange programme across research institutions and countries within the continent is another goal of the network for the medium term. In the long term they aim to establish regional research centers of excellence on solar power throughout the continent.

Individual bilateral aid agencies have also made contributions in this field. The Japanese International Co-operation Agency (JICA) is collaborating with the Ghanaian Ministry of Energy. A priority of Japanese bilateral aid in Ghana is electrification with a particular focus on making photovoltaic (PV) solar systems available. The long term goal is to have all households and commercial establishments connected to the national grid. PV solar systems are viewed as a high-potential interim solution to connection scarcity in the short to medium term. To this end, beginning in 2008, JICA has been supporting the Kwame Nkrumah University of Science and Technology (KNYST) and the Tamale Polytechnic with teaching and testing equipment for PV panels as well as the skills to develop and monitor a PV unit certification scheme. Certification schemes and other regulatory frameworks have been established in Ghana and many other sub-Saharan African countries to reduce the amount of low quality products and counterfeit products being imported into the country, most notably from China.

5.1.5 Case study Countries

When considering energy access and the scope of energy interventions on the ground, it is useful to examine the facilities and programmatic base of particular countries. Ghana and Tanzania have been selected for the purposes of this scoping study. In absence of a thorough overview of energy landscapes in sub-Saharan Africa, these two countries provide a glimpse of the on-the-ground reality of energy programming in rural subsistence-oriented communities in eastern and western Africa. By exploring several interventions in both countries and identifying key stakeholders, the scoping study lays out the groundwork for future collaboration, regional networking and capacity building with EASAC, MCSC and their partners.

Universal grid access is the long term goal of the governments of both countries with various interim measures for the short and medium term. As such, much of the programming and many of the decentralised technologies discussed herein are conceptualized as time-sensitive place-holders while grid development and capacity catches up with demand. However, in some cases individuals and institutions are choosing to go off-grid, preferring to instead manage their own energy generation rather than rely on national grids that suffer from surges, outages and volatile pricing. For many, the current availability of grid-based power does not instil confidence. Decentralised options may remain the preferred energy source and may prove to create a more responsive and resilient energy landscape for at least some parts of many sub-Saharan African countries. As such, the projects discussed should be considered both as bridging solutions to universal grid access, as they are largely intended by national governments, as well as potential long term energy solutions for hard-to-reach remote communities.

5.2 Ghana: Overview

Ghana is one of the best-performing economies in Africa. By improving policies and institutions, and investing in infrastructure and basic services, the country has experienced high growth rates during the last decade, averaging about 6% per year. Poverty levels were brought down from 39.5% in 1999 to 28.5% in 2006 (with extreme poverty falling from 27% to 18% during the same period). It has also become one of the few African economies that can attract significant foreign direct investment (FDI) in-flows (Government of Ghana, 2008). The Government of Ghana oversees the energy industry through the Ministry of Energy (MoE), which supervises activities through 4 key bodies: the Ghana National Petroleum Corporation (GNPC), the Tema Oil Refinery (TOR), the Voltic River Authority (VRA) and the Electric Company of Ghana (ECG). The ECG was formed to operate as the single distribution utility of electricity created by the VRA and transmitted by a separate entity entitled the Ghana Grid Company (GRIDCo).

The MoE estimates that €10 billion ($ 13.2 billion) of investment is needed to bring the country's energy sector up to industrial standards – primarily in the area of oil and gas (€6.8 billion ($ 9 billion)) and the energy sub-sector (€3.2 billion ($ 4.2 billion)) – and to reach its estimated potential as an energy exporter (Ghana Business News, October 2011). Ghana's oil and gas prospects are significant and stretch across the country's shoreline. All the major finds in the last wave of exploration which began in 2007 have been offshore. Similarly, the unexplored Volta Basin (which covers 40% of the country's land mass) is believed to have significant oil and gas reserves.

The energy sector is currently undergoing structural adjustment and other reforms after the production of oil in commercial quantities began in 2010. Public sector reform and privatisation measures are common elements of Ghana's reform policy for the energy sector among other industrial streams (African Economic Outlook, 2011).

While universal grid access remains the long term goal of the MoE, the focus remains on interim advances. The Ministry initiated a stimulus package in collaboration with rural banks to make the purchase of home solar systems more affordable for rural residents. Home solar systems typically have high up-front costs and slow but consistent payback periods, which subsistence-oriented individuals and households without access to credit or savings are poorly placed to capitalize on. In collaboration with rural banks, rural residents in select communities with little or no grid access are able to purchase home systems through a combination of loans (designed as microfinance schemes) and technical input subsidies through designated and accredited distributors. According to Ghana Business News (May 26th, 2011), the Minister of Energy, Dr Oteng Adjei, outlined two main goals of the project at its inception: (1) bridging the gap between rural and urban communities and (2) ensuring universal access to electricity across the nation by 2020. Initially, 20,000 home lighting systems will be made available with support from bi-lateral aid and co-implemented by development agencies.

To meet the 2020 goal of universal access, interventions like this and others will need to be scaled up considerably. The Ministry is also directly providing solar systems for public street lights and rural clinic (vaccine) refrigeration. National benchmarks have been set for product quality. Designs such as those of Barefoot Power (recipient of Lighting Africa's 2011 solar powered LED lamp design competition, see Section 5.8) have been officially endorsed.

Home solar systems are also increasingly in demand for the 'under-electrified' – usually residents in peri-urban or slum areas – where prices are increasing rapidly in Ghana. Blackouts impede the development of business enterprises – both small and large – and disrupt the functioning of households. Reliability of energy supply creates reliance on expensive and carbon-intensive diesel generators. The additional cost also makes enterprise development disproportionately more difficult for small business owners. The country is also currently suffering from a nation-wide scarcity of liquid petroleum gas. This is largely the result of commercial use of subsidized fuel. The subsidy was intended to make household fuel affordable but increasingly it is being used to fuel vehicles and commercial enterprises due to the rising cost of petrol (Ministry of Environment press release, October 6, 2011).

Increasingly, Ghana is looking east for differing terms of aid and foreign investment. Economic co-operation between China and Ghana is growing rapidly. The largest flow of investment from China to Ghana has been in the energy sector. €420 million ($ 562 million) was invested for the construction of the Bui hydroelectric dam. According to the Ghana country briefing of the African Economic Outlook (2011), China's investment in hydroelectric power will add 400 MW of electricity to the national grid, increasing grid capacity substantially. Ghana has also received interest-free loans from China for the development of public entities, including energy utilities, as well as road, rail, water and education.

Increased collaboration with China has raised many concerns within Ghana and other sub-Saharan African countries who are concerned about tenure and terms of trade related to natural resource rents. Public opinion is highly mixed on the subject. Regardless, collaboration is underway in Ghana and many other sub-Saharan African countries. It is unclear how such collaborations wil affect development trajectories but the trend will certainly alter the donor landscape which has traditionally been dominated by the aid agencies of Western Europe, North America, Australia and more recently, Japan.

5.3 Tanzania: Overview

Tanzania is the second largest economy in East Africa with growth rates projected at 6.5-7% between 2012 and 2013 by the International Monetary Fund (IMF). Rates of inflation are expected to decrease over the coming years and foreign direct investment is on a steep incline. Agriculture remains the foundation of the national economy, followed by mineral extraction and tourism. Close to 90% of Tanzanian's live without access to electricity (UNDP, 2010). A large proportion of them rely on expensive and often dangerous energy alternatives, including disposable batteries, charcoal, kerosene and diesel powered generators. Only a minority (10.5%) of the households are connected to the national grid, the majority of which are found in urban and peri-urban areas. In remote areas only 2% benefit from electricity use (Ashden Awards, 2007).

Unlike in Ghana, the government plans for increasing connectivity are inconsistent. One major barrier in Tanzania which has greater variance in population density is the variable costs associated with electrifying different regions of the country. Severe power shortages were experienced in January 2010 with major negative impacts on industry (African Economic Outlook, 2011b). The Energy and Water Utilities Regulatory Authority (EWURA) in Tanzania has developed regulatory guidelines for power projects entitled: Interconnections of Small Power Projects, which integrates small (generating up to 10 MW of electricity) and large (>10 MW of electricity) power projects.

Even in areas with grid access, individuals and commercial enterprises many wait months or even years for an individual connection because of backlogs in the applications for grid connections. As such, many are choosing to source electricity off-grid. Many customers of Zara Solar, featured in this scoping study for example, are located in areas serviced by the national grid but are choosing to purchase PV solar panels regardless. This has created an enormous market opportunity for decentralised renewable energy. There is considerable demand for electrification and the influx of cell phone use in remote areas following massive telecommunications infrastructural development in even the most remote areas of the country has added to the demand significantly.

Eastern Africa is also a regional center for energy innovation. A concentration of international aid agencies, UN agencies, private business interests and so forth, have created an environment in which networking, knowledge sharing and resource-pooling is more feasible than in other parts of the sub-continent. The few international distributors based in Africa are usually located in Kenya, Tanzania or Uganda to service much of sub-Saharan Africa, excluding South Africa. It also has unique trade relationships, such as its strong connections to the United Arab Emirates, from which it imports fuel oil, machinery and chemical appliances, aluminium, iron, steel, electrical instruments and consumer electronics in exchange for pearls and precious stones, fish, oil seed, grains and copper (African Economic Outlook, 2011b).

Large minority populations including Indian and Yemeni and Lebanese diaspora populations, also foster trade between Tanzania and their regions of heritage, which drives development of small, medium and large businesses, included several covered within this report. China is also becoming a major investor in Tanzania's energy sector. –For example, the National Development Corporation (NDC) of Tanzania recently announced that Sichuan Hongda Ltd from China is investing $ 3 billion (€2.25 billion) for a coal-fired power plant as well as 2 iron ore mines. Negotiations for a solar thermal plant are also reportedly underway (African Economic Outlook, 2011b).

5.4 Case Studies

Seven case studies, mostly based in Ghana and Tanzania, have been profiled to illustrate the challenges and opportunities of village energy provision in these two countries. It is very far from exhaustive of the models or scales of implementation that are currently operating in Africa. The examples presented are also not necessarily typical – rather they provide a helpful glimpse of some of the interventions with good potential to curb energy scarcity. Examples to the contrary are abundant and well documented.

The projects/companies profiled in this chapter are:

- Case study 1: Lebônê Solutions – Microbial Fuel Cells (Section 5.5)
- Case study 2: Katani (Sisal) - Biogas (5.6)
- Case study 3: EGG Energy – Battery Power (5.7)
- Case study 4: D.Light Design – LED Solar Lamps (5.8)
- Case study 5: Zara Solar – PV Home Solar Systems (5.9)
- Case study 6: Toyola Energy – Improved Cook Stoves (5.10)
- Case study 7: Eight19 – Pay-as-you-go Solar Systems (5.11)

5.4.1 Case study 1: Tanzania: Microbial Fuel Cells

A social enterprise with backing from Harvard University called **Lebônê Solutions**, recently completed a 3 month pilot study in Tanzania of their 'Dirt Power' project, using Microbial Fuel Cells (MFC) to provide direct current power for LEDs and small battery chargers (cell phones and radios, primarily). The word Lebônê in the Soho language translates literally to 'light stick'. The cells take advantage of one of Tanzania's most abundant resources – soil. Using other materials common to the African subsistence-oriented rural household, including manure, graphite cloth and chicken wire, the designers hope to further refine the design of the cell. They hope to build on the entrepreneurial spirit that African communities are known for to innovate further on the design.

This idea will resonate with anyone who has spent time in African countries and has watched small business-owners repair vehicles, homes, appliances and so forth by whatever means necessary. Under the right conditions with sufficient baseline training, MFC design and cell production could be capitalized on by enterprising individuals using locally available materials, including recycled materials. Lebônê currently holds a patented design for its MFCs, although the design itself is evolving and being tweaked with each stage of research and development.

Technology

The cells harness energy from the metabolic reactions of bacteria found naturally in soil and manure. The bacteria found in the soil/manure produce electrons while metabolizing organic matter (leaves, grass, food waste, etc.). The electrons are attracted to an electrode, which in this instance is a piece of graphite cloth, creating a chemical reaction – the byproduct of which can provide power to charge a cell-phone, or to operate a handheld radio or LED lamp.

The units can operate at any temperature as long as the soil is sufficiently moist to foster metabolic processes. As such, it is an example of a technological innovation that is robust to the environmental shifts that are expected in much of Africa as a result of global climate change.

The construction of MFCs, as well as their maintenance and repair, require minimal training and only low levels of numeracy and literacy. For most people, the basic skills could be transferred in a two-day workshop or training event. This is standard practise for many capacity development interventions within community based organisations for other sectors, such as the introduction of alternative agricultural methods and inputs, water purification units and so forth. The only component of the unit that is technically complex is the circuit board. Lebônê is currently trying to simplify this component to facilitate the expansion of their product. Regardless, the skills required are not beyond the capacity of a typical "fundi" - a Swahili word meaning a repairperson (usually referring to a man, but not exclusively).

A major advantage of the use of locally available materials, beyond accessibility, is that they will likely be less susceptible to crime than other technologies for decentralised energy generation. Unlike PVs which are imported, expensive and prone to theft, the components that make up a MFC are in relatively low-demand. As such, larger units or several MFC units wired together may be a better energy solution in some circumstances for public infrastructure such as schools, which go unpatrolled during the evenings.

Partners & Financing mechanism

Original investments for the pilot project in Tanzania came from private investors and a grant from the World Bank (€150,000 ($ 200,000)). The project is gaining increasing amounts of recognition and awards (see newspaper articles included under media sources) which bode well for future funding and scaling up of project trials and implementation. Lebônê Solutions are now expanding to Namibia and refining prototypes – ideally to include a greater variety of locally available materials and improve efficiency.

Process and Approach

Development of the unit has been bottom-up, which is distinctive. The Lebônê team is critical of the mainstream trajectory of off-grid energy technological development for developing areas, which is largely a process of reducing or simplifying technologies developed elsewhere to the African context. In contrast, Lebônê's MFC was piloted in Leguruki Village, Tanzania in its development infancy. They wanted to see how households would react to the technology right away and how the batteries hold up at household level. Their initial pilot was a very small sample of 6 households within one village who ran an LED light each night for three hours powered by a MFC made of manure, graphite cloth and buckets. A copper wire (common chicken wire is now used instead) was used to conduct the current to a circuit board in each of the participating households. They hope to eventually reach American and international markets, but wanted the testing to begin on-the-ground in Tanzania and for the unique needs of subsistence oriented rural African communities to be reflected foremost in the unit's design before considering other aspects such as economies of scale, sourcing etc.

Business Model

Their research and design ethos is reflected in their business model. They would like to see a new business model for rural African energy generation emerge and become commonplace, whereby technologies are tested and developed in Africa first; local distributors are engaged in the preliminary stages; and then if it makes sense to do so, to make fuel cell technologies available to distributors in developed nations.

Key Challenges

Making the units sufficiently cheap: the price of each unit may vary considerably depending on the quantity of materials that are currently available. Another factor that may affect pricing is the model adopted for training the individuals who will produce and service the units at household level. There are a number of programmatic models for dissemination that could be adopted at a large scale which will be further explored in later stages of the company's research and development. Each of the models at their core are essentially trade-offs between a number of variables. For example:

- Developing higher levels of fluency with the technology and therefore the capacity for the individuals charged with disseminating the units to adapt the units to differing needs. The obvious trade-off therefore being greater investment in low-level staff or local entrepreneurs vs. reaching the greatest number of households in-need by requiring only basic knowledge of production and repair.
- Keeping competencies 'in-house' such as through certification schemes, or allowing production to take a more evolving and adaptive path.

These and other implementation decisions will be made in future and will likely play a considerable role in the price per unit as well as overhead costs associated with monitoring and evaluation.

Presenting the units in a socially acceptable manner: this is a cross-cutting problem related to rural electrification off the grid, especially for technologies that differ considerably from technologies that the community at hand has been previously exposed to, such as technologies powered by 'dirt'. Perceptions of value associated with different technologies can have incredible influence on adoption rates. Bringing 'dirt' into a home may not be socially acceptable in all instances, at least not initially. Adoption of off-grid technologies can be problematic in this regard, as some communities have very strong preferences to be linked to the national grid which is often a source of pride or prestige. There is a substantial literature related to socially and culturally appropriate introduction of technology to this end that is beyond the scope of this review. It is however, highly relevant for the design of rural electrification projects. A short sample of the relevant literature is listed at the end of the chapter.

Ensuring sanitation: thorough hand-washing after handling soil/manure will be crucial, otherwise users can be susceptible to diarrheal disease and infections including eye infections to name but a few examples. Hand-washing consistent with regular practise after latrine-use, involving a small amount of water and soap or ash, is sufficient. It may be appropriate to pair MFC distribution with existing sensitization programmes for community-led total sanitation (CLTS), which are commonly a component of community development initiatives in Tanzania.

Media coverage

New York Times (2008) http://www.nytimes.com/2008/11/11/giving/11AFRICA.html?_r=2&scp=1&sq=lebone%20giving&st=cse

MIT News (2009) http://web.mit.edu/newsoffice/2009/ideas-popmech.html

Popular Mechanics (2009) http://www.popularmechanics.com/science/energy/biofuel/4332914

5.4.2 Case study 2: Tanzania: Biogas

Katani (Sisal) Ltd and Mkonge Energy Systems Ltd. based in Tanga, Tanzania are installing anaerobic digesters in each of their sisal plantations to produce biogas and biofertiliser. Sisal grown on the Coast of Tanzania and border of Kenya is one of the most important cash crops used to produce carpets, ropes, clothing, yarns and composites. Traditionally more than 95% of the sisal leaf is considered waste. As such, waste management is a constant concern, with many businesses choosing to dump waste pulp illegally on land or in rivers. Tanga Region has a population of around 1.7 million, with an annual growth rate in population from 1998-2002 of 1.8% and a population density of 60 persons per square kilometre. With the growing population density of Tanga Region since 1957, forests have become over exploited and wood is now too scarce to support income needs.

Technology

Beginning in 1999 Katani Ltd developed a small holder and out grower sisal farming system on the land owned by the company. A biogas plant to convert sisal biomass to biogas was developed to run electricity generators. They intend to become fuel self-sufficient and no longer use the grid, which is prone to frequent outages. The sister companies plan to fuel their processing plants as well as surrounding communities. This system is used for several stages of energy consumption. Process heat is used for drying fiber – a by-product of the sisal pulp. In normal production methods, approximately 4% of plant residue was either burnt or left to rot naturally giving out methane and carbon dioxide. However, 80% of sisal waste is suitable for bio-energy. Remaining portions of waste can be used for organic fertilizer for farms. Biogas is derived from the sisal waste at the Sisal decortication plant. The decortication plant uses up most of the electricity and the excess is used to supply domestic quarters within the estate. Another use of the excess power from biogas is to distribute is to surrounding communities for cooking and lighting requirements.

Details of the performance of sisal pulp waste anaerobic digestion for the production of biogas in Tanzania can be accessed online here: http://www.ajol.info/index.php/tjs/article/viewFile/18419/29873

Partners & Financing mechanism

The project was implemented in several phases. The initial investment for the pilot project (phase one) was supported by the United Nations Common Fund for Commodities (UNCFC) the United Nations Industrial Development Organisation (UNIDO) and the Tanzanian Government (€262,500 ($ 350,000)). It is managed by UNIDO and a 16-member coordinating committee which includes representatives of the United Nations Food and Agricultural Organisation (UNFAO) , UNCFC, UNIDO, the Tanzania Sisal Board (TSB), Katani Limited, the Sisal Association of Tanzania (SAT) and other government ministries. The SAT and TSB have been established by Acts of Parliament.

Process and Approach

Katani Ltd, has been assisting farmers in registering their community based operations and granting them access to low interest loans. Their approach to community engagement within the area models the ethos of corporate social responsibility. It facilitates connections and repayment of loans to the financiers. For example, in 2006, €0.9 million ($ 1.2 million) in loans was mobilized by Katani for the farmers; further procurement of €2.5 million ($ 3.3 million) in loans is currently being negotiated. The Mkonge Umoja Savings and Credit Co-operative Society with a seed capital of around €375,000 ($ 500,000) was set up by the firm. Katani has been assisting in strengthening farmer-led community based organizations to provide them with a variety of production and delivery services. To this end, the project has already benefited 1,000 families with incomes and electricity through the grid. Figure 5.1 outlines Katani's market map,

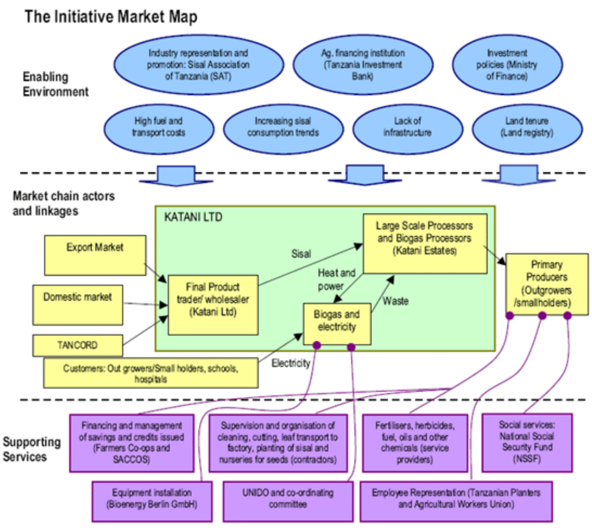

Figure 5.1: Sisal Biogas Initiative Market Map (Source: Practical Action, 2009)

Business Model

The biogas project has been profitable so far. Additional support from UN agencies and the government has allowed the project to absorb high upfront costs and include community benefits. Katani Ltd plans to implement a system of mini-grids through which bio-based electricity can be transmitted at low cost. This will ensure earnings all year round for farmers, paid monthly for the supply of their products to a guaranteed market. For every tonne of fibre produced by farmers, Katani Estates pays €280 ($ 370) to primary producers and €640 ($ 850) per tonne for processing. Katani Ltd has established marketing channels to buy and sell farm inputs to sisal producers. Contractual arrangements have been established between other providers of services and Katani for the work carried out by them, for which they receive a fixed income. Sisal is a drought resistant crop, thereby providing greater financial security to farmers during periods of abnormally low rainfall, which are expected to increase in frequency and severity as a result of climate change.

In Phase 2 the biogas project is planned to be scaled up to 300kW from 150kW at a coat of €350,000 ($ 472,000). Phase 3 will include the development of piping to supply excess biogas for use by households. Nine other commercial-scale plants will be established at the other nine factories owned by the company, each with the capacity to produce 1 MW of electricity. This will give Katani an overall output of 10 MW of electricity, together with an output of process heat for other uses. Figure 5.2 outlines the company's relationships with external actors and its expectations thereof:

Key Challenges

- Labour, land and production taxes discourage farmers from expanding farmland growing Sisal.
- Accessibility of investment funds for agriculture has been a challenge in Tanzania. Firms with foreign connections have been able to fundraise and access finance for themselves, but national enterprises experience greater difficulty. Currently, one of the only local financing sources available to medium-size

enterprises is through the Tanzania Investment Bank.

- Local transport costs are extremely high and drive up unit costs to a prohibitive level in some regions.

Balance of Rights, Responsibilities and Revenues of Market Actors

Actors\'3Rs'	Rights	Responsibilities	Revenues
Katani Ltd (including Estate Management, Mkonge Energy Systems Ltd and Central Workshop Ltd)	- Guaranteed purchase of all sisal grown by small holders & out-growers.	- Out-grower / small holder extension services and training - Running electricity generators which power production machinery, - Providing excess electricity generated from biogas to homes, schools and hospitals. - Management of sisal operation, from growing through to marketing and sales - Strengthening CBOs to provide services	- Income from selling Sisal and potential income from sale of bioenergy to the national grid in the future. - Savings through use of biogas instead of bought fuel. - 6 MW of electricity will make substantial fuel savings once installed
Out-growers/ Small holders	- Use of land for sisal production. - Guaranteed revenue from sale of sisal leaves to Katani.	- Production of sisal meeting quality control standards. - Maintenance of the land - Planting of sisal crop Adherence to terms of land lease.	- Income from sale of sisal leaves - Income from sale of food grown alongside sisal
Farmers Co-Operatives	Negotiating a fair price for farmers	- Representing interests of small holders/out growers. - Management of savings and credits issued, and financing of farmer operations.	
Tanzanian Sisal Board (TSB)	Regulation/development of sisal industry	Regulation, development and Promotion	
TANCORD		Purchase of sisal fibre from estates Production of various sisal goods	Income from sisal products
Sisal Association of Tanzania	Operate under act of parliament	Representation and promotion of mutual intercessions with government	
National Social Security Fund (NSSF)	Operate under act of parliament	Provision of social services	
Tanzanian Planters & Agr. Workers Union		Out-grower/smallholder and employee representation	
UNIDO and the Common Fund for Commodities	Promotion of sustainable development via industrial development	- Managed the Project on Product and Market Development for Sisal and Henequen Products through the Project Coordinating Committee - Management and Coordination of Cleaner Integral Utilisation of Sisal Waste for Biogas and Biofertiliser project. Provision of investment, knowledge and support	- International donor countries

Figure 5.2: Katani's relationships with external actors (Practical Action, 2009)

Media Coverage

New Agriculturalist (2009) Sustainable sisal in Tanzania. http://www.new-ag.info/en/focus/focusItem.php?a=740

5.4.3 Case study 3: Tanzania: Battery powered 'portable grid'

EGG Energy (Engineering Global Growth) is creating a 'portable grid' by selling subscriptions to a battery swapping system. They are providing low income households and small entrepreneurs with safe, reliable and affordable energy services. They employ rechargeable batteries, a long existing technology, in an innovative way and self-ascribe as 'the net flicks of batteries'. Their aim is to increase 'last mile connectivity' which refers to the final leg of delivering a connection to an electricity supply. In rural Tanzania, and much of sub-Saharan Africa, the last mile is from peri-urban areas to remote communities, far from the national grid. They have completed extensive monitoring of cost-savings, in particular savings upwards of 50% in comparison to diesel generated battery power have been realized as well as environmental and health and safety improvements at household level.

Technology

The battery itself is an absorbed glass matt battery, about the size of a brick. It is very durable and does not leak. The battery type was originally developed to power airplane black boxes. The unit's robustness also helps keep costs down as they are easier to ship from China, where the batteries are produced at low cost. Customers purchase a subscription from a local salesperson, usually after a home visit and demonstration of the battery itself with a light and a phone charger. After the subscription, local EGG Energy technicians (locally trained individuals) come to the home or place of business and fit the building with wiring, overhead lights and switches. In effect, the set up looks very modern which is appealing to many of their customers.

Each of the lights or charging points is connected to one battery. The battery will last the typical household for 3-5 days depending on the intensity of use. Once it is drained, the battery is brought to a swapping station. From the swapping station the batteries make a loop to the central charging station and then back to the swapping station. Each battery will last 300 to 500 re-charges depending on the way it is used. They also provide some appliances, including cell phone chargers, radio adapters and LED light bulbs. Most recently they have also powered television sets.

Partners & Financing mechanism

They were founded in 2008 by a group of 8 students from MIT and Harvard University. Operations in Tanzania began in 2009 with approximately €52–60 k ($ 70-80k) – made up primarily of the winnings of several competitions, including business plan competitions and technological innovation grants. For example, EGG Energy was the winner and principal beneficiary of the UK Government's Department for International Development Africa Enterprise Challenge Fund. They are currently in the process of procuring additional rounds of funding. Most immediately, they hope to raise equity to increase the number of charging stations and distribution centres to make the largest footprint possible in the next 5 years.

Process and Approach:

EGG Energy conducted a feasibility study in 2009 in Tanzania. They performed installations in 10 different households and observed how much they swapped the batteries. This information was essential in determining the appropriate price point and their willingness-to-pay. EGG Energy has a market-based implementation strategy. Customers pay approximately €25 ($ 33) for an annual subscription. Subscriptions can also be purchased for 6 month periods for a slightly higher (monthly equivalent) premium. Each time a battery is swapped, the customer is charged the equivalent of €0.26 ($ 0.35).

The feasibility study confirmed that there was in fact a large market for their product, given that households were already purchasing energy services in the form of disposable batteries and paying fees to charge cell phones at a price less competitive than what they would be able to offer. They also observed kerosene drop almost completely from use in the sampled households which spoke to the company's environmental, and health and safety potential.

The feasibility study in 2009 was a proof of concept. As such, the company now focuses the majority of its research and development efforts on fine tuning its distribution model, as opposed to tweaking the technology. For example, they employ a local sales team which deals regularly with local authorities and community leaders and they are exploring ways to make their local networks as efficient as possible. In this way they also keep abreast of the needs of the community. They are also developing a local team with IT skills to keep track of subscriber accounts, operations and customer service more efficiently and transparency.

The model leverages a tried and tested technology (the battery) and the network of small entrepreneurs (vendors, transporters etc.) that is already well established in the region. They are also exploring other leveraging opportunities, including mobile phone payments to reduce cash-handling at local swapping stations, and local savings and loans cooperatives to reduce the burden of up-front costs to potential subscribers. The swapping points are existing small businesses who have been engaged by EGG Energy. They have plans in future to have a greater number of charging stations which are decentralized, which would cut down on the step between swapping and charging stations.

Business Model

They have already connected 2000 households with plans to scale up rapidly and to expand to neighbouring countries such as Malawi or Kenya by 2015. Specifically, they aim to have 9,000 subscribers, which would translate to €5.6 million ($ 7.2 million) in revenues. It is a for-profit company, which is a unique aspect of its design. The following rationale was included in a staff blog post entitled 'Treating the Poor as Consumers' (May 2010)

'First, it increases the likelihood that the service we sell will be used and valued by our customers. Like any for-profit business, we allow potential customers to decide for themselves how they value our service, instead of deciding for them that it suits their needs best. Those who elect to purchase our service believe it will benefit them and are thus more likely to use, take care of and potentially improve our service.

Second, operating this way allows us to provide a higher-quality, more sustainable service to our customers. We price our service above our cost. If we instead sold it at an artificially low price, our ability to serve current and future customers would depend on the (sometimes unpredictable) availability of outside funding to fill the gap. In addition, because we pay attention to our profits, we invest in increasing the quality, convenience and cost-efficiency of our service in order to remain competitive.

Their model resembles the set-up of a franchise. At the moment they have four pre-existing local stores that act as swapping stations. Figure 5.3 illustrates the complete distribution model.

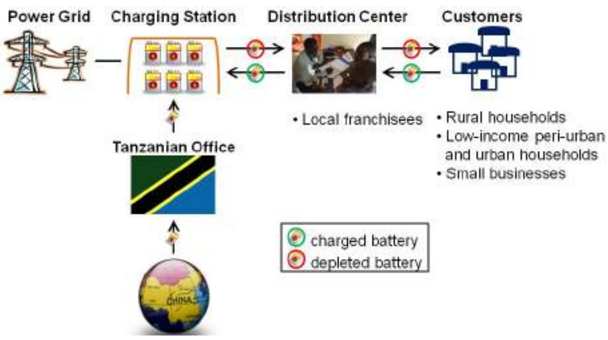

Figure 5.3: Sisal Biogas Initiative Market Map (Source: Practical Action, 2009)

Key Challenges:

- The project is still in its early stages and currently only operating at a small scale. Proof of concept and its ability to scale up to other regions of Tanzania and internationally remains to be demonstrated, but appears to have very high potential. They are currently sourcing capital to enable this next step.

Media coverage

Smart Planet (2011) http://www.smartplanet.com/blog/business-brains/this-years-top-global-innovations-8216portable-grid-retrofit-hybrids-real-time-intelligence/16002

University of Pennsylvania (2011) http://knowledge.wharton.upenn.edu/10000women/article.cfm?articleid=6279

Tanzanian Affairs (2011) http://www.tzaffairs.org/2011/09/a-grand-prize/

5.4.4 Case study 4: Ghana & Tanzania: Solar Powered LED Lamps

There are enumerable private businesses, social enterprises, international development agencies and government agencies in Africa that are promoting solar lighting units. The units themselves vary in design, price point, place of manufacture and distribution scheme, but all serve the purpose of replacing costly, often dangerous, carbon intensive fuels for lighting – most notably kerosene lamps, open flames and disposable battery-powered flashlights. One high-potential organisation distributing solar powered LED lanterns is **D.Light Designs** in Tanzania, Ghana and many other countries within sub-Saharan Africa. The founders of D.Light Designs were listed by Forbes in the top 30 social entrepreneurs of the year in 2011.

Technology

At one Nairobi-based trade fair and business conference alone last year put on by Lighting Africa (www.lightingafricaconference.org) there were more than 50 companies showcasing various solar powered lighting products. Evaluation criteria have been developed for such products to test durability, efficiency, light quality and appropriateness of design for models at various price points and for multiple levels of end users (households, small business owners, small-scale manufacturers, schools and so forth). Lighting Africa shortlist 24 high potential lighting units and made awards to the following five:

- Barefoot Power's 'PowaPack' (1st place Room Lighting; 2nd place Top Performance)
- Greenlight Planet's 'Sun King' (1st place Task Lighting; 2nd place Best Value – under USD 40)

- Barefoot Power's 'Firefly' (1st place Best Value; 2nd place Task Lighting)
- SunTransfer's 'SunTransfer2' (2nd place Top Performance)
- D. Light Design's 'Nova S200', (2nd place Room Lighting)

(Source: Lighting Africa Press Release, May 20th 2010)

Given the multitude of options, the awards help to identify the top units currently available on the market to guide consumers, donors and investors. D.Light Design produces and distributes their own award-winning portable solar study lamps (Figure 5.4) in various African countries with a great deal of business in Ghana and Nigeria. The features of their lamps include a high-efficiency integrated polycrystalline solar panel, multiple lighting settings and sturdy light weight portable designs. If left under the sun for the majority of daylight hours the lamps reach full charge, which provides approximately 8 light hours of regular use or 4 light hours with the high setting.

Figure 5.4 D.Light Products (top left: S250, top right: S10, bottom: S1) (Source: D. Light Designs)

Partners & Financing mechanism

Their target is to improve the quality of life for 50 million people by 2015. To do this they have received angel investments plus support from venture capitalists including Garage Technology Ventures and Draper Fisher Jurvetson.

Although their Ghanaian projects currently do not benefit from carbon financing, the company itself is involved in the carbon market. D.Light Design receives support through carbon offsetting (Verified Carbon Standard, Climate Action Reserve, and Gold Standard) through Radiant Carbon (radiantcarbon.org), based in Vancouver, Canada. Each tonne that is offset through Radiant Carbon includes in addition, a D.Light S10 lamp which retails for €7.5 ($ 10). The LED lamp is given to a low income household in Sri Lanka, which is meant to make redundant one kerosene lantern per solar lamp in use. Based on the outputs of a typical kerosene lantern, they estimate that each D.Light lamp offsets 0.3 tonnes of carbon over a period of four years. As such, when you purchase a 1 tonne carbon offset from Radiant Carbon, the actual savings are 1.3 tonnes. This addition is meant to make the scheme more socially minded.

Donations through the official D.Light website are tax deductible and subsidize the purchase of lanterns. At the moment, the lanterns subsidized through online donations are sold in East Timor. D.Light solar lights are also featured through Kopernik (www.kopernik.info/) - an online store of high potential technologies designed for developing countries to facilitate "technological leapfrogging" to skip less-efficient technologies and practices in favour of more advanced ones where unit price or access is a barrier to uptake. Through donations to Kopernik, D.Light solar lamps are being provided to needy families in the Ivory Coast – Ghana's neighbour to the west.

Process and Approach

For D.Light, building the solar lamp is only the first part of the enterprise – the second is creating a sales network to get their products to the people most in need of lighting in marginalized parts of the world. Their approach is one of many similar efforts geared towards market-based solutions to energy poverty in sub-Saharan Africa. They acknowledge that product development that is culturally appropriate, affordable and fit for the climate and preferred use patterns, is only one step towards rural Africans attaining home lighting after dusk.

Within the energy social enterprise sector, methods to distribute and encourage the use of solar powered LED laps are nearly as numerous and varied as the units themselves, with greater or lesser efficacy. Methods of implementation range from micro financing and other credit schemes for unit purchase, to payment (in kind) for service, to 'rent-to-own' programmes and in some cases, free distribution. Pairing unit distribution with other poverty relief programmes delivered by aid organisations has become commonplace including subsidizing the cost of units for sale at reduced rates, offering marketing support to small business owners, training and 'sensitization' of communities, potential vendors or maintenance persons, to list only a few.

Ranking methods of distribution of solar powered LED lamps is more complicated than product-testing because end users have complex and differing use patterns and preferences, layered with differing conceptualisations of risk, investment/savings, and modes of adaptation, all of which affect technological uptake. Monitoring and evaluation of the products available through various social enterprises in sub-Saharan Africa has largely been limited to assessments of small numbers of similar unit models with a single, or in a few cases two to three, methods of distribution. The results of such assessments are helpful to the organisations in the business of distributing a set of units in a defined programme area but for higher level analysis they offer anecdotal evidence at best, which is highly contingent upon the unique competencies and social standings of the implementing organisation at hand, the technology under focus and the unique sociocultural and economic characteristics of the beneficiary communities.

Baring this in mind, short of primary data collection, these analyses are some of the only data-sets available. As such, comparing solar lamp products must be considered with the understanding that conclusions are not necessarily generalizable to other implementing organisations, energy technologies or other communities in time and space.

Business Model

D. Light attest that their main competitor is still Kerosene, despite the multitude of other social enterprises producing solar lamps that have popped up around East Africa (GreenTech Interview, March 2011). Figure 5.5 outlines their carbon financing based distribution – a partnership with Radian Carbon Offsetting.

Figure 5.5: Model for Sri Lanka distribution. (Source: Radiant Carbon Offsets website, 2012 (http://radiantcarbon.org/))

Key Challenges

- The primary inhibitor to uptake of rural inhabitants remains ability-to-pay.

Media coverage

Forbes Magazine (2011) List of top 30 social entrepreneurs. Available online: http://www.forbes.com/sites/helencoster/2011/11/30/forbes-list-of-the-top-30-social-entrepreneurs/ Accessed Feb 28th, 2012

GreenTech Media (2011) The Human Side of Solar and Renewables. Available online: http://www.greentechmedia.com/articles/read/the-humanitarian-side-of-solar-and-renewables/ Accesses Feb 28th, 2012

Marketplace Business (2011) Entrepreneurs Crowd Into Social Ventures. Available online: http://www.marketplace.org/topics/business/entrepreneurs-crowd-social-ventures Accessed Feb 28th, 2012

Time Magazine (2009) Community Service 2009. Available online: http://www.time.com/time/specials/packages/article/0,28804,1921165_1921239_1921221,00.html Accessed Feb 28th, 2012

5.4.5 Case study 5: Tanzania: Home Solar Systems

Zara Solar is a small privately owned business of Mr Mohamed Parpia in Mwanza, Tanzania that sells PV panels. The business owner was given the Ashden Award in 2008. The business now serves over 20,000 households in the region. He is the leading provider of solar panels in northern Tanzania and has recently opened a second branch in Dar es Salaam, the national capital. The company employs 5 technicians and has a large network of self-employed technicians with training certification in more rural areas of their customer base.

Technology

The PV solar panels are standard 14 W amorphous silicon and feed into a lead-acid battery. Typically they can power 2 fluorescent lights for about 3 hours nightly. Crystalline modules are generally more efficient, but for the purposes of most of Zara Solar's customers, the less expensive Amorphous silicon PV modules are quite reasonable for their relatively small power demand. In some places, for example parts of south East Asia, Amorphous silicon PV modules gained a reputation for degrading rapidly in environmental conditions typical of the tropics, but their design and functionality has improved dramatically over the past decade.

Zara Solar sells charge controllers to their customers, but for those unable or unwilling to pay the additional premium, which adds approximately 17% to the system cost, they offer training on how to minimize over-discharging the battery, which otherwise would reduce its life. A small range of batteries (including empty/dry batteries which are later filled with lead acid) are on offer to try and meet the variable ability to pay that exists within Zara Solar's customer base. In some cases the batteries at the lowest-end not only last for shorter time spans, but are inherently less safe. Most of their customers buy the sealed lead acid batteries within the 14-60 W range, while institutions usually opt for 100 W systems.

Inexpensive and low quality imports from China, as well as counterfeit products out-price the higher quality models on offer by Zara Solar. In comparison, Zara Solar's products, which are mainly imported from Europe, seem very expensive to the average resident of Mwanza -the small city where Zara Solar's initial store is located. The alternatives however, have a much shorter life and are prone to breakdowns.

Process and Approach

The company places a strong emphasis on the training of its technicians. All its technicians have completed a course at one of the local polytechnics that is technically and culturally appropriate for the equipment, educational background of the trainees and the local environment. At one point the UNDP was financially supporting these courses. The trained technicians are then able to train customers to complete simple maintenance on their systems safely and effectively, and to prolong the life of their systems by not over draining the battery. User-training is a key priority of the technicians. Repair requirements are generally minimal, since the equipment itself is of a very high quality. Customers in the areas nearest the

Mwanza and Dar es Salaam shops are serviced by the full-time employed technicians of Zara Solar. Those in more remote areas are serviced by self-employed free-lance technicians that are certified and recommended by Zara Solar.

Increasingly, cheaper models are being imported from China into the region, which often degrade quickly and have malfunctions which the local technicians are ill-prepared to service. In some areas where cheap models have permeated the local market heavily, it has reduced community confidence in solar panels more generally and contributed to ground-level waste. Zara Solar is working to combat the problem of counterfeit equipment, especially those that are designed and packaged to look like higher quality brands, by having examples in the Mwanza shop with directions on how to better identify 'fakes' if community members see them for sale elsewhere (Ashden Awards, 2007).

Business Model

Zara Solar is a viable private small business and much of their approach is simply good business sense, but it also has a philanthropic flare with a sense of social responsibility permeating throughout each sale and service of the company. To address the varying ability to pay of their customer base, the sales technicians provide a very detailed and comprehensive list, and verbal explanation of the various systems on offer and price ranges. They are committed to finding energy solutions for even the poorest households.

A 10% charge is incurred on top of the unit price for customized installation to ensure safety and quality, and for set-up. Individuals usually incur the cost privately, often with access to credit through various community loans and savings groups. Institutions such as hospitals and schools also purchase larger systems – usually with assistance from government, donations or through bilateral aid programmes. However, as good practise, the institutions are expected to pay for at least a portion of the upfront costs to demonstrate their commitment to the system and their willingness to upkeep it.

The ethos and philanthropic nature of Zara Solar's owner, Mr Mohamed Parpia, is one of the defining features that sets the business apart and makes it a notable case study. However, such personal attributes are one of the most difficult to replicate elsewhere. The literature on how to build on individual leaders to create social movements, service delivery and socially responsible enterprise is mixed on how to best achieve this, if it is possible at all. A sample of the literature can be found at the end of the chapter. One high-potential method is to include such characteristics (for example in the form of weighted categories) in the suggested criteria for angel investors or bilateral aid driven small business assistance.

Key Challenges

The following challenges were outlined as the key barriers to further expansion:

1. To ensure quality, Zara Solar has a strict policy to only buy from reliable suppliers that offer customers a warranty. As such, they must import all their panels from the USA or Europe. This has been a source of criticism by some who have put pressure on the company to offer cheaper models.
2. Consumers are frequently unwilling to pay up-front infrastructure costs. According to Zara Solar, this applies regardless of the level of income or education of the customer. For the distributor, this was particularly concerning – he worries that this will hinder progressive investment which ideally starts on a trial basis, but mushrooms as it generates rural economic benefits.

5.4.6 Case study 6: Ghana: Improved Cook Stoves

There are many varieties of cook stove models designed to burn more efficiently and contribute less to household air pollution associated with eye irritation and lung disease, particularly amongst women and children who spend more time in and around the area where meals are prepared. The projects have varying degrees of success – some with abysmal uptake rates, primarily because the stove is difficult to use, is time consuming or is not appropriate for the cooking method. One very successful example which has received international recognition recently, including the Ashden Award, is **Toyola Energy Limited**. Toyola Energy manufactures and distributes energy efficient cook stoves for household use called 'Coalpots'.

Their stoves are 40% more fuel efficient than traditional cook stoves, reducing consumption of charcoal which is sourced primarily from local forests. They have also been proven to reduce cook stove related burns by 90% and save women 30 minutes per day in cooking time. Uptake rates are quite high with households using them quite consistently. After 1 year, only 2.5% of stoves go out of use, and only 15% within the first 3 years after purchase. In 2011, 154,000 Coalpots had been produced to Toyola's specifications.

The stoves are all produced by independent self-employed artisans and are sold through existing retailers or by Toyola commission-based agents, many of which have received training from the Ghana Home Energy Programme (GHEP). As of 2011, 77 artisans were making a living through the production of Coalpots (Ashden Awards, 2011). They are also now selling solar lanterns to replace kerosene fueled lanterns (E+Co, 2009).

Technology

Coalpots are designed to be as similar as possible to the stoves traditionally used in Ghana – the three-legged Gyapa. The most significant difference between the Coalpot and the Gyapa is the stovetop, which hugs the round-bottomed pots, increasing heat transfer and reducing heat loss. The stoves are made of scrap metal with Toyola-specific templates whenever possible, and burn charcoal in a ceramic lined heat-retainer (E+Co, 2009). The ceramic liner is another significant improvement on the Gyapa, which is also found in many other improved cook stove designs. The ceramic liner adds significantly to the efficiency of the stove; they are made by KT ceramics which is business 90% owned by Toyola limited. The liners are made of locally available sawdust, sand, water and clay on a potter's wheel, which is a common artisanal tool in Ghana.

The metal components of the Coalpots are produced by self-employed local artisans who have been trained to produce the stoves to strict Toyola specifications at one of the central Toyola production centers. They work on a production line and self-check for quality at each step. They are durable and difficult to tip, which is important for dishes requiring brisk stirring. All metal work is of a simple design, requiring only basic metal-working skills and tools (steel bending, producing joints and smoothing edges for safety). The rate of burning on the Coalpot is controlled by an adjustable door (Ashden Awards, 2011).

Partners & Financing mechanism

The social business was founded in 2006 and started production in 2007. Co-founders Suraj Wahab Ologburo and Ernest Kwasi Kyei received training in stove production through the Ghana Household Energy Programme (GHEP). The founders originally obtained a loan from E+Co (*Energy through Enterprise*), which makes investments in small and growing energy enterprises. Through E+Co support, they were able to begin commercial scale production and make sales to a larger area. They now have five production centers throughout Ghana and have opened their first international production center in Togo. They hope to expand to other parts of western Africa, including Nigeria, Benin and Sierra Leone (Ashden Awards, 2011).

Process and Approach

Coalpots are produced in five different sizes (stove top diameter: 270 to 510 mm) for either domestic or commercial use, with prices ranging from $ 6.60 to 33 (€5-25) (Ashden Awards, 2011). The units are subsidized by carbon finance by approximately 28%. If users are purchasing charcoal from local producers and not making it themselves, it is expected that the savings will pay for their initial investment in 3-4 months. In practise, the majority of rural inhabitants of Ghana produce their own charcoal, but other less measurable benefits are accrued regardless – health, environmental, safety, time etc.

The majority of customers (75%) purchase Coalpots through a credit scheme, either directly through Toyola or through one of its official retailers/salespersons. A minority (20%) pay cash up front and a smaller minority make a bartering arrangement with local sales agents, often trading farm produce from harvests. Like many other energy enterprises, Toyola collaborates with external microfinance institutions to reduce the burden of up-front costs on its clientele and are continuing to forge more arrangements of this kind in order to ensure the sustainability of the project. They also have an innovative savings scheme, which is unique to the company, called the 'Toyola money box', which is used by approximately 25% of their customers. The money box allows households to stash the money they have saved from reduced charcoal purchases to help them repay their loans for the initial cost of their stove.

Each stove that is produced and sold is given a unique serial code to identify the producer, salesperson and owner. Such record keeping is necessary for the purposes of carbon verification and is used in their sales tracking system which operates on the mobile phones of employees and sale agents. Figure 5.6 shows an example of the record structure used by Toyola to track sales on the mobile phones of its agents.

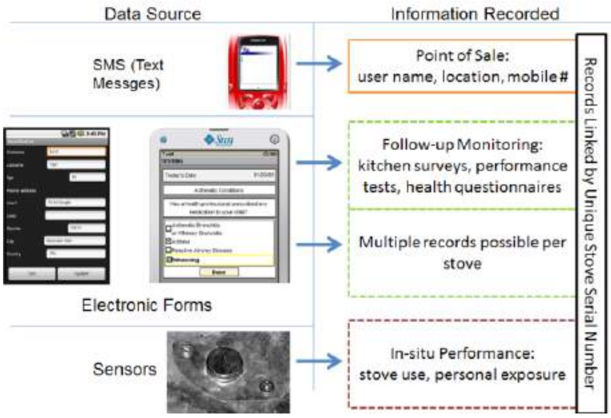

Figure 5.6: D.Light Products (top left: S250, top right: S10, bottom: S1) (Source: D. Light Designs)

Business Model

Carbon financing has become an integral part of Toyola's business model, representing 28% of the company's income. The Coalpot has been externally verified for the carbon market. In one year the coalpot saves one tonne of carbon by the average Ghanaian household. In the production centers, random checks are done by carbon verifiers to ascertain standardized carbon savings.

Key Challenges

- Several community-based organisations in Ghana have sporadic donor-based projects that provide other varieties of improved cook stoves for free, which distorts the market and can create expectations for 'hand-outs'.

- Supply is currently still not meeting demand. In order to scale up sufficiently, including to neighbouring countries, Toyola Energy will need to develop a more scalable credit scheme, such as with a large bank or lending institute. According to the company, the current arrangements for direct credit for unit purchase from the company are not scalable or sustainable in the long term.

5.4.7 Case study 7: Select African Countries: Pay-as-you-go Solar Systems

Eight19, named after the time it takes for the sun's ray to each the earth (8 minutes and 19 seconds) is a UK-based start-up that offers a unique pay-as-you-go fee for service scheme for individuals to pay-off the initial costs of their solar systems. It models the mobile top-up scheme which is common throughout sub-Saharan Africa, whereby scratch cards, good for 7 days of solar power, are purchased from local vendors. Each scratch card indicates a unique reference number which is sent via SMS to Eight19. An access code is then generated and sent immediately to the customer by the company server, also via SMS. The access code is then keyed into a panel on the solar system, which is usually installed on a wall in the home of the customer. The current system is call **IndiGo** and includes an in-built battery, a solar panel, LED lights, and a phone charging device, pictured below.

Figure 5.7: IndiGo Solar Unit (Source: Eight19)

The social business is based out of Cambridge University. It was first brought to market in Kenya in 2011 and has now spread to 3 other African nations – Zambia, Malawi and most recently to the newly established South Sudan. The pay-as-you-go service eliminates the high upfront costs of solar power systems, which is a typical barrier to solar energy uptake. It also bypasses many of the logistical costs and complications of accessing credit. Overhead costs are kept to an absolute minimum and the potential for mismanagement or counterfeiting is reduced significantly. It is a particularly appropriate innovation for areas like rural South Sudan with very little infrastructure. Formal supply chains, such as those that service the solar-based businesses in Ghana and Tanzania are not nearly as developed in the newly established South Sudan. It is hoped that eventually the unit will be able to power other devices, including tablets and laptops for internet access.

Technology

With the initial IndiGo unit that customers are offered when they begin the pay-as-you-go scheme, the solar cell generates 2.5 watts of electricity. When the unit is activated through the scratch card and access code system, the battery can deliver a 3-amp current. When the battery is fully charged, the LED lamps can light two small rooms each night and power a mobile phone charger for 7 hours of charging. As customers move up the "energy escalator" (see section 5.11.3) and purchase higher capacity systems, their energy production, storage capacity and access grows incrementally.

It is intended that the devices will eventually be upgraded by printable, thin-film plastic solar cells which are currently being developed by the company. The plastic solar cells are a mix of two organic semiconductor materials between metallic electrodes, which is surrounded by plastic substrates (IOP, 2012). Production costs are expected to be dramatically cheaper than existing solar cells, which is meant to reduce the unit cost of IndiGo substantially.

Partners & Financing mechanism

The pay-as-you-go design and development was financed through a €5.4m (£4.5m) investment by the UK's Carbon Trust (www.carbontrust.com). Private donations and angel financing also helped the company enter markets in Kenya, Malawi and Zambia in 2011 installing more than 4000 units in total. Currently, in collaboration with the charity SolarAid, Eight19 has established a stabilized revolving fund called the Kickstart Sustainable Energy Fund of €150,000 ($ 200,000) which is regenerated by sales of solar credit scratch cards, detailed below. The company is beginning a new funding round, aiming for €6m to €12m (£5m to £10m) by the end of 2012.

Figure 5.8: "Kickstart" Funding Cycle (Source: www.greenpacks.org)

The company has local partners in its areas of operation. In South Sudan the local implementer is WorldVenture, an international charitable organisation. Through this partnership, the company hopes to install approximately 1000 units in the first half of 2012.

Process and Approach

Customers make a deposit payment equivalent to €7.5 ($ 10). The full cost of each unit is approximately €60 ($ 80). Through the top-up scratch cards, users make incremental payments for their systems. In practise it is as if each week they are purchasing a week's worth of energy comparable to a pre-paid metre, when in fact they are actually making weekly loan re-payments. The loans are 'soft loans', as is typical of social enterprises in sub-Saharan Africa which do not require collateral or incur penalties. Customers simply do not generate solar energy if they do not make payments (purchase the scratch cards). In this way, it could also be understood as a rent-to-own scheme.

Once the scratch card-based payments have covered the unit cost of their solar system, customers will own their system, at which point they have the option to keep using their system free of charge or to upgrade the system to a higher capacity, by trading it in for another and continuing to purchase top-up scratch cards. This is what Eight19 calls the 'energy escalator', illustrated in Figure 5.9, whereby a customer's user profile changes gradually from basic lighting and phone charging to household and smallholder business electrification . The company estimates that with regular payments, a customer will own his/her solar system within 18 months. The payments themselves are approximately half of what a typical family would spend on kerosene per week. As such, cost savings are realised immediately, and continue to grow.

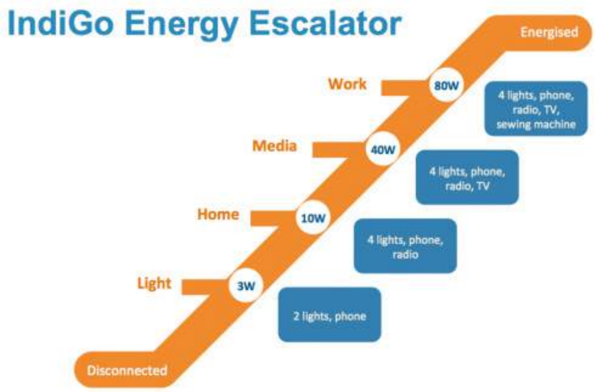

Figure 5.9: Indigo Energy Escalator (Source: www.eight19.com)

Business Model

In comparison to average household spending on kerosene for lamps, extra batteries for battery-powered lights and devices and the service fees for charging cell phones in local markets, usually through a diesel powered generator, etc., the IndiGo pay-as-you-go solar system is cheaper, cleaner, more convenient, and provides better quality household light. For the upwardly mobile, it also provides a chance to increase electrification at very low up-front costs, including for commercial purposes. The costs will fall further if the company is able to supply solar film, which is currently under development. The company estimates the market for mobile phone charging alone is worth €1.1 billion ($ 1.5 billion). If they are able to expand and take a share of it, they hope to be able to reduce kerosene use substantially, or perhaps eliminate it all together (Green Business, 2012, b).

Key Challenges

- A key component of product design (thin-film plastic solar cells) is still in the research and development phase, although roll-out of the project is underway.
- The project still very much in its infancy; any limitations of the design will become clearer in time.

Media Coverage

The Economist (2012) Starting from Scratch. Available online: http://www.economist.com/node/21548482

5.5 Conclusions from case studies

The seven African case studies reflect a wide range of technologies and business approaches serving customers at the household and small business level. A number of general conclusions can be drawn from them:

- In order to overcome the affordability barrier, Innovative approaches have been needed to enable customers to pay for the energy services that they desire. Pay-as-you-go and subscription-based approaches have proved to be successful in overcoming the hurdle that would otherwise be presented if the capital cost of the energy producing and using equipment had to be paid for up-front. In the longer run, savings to households, for example on kerosene purchases, can substantially outweigh costs.
- Advantage has been taken of the wide ownership of mobile phones by using them as the method for making payments and accessing pay-as-you-go electricity, thereby reducing overhead costs and facilitating access. Careful design of such schemes can create a ladder of energy opportunity to progressively access a wider range of energy services.
- There is value in establishing initiatives as viable businesses which succeed or fail based on their ability to respond to customers' needs, delivering a desired product at an affordable price. The economics of such enterprises can appropriately be helped through access to funding mechanisms such as carbon finance.
- It is important to be sensitive to cultural contexts, particularly for technologies such as cook stoves which occupy a central role in family life, and where there may otherwise be resistance as has been addressed in the development and deployment of microbial fuel cells. More generally, quality and reliability of equipment are important, as technologies can get a bad reputation if not.
- The coming together of efficient energy using technologies such as LED lighting and more affordable, small solar PV devices and batteries are opening up new possibilities to leapfrog western development paths, and offer step-change gains in respect of education, health etc. Similarly, more affordable charging of mobile phones will help to spur progress on that ladder to smart phones, tablets internet access etc.
- Training of locals to support the installation, operation and maintenance of energy systems is essential, and also opens up new opportunities for employment and local businesses.

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CHAPTER 6: COMPARATIVE ANALYSIS AND DISCUSSION

This chapter provides a comparative analysis of the studies from India, Ghana, and Tanzania. Specifically, it discusses the key messages that have emerged regarding successful approaches and technologies, and some of the challenges identified in enhancing rural energy provision in developing communities.

The case studies have reinforced the messages about, and given specific examples of, the potential benefits to rural development of decentralised energy provision that are discussed in more general terms in the earlier chapters of the report. Such benefits include reduction in pollution and ill health with consequent benefits to the economy, improved education, the ability for rural populations to access government information and communications provided centrally (on tv, radio, internet etc.), access to media, and economic empowerment and participation.

6.1 Emerging approaches: Social businesses

A consistent message from the case studies is the effectiveness of social businesses (or social enterprises) as a model for knowledge transfer and development. A social business can be profit or non-profit; it combines business methods and strategies to achieve philanthropic outcomes. It is an increasingly popular model, both in developed and developing country contexts. In post graduate education, social business courses are gaining in popularity across much of North America, Australia, South Africa and Western Europe. In the context of rural development, this trend will likely continue in the near future at least in part because many are increasingly attempting to avoid aid funds which can be volatile, restrictive and require significant time investments to obtain. Tag lines such as “Get rich doing good” (Times Magazine, Forbes Magazine) have become commonplace to encourage the use of social business, especially in the developing country context.

There are several benefits of a social business model over traditional approaches. From a technical perspective, social businesses can facilitate the establishment of important supply chains, and the operation and maintenance of renewable energy technologies. As discussed in Chapter 3, the inability to establish sustainable supply chains is an often cited reason for technology failure in low-resource communities in developing countries. Thus, social business can facilitate near-term sustainable provision of rural energy services.

From a development perspective, social businesses can provide additional benefits beyond just the service they provide (e.g. rural energy services). These benefits include stimulating local growth, providing employment opportunities for youth that can curb rural-urban migration, and assisting in the training of a local technically proficient workforce. However, social-business models are not without challenges. For example, one of the criticisms of social-businesses is that they tend to neglect the most marginalised and poor in a community who often cannot afford any product or service even with creative financing mechanisms. While tensions can sometimes arise when social businesses and NGOs work together, NGOs can potentially support social businesses, for example through provision of equipment and know-how. Such collaborations may be particularly apposite in meeting the needs of the most marginalised and poor.

6.2 Promising technologies

The case studies indicate that technology is only one of the necessary ingredients for successful rural energy service provision. Indeed, institutional capacity, availability of an adequately trained and technically proficient human resource, and the social context are often more important to the sustainability of an energy service than the technology selected. Nevertheless, there were several promising technologies (and energy enabled technologies) that emerged from the case studies. A key factor is the availability of more efficient energy using technologies such as LED lighting which require substantially less power than earlier technologies, and can therefore transform the possibilities for provision of that power.

Photovoltaic (PV) cells continue to dominate many of the successful rural energy service projects. They are often favoured because of their comparatively low cost and maintenance requirement, and their ability to provide a high-quality energy source. They can also be easily combined with wiring and switches, creating a sophisticated electrical scheme for the home or business, which many end users have a particular preference for.

Biomass based technologies (e.g. biogas digesters and producer gas designs) have promise, particularly when combined with mini-grids at the village or household cluster level and pay-for-use services. Biomass places higher demands on human resources than some other energy technologies because of greater operation and maintenance requirements (i.e. often daily). This is due to the sensitivity of biomass-based systems to feedstock (e.g. agricultural waste, cow manure, etc.) quality and availability. Care must be taken in expanding biomass schemes to ensure that they do not draw unsustainably on environmental resources, particularly in respect of maintaining soil quality, ecosystems etc.

One promising aspect of technology is an increased focused on technology design for a high quality user experience. An often-neglected aspect of energy technology for a developing country market is the design elements that influence the user experience. This includes simple finishes such as light switches and battery boxes, as well as supply quality and reliability. At the household level, technology must have sufficient flexibility to allow customisation to meet the needs of a particular household. There is a high preference for technologies that are designed with an appealing aesthetic. While first generation technologies often must place a priority focus on efficiency and process, subsequent iterations have an opportunity to increase impact by focusing on user experience and packaging. This is in part why pre-packaged photovoltaic systems for lighting (e.g. products from Barefoot Power[19]) have found success and increasing demand.

6.3 Synergistic opportunities

There are opportunities emerging through the parallel development of non-energy technologies and initiatives. For example, there is significant opportunity arising from the provision of energy and the availability of low power consuming information communication devices. This includes power for connected tablets and mobile phones which open up new opportunities for education and business.

Mobile payments systems, for example, have transformed banking services for the poor, who historically have not held bank accounts for reasons including fees, minimum balance requirements, or limited access to a physical branch. Mobile banking has the potential to decrease theft, reduce transaction costs, and reduce corruption. Another opportunity is the use of carbon-financing schemes to provide subsidies to rural energy technologies. Such schemes could facilitate access for the very poor to a basic level of a technology, or provide the ability to upgrade to a higher quality technology.

The ability to receive area-specific weather forecast information or disaster warnings through mobiles phones (SMS and android applications) also has considerable potential through energy access. This includes increasing the ability to adapt to the fluctuations in seasonal weather patterns and extreme weather events that are likely to be a barrier to food production, health

19 http://www.barefootpower.com/

and safety and service delivery with global climate change.

Financing through carbon offsets is another synergistic opportunity. There are a couple of examples within the case studies of carbon financing being used to subsidize unit costs of decentralized energy technologies. The small but significant financial boost provided by carbon offsets can often make the difference in price point, opening up the market to poorer individuals or facilitating the purchase of higher quality, more costly units. In the latter scenario, carbon financing can foster technological leapfrogging as technologically inferior, but less expensive units are by-passed.

6.4 Recurrent barriers to success

One of the often-identified challenges in the interviews conducted for the case studies was the unavailability of a technically proficient human resource. Rural energy technologies often require technical skills for assembly or design. For example, sizing a PV system is nontrivial, and requires a delicate balance between the size of the PV panel, battery array, and electrical loads while taking into consideration the local solar insolation. The failure to size a PV system correctly can lead to a significant reduction in the expected life of the batteries (which represents a large portion of the PV system cost) or low quality of supply (i.e. frequent system failures). Entrepreneurs often either do not have sufficient technical knowledge, or lack the ability to provide a technical staff to support sales or support post-installation. There are of course exceptions, for example, though Zara Solar is only a one-man business selling PV panels, the company places a strong focus on training. Thus, Zara Solar offers sales and technical support, or advice for ways of increasing the lifetime of a system even if a household declines the additional products.

There are significant policy and institutional barriers that remain to be overcome. Policy and governance frameworks are needed that enable and support the deployment of rural energy technologies. Additionally, new networks are needed to support social businesses. Several of those interviewed in the case studies in India identified that such networks would be instrumental in facilitating communication, knowledge sharing, opportunities, and lessons learned for those involved in off grid energy. Arguably one of the factors in the success of micro-financing was the existence of these kinds of networks.

Another policy challenge is the limited standardisation of rural energy as a way to ensure good business practice, and establishing requirements for sufficient expertise in the design, installation and support of products. This kind of standardisation could assist in providing some quality control to technologies used for off-grid power. A prime example is the Lighting Africa Awards for solar lighting discussed in Chapter 5. It is important to use high quality technologies when possible so that communities do not develop a negative perception of technological change. Such quality control is essential for sufficient uptake of energy technologies. Standardisation has been shown to increase the quality of service in other sectors (e.g. micro-financing), and has the potential to positively influence off-grid power provision. However, standardisation should not stand in the way of innovative products and solutions entering the market.

Poor quality products which breakdown frequently and have short lives can get a technology a bad name. Another partial, but valuable, response to this problem is providing access to reliable and independent information on product costs, quality etc., and to enable users to distinguish 'fake' products.

Funding challenges played a role in nearly all of the case studies. For example, financing business start-ups is challenging because would-be entrepreneurs in the case study countries generally have less access to credit. Further, mainstream funding entities tend to see new technologies as higher risk than established technologies for off-grid power - this can act to discourage innovation. New and creative funding mechanisms are needed in order to fund entrepreneurs, and to support the development of new and innovative technologies to meet off-grid power needs.

At the individual or household level, high upfront costs are a consistent barrier. For subsistence-oriented communities, savings and access to credit, even in very small amounts, is a continual challenge. Many of the examples highlighted in the report are attempting to connect with micro financing institutions (e.g. Katani Sisal, EGG Energy, D.Light Design, Zara Solar) to reduce the initial burden of investment. This is a viable but not perfect solution, as there are limitations to the micro finance model – most notably its difficulty serving the most marginalized within communities. There are other examples of unit subsidization through donors or carbon financing (e.g D.Light Design) to reduce the burden of upfront costs.

Different models of ownership of energy producing and using equipment have been found to work in different settings, full ownership resting with the household at one end of the spectrum, and being retained by an energy service company at the other. A progressive transfer of ownership through payment by instalments has been another mechanism used successfully to overcome initial affordability hurdles.

Appropriateness of scale is another recurrent theme. A technology may be viable when delivered at one level (household, group, village, village cluster etc.), but be less so, or inappropriate, at another. Less conventional yet salient technologies like bio-gasifiers and microbial fuel cells are pertinent examples. Bio-gasifier projects, such as Katani Sisal, are more feasible at higher levels and are generally not attempted at more localised levels than village clusters. There are a combination of reasons for this, including the technological proficiency needed, the need to achieve economies of scale, and sourcing of large quantities of biomass. The maintenance and upkeep of such projects would likely overwhelm a household. However, the microbial fuel cell project, 'Dirt Power' by Lebone Solutions, provides a counter example with a household level delivery scheme. As of yet it is still in its infancy. This will be an interesting project to watch as it develops to see if it will be successful at the household level or if it will evolve to a village level with larger numbers of fuel cells, which is more typical for a technological intervention of this type.

6.5 Further developments needed

There are additional developments needed in technologies, commerce, and the governance and regulatory conditions for energy services in developing rural communities. Many of the problems commonly identified in rural energy provision in years past focused on unit breakdowns, over-reliance on imported parts, and lack of local know-how for operation, repairs and maintenance. While these problems have by no means been rectified completely, they are well-documented and most of the interventions currently operating are addressing them in some fashion. The more timely critiques of rural energy provision interventions are related to user experience, price points etc. As previously discussed, more emphasis is needed on the user experience in the technological design. This will involve continued development of existing technologies adapted for the specific social context. More designers from both the developed and developing world are needed to continue this development.

Further, improved governance arrangements and new policies (e.g. standards) are needed to support energy services in rural communities. Although technology itself tends to be the focus for service provision, initiatives often fail due to a lack of appropriate policy and institutional support. Further, it is important that initiatives do not exacerbate existing inequalities in communities. Thus, new programme designs are needed for rural energy service provision that addresses such issues, particularly related to gender inequality. Such programmes should recognize that the village level energy market is heterogeneous.

6.6 Scaling up: Expanding from pilots to larger implementation

One of the challenges of scaling up is the lack of access to a technically proficient workforce. Thus scaling up will require the development and training of human resources in basic competencies. As deployment of technologies expands, local economies should also benefit from opportunities to manufacture components, not just to install systems imported from elsewhere. Some technologies provide more opportunities for local manufacturing than others, and this may be an appropriate consideration in deciding on which technologies to adopt. Similarly, as indigenous scientific and technical capacities increase, for example through schemes such as those run by the International Science Programme as discussed earlier, opportunities should arise for innovation and technology development to be driven locally.

As previously discussed, scaling up will also require new financing mechanisms with standardisation of the rural energy off grid sector. In order for these funds to minimise the transaction cost, they must be appropriately priced. Crowdsourcing funding may be an effective approach to obtain some funding, with organisations such as Kopernik[20] finding some success in providing access to funds. Subsidy schemes can facilitate greater implementation by moving technologies between affordability brackets.

Another challenge to scaling up arises when an initiative has relied on the drive and charisma of a distinctive individual. Making the transition from a one (wo)man initiative to an organisation that can scale up implementation by several orders of magnitude shares many of the challenges of start-up companies generally, and there may be some read-across of appropriate responses.

6.7 What are the similarities and differences between the three countries, and why?

There are both similarities and differences between India, Tanzania, and Ghana. Similarities between the case studies included the challenges of securing funding. Another is that unreliable and poor quality electricity supplies from a centrally planned grid system often motivate individual households and villages to 'go it alone' and develop their own more controllable power solutions. This trend is on the rise in Tanzania, but less so in Ghana, which tends to experience fewer black and brown-outs, and energy price fluctuations.

A notable difference between the countries is of course their geography, which plays an important role in the economy: for example, East Africa is a hub, thus imports tend to be less expensive than in Ghana. There are also differences with regard to gender issues. For example, there has been a strong women's empowerment initiative in Tanzania over the last 20 years, but the same has not been the case in Ghana. Discrepancies between rural and urban connectivity are also more significant in Tanzania than in Ghana. Finally, India tends to have a human resource base that has a higher level of education, particularly at the graduate and doctoral levels.

20 http://www.kopernik.info/

Chapter 7: Recommendations for Phase 2

Although there are already a number of initiatives on village energy development in the focal countries, we conclude that an EASAC-MCSC phase 2, if appropriately designed, has the potential to add significant value. The following paragraphs summarise the ways in which initiatives in each country could add value and the shapes that they might take.

An important point is that any initiatives should be locally-rooted, in this case through collaboration with the local academies and the appropriate networks of academies in Africa and Asia.

In many countries, the academies are a preferred source of authoritative scientific advice for governments and society. They also have good 'convening power': a call from an academy to participate in a study or workshop is more likely to elicit a 'yes' response than a less well known body. These favourable features may be further strengthened through collaboration with the network of European academies: EASAC's experience in Europe is that governments can be more receptive to the advice of their national academies if it is backed up by, or arises from, an EASAC study.

An academy-led initiative, distinctively from those led by others, may consequently be able to address a key, underlying problem: that village-level energy developments tend to sit some way down governments' priorities. Governments generally take a 'centralist' approach to the development of their country's energy systems, focusing on large plants and access to electricity through national grids, and prioritising urban over rural areas. As a result, villages are neglected with the dire consequences for energy access discussed in chapters 1 and 2. An overall aim then for phase 2, should be to help get village level energy provision 'up the government agenda' in India, Tanzania and Ghana.

An overarching conclusion of this phase 1 study is that it is generally not the availability of suitable technologies that is the main barrier to progress (though making them cheaper, more reliable, and easier to install and maintain will help), but ensuring that the overall 'package' – including its commercial, social, financial and regulatory parameters – appropriately addresses the specific local needs and constraints. Making progress will require the key players responsible for the various dimensions of the energy package to be brought together in constructive collaborations. Convening these players in effective events to catalyse these collaborations will be a key aim of the proposed phase 2 workshops. Such workshops will need to be embedded as one step in an on-going process.

One element of the workshops will be to inform government policy in India, Tanzania and Ghana on how best to take forward village energy development in their countries. Reflecting EASAC's core role as advisor to the EU policy institutions, they should also inform the EU's international development policy which, as mentioned in chapter 1, has energy provision in developing countries as one of its core aims. Consideration should therefore be given to involving representatives of the European Commission's Directorate General for Development and Cooperation (http://ec.europa.eu/europeaid/index_en.htm) in the workshops, along with representatives of the country's government responsible for energy policy and initiatives.

Other key groups that will need to be represented in an appropriate mix at the workshops are:

- entrepreneurs and leaders of social businesses and enterprises who are already engaged in providing energy services in villages;
- bankers and other providers of finance;
- relevant local and international NGOs;
- the 'customers': representatives of the villagers whose energy needs are to be met; and

- scientists and engineers with experience of making the relevant technologies work in the field.

Two, often under-represented, groups of stakeholders should have a good presence at the workshops:

- women: who often have a key role to play, both at the individual household and village levels, in defining what energy services are needed, ensuring the effective operation of installed systems, and realising the educational, welfare and income generating opportunities generated by access to energy; and
- young people – scientists, engineers, entrepreneurs, activists and administrators – on whose energy and commitment rests the future success or failure of many potential initiatives.

The aims, design, location and timing of the workshops will need to emerge from the proposed dialogue with the academies and stakeholders over coming months. Provisionally, we would expect them to require at least two full days to properly address the substance of the issues, and to enable the relationships and connections to be made which will be a key outcome of the workshops. A well-constituted participation of around 30 people is considered at this stage to be an appropriate size, enabling open discussion and frank exchanges of views. Consideration should be given to professional facilitation of the workshops.

The workshops cannot cover the full range of potentially relevant issues: if they try to, they will end up being too superficial. Appropriate areas of focus will need to emerge from the anticipated interactions in the initial months of phase 2. However, several ideas have emerged from phase 1:

- identify the educational opportunities that are emerging from synergistic, current developments in energy provision and information connectivity, and consider how consequent benefits can be maximised;
- consider the benefits arising from, and design of, networking initiatives (possibly web-enabled) which enable local groups, social businesses and enterprises to share information and experiences;
- review how standardisation – of technologies, financial packages etc. – may help roll out and scale up, and what forms it could take;
- undertake visioning exercises for village energy development in +10, +20 years etc. to generate motivational views of the future which will guide and inspire individual initiatives;
- consider the role of women in village energy development and how it may be further developed;
- address how to improve access to affordable financing, and how to connect people/organisations with venture capital (both in the countries and elsewhere) with those who need it; and
- consider how to improve access to information on the cost, quality, reliability etc. of energy products.

In respect of the three individual countries, the requirement to choose an appropriate focus is arguably strongest in India given its size and diversity, and the wide range of issues that it faces in respect of village energy development. Early contact with the Indian Academy, and further interactions with key players will be needed to decide on the focus and the consequent design of the workshop (tentatively planned for early-2013). The contacts made with government officials and social enterprises in India during phase 1 will be a good starting point. An initial Cambridge-based workshop is under discussion and may provide an appropriate stepping stone to the workshop proposed to be held in India.

Renewable off-grid power generation and related In respect of Tanzania, a collaboration was initiated during phase 1 with the International Science Programme based at Uppsala University in Sweden, and the Royal Swedish Academy of Sciences who plan to hold a workshop in September 2012 looking at village energy development in Tanzania and Kenya. This workshop will be held in Sweden. Collaboration in this workshop would be an appropriate next step for the EASAC-MCSC initiative, and would enable a view to be taken on the value and aims of any follow-up workshop in Tanzania that EASAC-MCSC might take forward.

Ghana, and West Africa generally, tend not to get as much attention and support as East Africa, which suggests that EASAC-MCSC might prioritise a workshop here over Tanzania. However, more work will be needed to better understand the challenges and opportunities, and to identify the key players to collaborate with.

For both Tanzania and Ghana, early contact with the African network of academies (NASAC: www.nasaconline.org) will be appropriate, building on the relationship already established. Working through NASAC may be particularly helpful in taking forward the possibility of a Ghana-based workshop.

Annex 1: Study team short biographies

Meghan Bailey

Meghan Bailey is a DPhil candidate at the University of Oxford's Environmental Change Institute specializing in climate compatible development and disaster risk reduction. She is a community-based natural resources specialist with field experience in Africa. Before coming to Oxford she worked for 5 years on community development projects in Ghana, Botswana and Kenya and returns frequently to the field for her current research. She is currently managing a large-scale coastal resilience programme outside Mombasa, Kenya.

She is a Young Humanitarian Scholar of the International Federation of Red Cross/ Red Crescent's Climate Center and an International Development Management Fellow of the Aga Khan Foundation. She also holds a Master of Science degree in Environmental Change and Management from the University of Oxford and a Bachelor of Public Affairs and Policy Management from Carleton University in Ottawa, Canada.

Justin Henriques

Justin Henriques is currently a postdoctoral analyst in the Environmental Change Institute at the University of Oxford. He holds a PhD and MSc in systems engineering, a masters in Urban and Environmental Planning (MUEP), a BSc in applied science, and a BA in philosophy. He was a National Science Foundation Graduate Research Fellow from 2008-2011, and a fellow in the University of Virginia's Interdisciplinary Water Resources and Contaminant Hydrology Program from 2007-2008. Justin is the cofounding director of a nonprofit aid organization that provides basic needs infrastructure to developing communities. His areas of specializations include infrastructure systems, and distributed energy and water systems for developing communities.

John Holmes

John Holmes is a Senior Research Fellow in the Department of Earth Sciences of the University of Oxford, where his research is concerned with making better links between science and environmental policy making, and is Secretary to the Energy Programme of the European Science Academies Advisory Council. He also works as an independent consultant undertaking science-policy studies for Government ministries and research councils across Europe.

His previous career spanned the assessment and development of clean coal technologies, responsibility for the science and the engineering of the UK's radioactive waste disposal programme, and then roles as Head of R&D and of the Science Programme of the Environment Agency (the environmental regulator for England and Wales). He is a Chartered Engineer with a first degree in natural sciences from Cambridge University, a PhD in energy engineering from Imperial College, and an MBA from Brunel University.

Ruchi Jain

Ruchi Jain completed her Masters in Environment Change and Management from the Environment Change Institute, University of Oxford in 2011. Prior to her Masters, she worked with 350.org as South Asia Co-Coordinator and went on to become the National Co-Coordinator of Indian youth Climate Network. She was part of the first youth delegation to COP14 and has played an active role as the Agents of Change Director, 2009, for the Indian Youth Delegation to COP15.

Ruchi did her schooling at two J- Krishnamurti schools and is a graduate of political science from St Xaviers College. She attended The Rotary International One Year Study Exchange Programme in France. In school she gained experience on field visits to a Bangalore based NGO called Navdarshanam, Kaigal Environment Education Programme (KEEP), and a Krishnamurthy Foundation India (KFI) project, Ralegan Siddhi, a model village create by Anna Hazre.

Her experience has been is environment advocacy, rural energy and development, and climate change. Currently she holds a Project Associate position with the Ministry of New and Renewable Energy based out of New Delhi. The project she is working on is “Scaling up Deployment of Renewable Energy Technology for Promoting Innovative Business Models”.

Annex 2: Energy and Climate Change Resilience (Meghan Bailey)

While sub-Saharan African countries emit only a small fraction of global carbon emissions, they will acutely bear the brunt of climate change because of both physical and socio-economic attributes. Contributing factors include location in the tropics with higher propensity for natural disasters, weaker physical infrastructure to offer protection and less government capacity to respond; marginal and degraded lands that are increasingly being used for residence, farming and industrial development; dependence on rain fed agriculture, and so forth. The risk of climate change exacerbating global inequalities and the potential for major humanitarian crises is immense. A report commissioned by the World Bank summarized the geopolitical situation as follows: "Climate change will be pivotal in redefining development in the twenty-first century. How nations, societies, communities, and households respond to the impacts of climate changes and variability to which the world has already been committed will in many instances determine their prospects for growth, equity, and sustainability" (Argawal, 2008. p.2).

Climate change considerations are particularly relevant when discussing Ghanaian and Tanzanian case studies. Global vulnerability maps identify two regions of Eastern Africa (the coast and the semi-arid rangelands) and one region of Western Africa (the arid and semi-arid systems of the Sahel) as three of four African 'hotspots' where climate change is expected to severely impact agricultural production with the potential to evoke major humanitarian crises and unparalleled out-migration (Thornton et al, 2009). In the next 40 years climate change will therefore likely be a leading contributor to extreme poverty in these countries. To effectively adapt to increasingly unpredictable rainfall patterns associated with climate change, farmers will need to diversify their income generating activities. Access to energy opens up a host of alternate employment and training opportunities. Such income and education diversification has the potential to make communities less vulnerable to fluctuations in seasonal rainfall that are expected to increase in severity and frequency as a result of global climate change, and help subsistence-oriented families adapt to their changing environment.

During the International Institute for Environment and Development's (IIED) Community-Adaptation Conference in Dakar (April 2011) it was noted by Dr. Ian Burton of the University of Toronto during his speech to the plenary that there has been a shift in mentality towards foreign assistance by donor countries as a result of climate change. Assistance for adaptation and mitigation has ushered in a renewed sense of responsibility that differs from sentiments of the past. He stated "Responsibility is what distinguishes climate adaptation from general development assistance. We are now is a world of responsibilities. Moving forward on adaptation – we are just beginning… There is talk of funds for adaptation and mitigation reaching 100 billion on an annual basis annually within the next decade". It is still unclear how closely these mechanisms will operate in relation to traditional chains of foreign assistance which will undoubtedly affect their design and delivery – regardless, it represents a potentially enormous and unprecedented opportunity to improve energy access within subsistence oriented communities in sub-Saharan Africa. No doubt it will have a dramatic impact on the donor landscape that energy access programmes rely on and the social enterprise investment interests are influenced by.

Climate adaptation and funding to build adaptive capacity may eventually dictate most of the development and humanitarian agenda. Nelson et al. (2007) define adaptation as "…actions and adjustments undertaken to maintain the capacity to deal with stresses induced as a result of current and future external changes" (p.396) and adaptive capacity as "…preconditions that enable actions and adjustments in response to current and future external changes; dependent both on social and biophysical elements" (p.397). Much scholarly literature has been devoted to exploring whether it is even possible to build adaptive capacity and at what scale.

Community-based adaptation to climate change projects have been quickly growing in number since 2008 and their number will likely spike in the next few years with the United Nations Environmental Programme's (UNEP) plans to launch a large scale programme called the *Global Partnership on Community-based Adaption that will bring together UN agencies, civil society, private foundations as well as the private sector. Further, the number of donor agencies committed to funding adaptation schemes including the Global Environmental Facility (GEF), Australian Government Overseas Aid programme (AusAid), the European Commission, the Canadian International Development Agency (CIDA) and the UK's Department for International Development (DFID) is increasing (Reid et al., 2010. p.6-7).*

References:

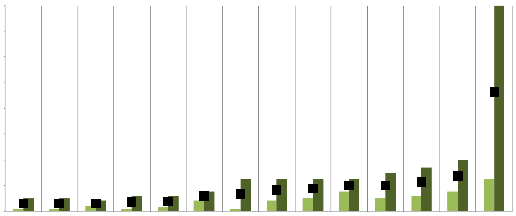
Argawal, A. (2008). *The Role of Local Institutions in Adaptation to Climate Change.* Report prepared for the Social Dimensions of Climate Change, Social Development Department, The World Bank, Washington DC. http://www.icarus.info/wp-content/uploads/2009/11/agrawal-adaptation-institutions-livelihoods.pdf

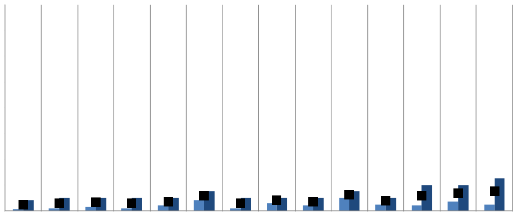
Nelson, D.R., Adger, N.W, and Brown, K. (2007). *Adaptation to Environmental Change: Contributions of a Resilience Framework.* Annual Review of Environment and Resources, Vol. 32, pp 395-419.

Reid, H., Huq, S., and Murray, L. (2010). *Community Champions: Adapting to Climate Challenges. International Institute for Environment and Development. London.* http://pubs.iied.org/pdfs/10028IIED.pdf

Thornton, P., Jones, P., Alagarswamy, G., Andresen, J. (2009). *Spatial variation of crop yield response to climate change in East Africa. Global Environmental Change, Vol. 19, pp 54-65.*

Annex 3: Indicative costs for energy technologies for village applications





To illustrate potential costs of village energy provision, Figures A3.1 and A3.2 below show current and projected costs of renewable energy technology (in US cents per kWh). The figures are from Ahuja and Tatsutani (2009) (which adapts data from the UNDP (2004) Table 7, p. 50). Ahuja and Tatsutani note, "...(wholesale) electricity production costs in many developed countries in recent years have been on the order of 2–4 c/kWh; retail prices have been on the order of 8 c/kWh; prices in off-grid niche markets have been on the order of 14 c/kWh and peak power prices have typically ranged from 15–25 c/kWh".

Sources:

Ahuja, D. and M. Tatsutani (2009). *Sustainable energy for developing Countries*. Sapiens Sapiens Vol. 2, no. 1.

UNDP (2004). World Energy Assessment: Overview—2004 Update. New York.

ANNEX 4: FUNDING SCHEMES AND INFORMATION

Listings of funding schemes and relevant initiatives

Byrne, R., Smith, A., Watson, J., and Ockwell, D, 2011. Energy pathways in low-carbon development: from technology transfer to socio-technical transformation. STEPS Centre, University of Sussex. http://www.steps-centre.org/PDFs/Energy_PathwaysWP.pdf

Page 13:

Many of the current and proposed arrangements for financing low-carbon development (conceived principally as an issue of technology transfer) are discussed in Annex B. Donor countries tend to have their own bilateral agencies that include some form of technical assistance but our discussion here (and in Annex B) focuses on those institutions that are multilateral. In part, this is to simplify the discussion but also it is in the multilateral institutions that we can see most clearly the negotiations over technology access and how to improve it. There has been or continues to be the Energy Assessment Programme (EAP), Energy Sector Management Assistance Programme (ESMAP), Global Environment Facility (GEF), the Clean Development Mechanism (CDM), Climate Investment Fund (CIF), and possibilities of using Advance Market Commitments (AMCs) and a new Copenhagen Green Climate Fund. Each has different motives and forms of engagement, but all except ESMAP and the GEF (to some extent) emphasise finance for 'technology transfer'.

Annex B on pages 74-8

IEA, 2011. Energy for all: financing access for the poor. Special excerpt from the World Energy Outlook 2011. http://www.iea.org/weo/financing_access.asp

Pages 36-42 provide a useful generic analysis of funding sources.

Links provided by Low carbon energy for development network (**www.lcedn.com**):

International Institutions

International Energy Agency (IEA) http://www.iea.org/

International Renewable Energy Agency (IRENA) http://www.irena.org

IRENA Renewable Energy Africa Country Profiles http://www.irena.org/REmaps/africamap.aspx

United Nations Environment Programme (UNEP) - Environment for Development http://www.unep.org/

United Nations Development Programme (UNDP) - Environment and Energy http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/overview.html

Government Agencies / Initiatives

Department for International Development (DfID) http://www.dfid.gov.uk/

Department of Energy and Climate Change (DECC) http://www.decc.gov.uk/

Science and Technology Research Partnership for Sustainable Development (SATREPS) http://www.jst.go.jp/global/english/

Non-governmental / not-for-profit Organisations and Initiatives

African centre for Technology Studies (ACTS) http://www.acts.or.ke/

Energy, Environment and Development Network for Africa (AFREPEN) http://www.afrepren.org/

Change Agents for Sustainable Development (E3G) http://www.e3g.org/

Global Village Energy Partnership (GVEP) http://www.gvepinternational.org/

Household Energy Development Organizations Network (HEDON) www.hedon.info

International Network on Gender and Sustainable Energy (ENERGIA) http://www.energia.org/

Lighting a Billion Lives Campaign (TERI) http://labl.teriin.org/

Practical Action http://practicalaction.org

The Program for Basic Energy and Conservation (ProBEC) http://www.probec.org/

Renewable World (formerly The Koru Foundation) http://www.renewable-world.org/

Sustainable Energy Society of Southern Africa (SESSA) http://www.sessa.org.za/

Academic Institutes / Departments

China Low Carbon Platform - Institute for Development Studies (IDS) http://www.ids.ac.uk/idsproject/china-low-carbon-platform

Durham Energy Institute (DEI) - University of Durham http://www.dur.ac.uk/dei/

Energy Futures Lab - Imperial College London http://www3.imperial.ac.uk/energyfutureslab

Energy Research Centre (ERC) - University of Cape Town http://www.erc.uct.ac.za/

Governance of Clean Development (GCD) Project - University of East Anglia

http://www.uea.ac.uk/ dev/gcd/

Institute for Energy and Environmental Research - University of Strathclyde http://www.ieer.org/

Institute for Energy Research and Policy - University of Birmingham http://www.ierp.bham.ac.uk/

Science and Technology Policy Research (SPRU) - University of Sussex http://www.sussex.ac.uk/ spru/index

Sustainability Research School - Loughborough University http://www.lboro.ac.uk/schools/ sustainability/

The Energy and Resources Institute (TERI) http://www.teriin.org/index.php

UCL Energy Institute - University College London http://www.ucl.ac.uk/energy/

UK-India Sustainable Energy Technologies Network http://www.uk-india-energynetwork.ac.uk/index.php

Research Networks / Clusters

Centre for Low Carbon Futures http://www.lowcarbonfutures.org

Energy, Environment and Development Programme (EEDP) - Chatham House http://www.chathamhouse.org/research/eedp

Energy Geographies Working Group (EGWG) - Royal Geographical Society-Institute of British Geographers (RGS-IBG) http://energygeographiesworkinggroup.wordpress.com/

Energy Research centre of the Netherlands (ECN) http://www.ecn.nl/home/

The Green Growth Knowledge Platform (GGKP) http://www.greengrowthknowledge.org

Interdisciplinary Cluster on Energy Systems, Equity and Vulnerability (InCluESEV) http://incluesev.kcl.ac.uk/

Midlands Energy Consortium http://www.midlandsenergyconsortium.org/

Policy Innovation Systems for Clean Energy Security (PISCES) http://pisces.or.ke/

Research Councils UK (RCUK) Energy Programme http://www.rcukenergy.org.uk/

Science and Development Network (SciDev) http://www.scidev.net/en/climate-change-and-energy/

Social, Technological and Environmental Pathways to Sustainability (STEPS Centre) http://www.steps-centre.org/

The Energy and Resources Institute (TERI) http://www.teriin.org/index.php

Tyndall Centre for Climate Change Research http://www.tyndall.ac.uk/

UK Energy Research Centre (UKERC) http://www.ukerc.ac.uk/support/tiki-index.php?page=Home

Other

Central Energy Fund (CEF) Group www.cef.org.za

Climate and Development Knowledge Network (CDKN) http://cdkn.org/

Ecoequity http://www.ecoequity.org/

Energy Generation and Supply Knowledge Transfer Network (KTN) https://connect.innovateuk.org/web/energyktn

Energy Geographies Blog www.energygeographies.com

Energy Technologies Institute (ETI) http://www.energytechnologies.co.uk/Home.aspx

Foundation Rural Energy Services www.fres.nl

Greenhouse Development Rights (GDRs) http://gdrights.org/

Green Growth Knowledge Platform (GGKP) www.greengrowthknowledge.org

The Global Green Growth Institute (GGGI) www.gggi.org

International Year of Sustainable Energy for All http://sustainableenergyforall.org/

Renewable Energy & Energy Efficiency Partnership (REEEP) http://www.reeep.org/31/home.htm

Renewable Energy Policy Network for the 21st Century (REN21) http://www.ren21.net/

Responding To Climate Change (RTCC) www.rtc.org

Sustainable Energy Policy & Practice (International institute for Sustainable Development) http://energy-l.iisd.org/

Life Without Lights www.lifewithoutlights.com

Low Carbon Innovation Group (LCIG) http://www.lowcarboninnovation.co.uk/

Working Group on Development Techniques (WOT) www.wot.utwente.en

World Future Energy Summit (WFES) http://www.worldfutureenergysummit.com

SMART VILLAGES

New thinking for off-grid communities worldwide

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