
Microfinance and its Role in Facilitating Access to Renewable Energy Sources for the Poor

Tina Matusinovic
Karen Sims
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<th>Description</th>
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<tbody>
<tr>
<td>ARC</td>
<td>Aprovecho Research Center</td>
</tr>
<tr>
<td>BC</td>
<td>Black Carbon</td>
</tr>
<tr>
<td>BoP</td>
<td>Base of the Pyramid</td>
</tr>
<tr>
<td>CER</td>
<td>Certified Emission Reduction</td>
</tr>
<tr>
<td>DFID</td>
<td>Department for International Development</td>
</tr>
<tr>
<td>GACC</td>
<td>Global Alliance for Clean Cookstoves</td>
</tr>
<tr>
<td>GSMA</td>
<td>Groupe Sociale Mobile Association</td>
</tr>
<tr>
<td>IADB</td>
<td>Inter-American Development Bank</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IFC</td>
<td>International Finance Corporation</td>
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<td>ITU</td>
<td>International Telecommunications Union</td>
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<tr>
<td>LPG</td>
<td>Liquefied petroleum gas</td>
</tr>
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<td>MDG</td>
<td>Millennium Development Goal</td>
</tr>
<tr>
<td>MFI</td>
<td>Microfinance Institution</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-Operation and Development</td>
</tr>
<tr>
<td>PAYG</td>
<td>Pay-As-You-Go</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>SACCO</td>
<td>Savings and Credit Co-operative</td>
</tr>
<tr>
<td>SE4ALL</td>
<td>Sustainable Energy for All</td>
</tr>
<tr>
<td>SHS</td>
<td>Solar Home System</td>
</tr>
<tr>
<td>SKDRDP</td>
<td>Shri Kshethra Dharmasthala Rural Development Project</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>WTP</td>
<td>Willingness to pay</td>
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</table>
Abstract

This paper examines the role that microfinance can play in facilitating access to renewable energy sources. Rural off-grid poor households in many countries are excluded from access to modern, reliable and safe energy sources. Energy poverty imposes severe consequences which affect finances, health, education and the environment.

An estimated 2.6 billion people lack clean cooking facilities and approximately 1.3 billion don’t have access to electricity. Relying on solid biomass for cooking and kerosene for lighting has significant economic, health and environmental impacts which compromise the attainment of the UN’s Millenium Development Goals.

BoP household energy expenditures are significant but are often spent on inefficient and unhealthy fuels. The associated opportunity costs are also considerable.

Advances in distributed renewable energy household-level devices have led to increasing affordability, but upfront costs and lack of consumer awareness of the benefits remain barriers, among others. This paper reviews selected technological innovations: solar lighting, improved cookstoves, and biogas digesters.

Innovative financing mechanisms are the primary selection criteria for the cited case studies of renewable energy products and projects. These case studies demonstrate the role that microfinance can play in affording access to renewable energy. Repayment capacity, represented by the proxy of current energy expenditures, and willingness-to-pay indicators are examined.

Keywords: energy poverty, microfinance, sustainable energy, renewable energy, BoP

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1. INTRODUCTION

As the microfinance industry matures, more varied services are being offered. The original emphasis on providing microcredits has broadened to offering savings, insurance, and remittance products. As the outreach of Microfinance Institutions (MFIs) expands, so do their abilities to offer innovative solutions to problems besetting the poor. Financial inclusion is only one aspect of full inclusion in society. Access to energy is equally, if not more, important as access to financial services. The poor in many countries are excluded from access to modern, reliable and safe energy sources. This is particularly true among the rural poor. Just as they have been marginalized by conventional banks, the poor are often off the grid when it comes to energy sources, and not by choice.

Thanks to advances in renewable energy and its increasing affordability, the time has come to make a concerted effort to expand access to modern and healthy energy sources, and MFIs can play a leading role.

There have been isolated efforts in the past and this paper, through a thorough literature review, summarizes the academic and industry research on such initiatives. While there have been some successful development projects at the community level utilizing technologies with higher energy generation capacity, this paper focuses on the technologies and lending methodologies appropriate to the energy needs of off-grid poor households in remote areas for cooking, lighting and communication.

Drawing on this knowledge base, this paper reviews past projects, looking for successful, sustainable and replicable implementations of projects that provide microfinance for renewable energy technologies while recognizing that there are aspects that can and do go wrong.

Microfinance has been a successful tool to expand access to financial services for poor and rural populations previously underserved by traditional financial institutions that deemed such markets as unprofitable. The rural poor are also underserved by traditional energy providers. Economies of scale make it prohibitive for energy companies to invest in infrastructure in remote, scarcely-populated areas. Microfinance has proven to be an important catalyst redressing this inequity enabling financial access to affordable alternative small-scale renewable energy technologies.

This paper posits that microfinance is an effective enabling mechanism in development projects that focus on enabling sustainable access to affordable renewable energy services for poor and rural populations in off-grid remote regions. Our objective is to review renewable energy acquisition projects that have been funded by microfinance credits to analyze how granting microcredits to energy poor households in remote off-grid areas to adopt renewable energy
systems is a sustainable business proposition to reduce poverty. By looking at numerous case studies of implemented projects and analyzing current energy expenditures as a proxy for repayment capacity, the results and reasons for success are presented across different countries and across technologies implemented for this specific target population.

2. PROBLEM DIMENSION

2.1. Context analysis

Beyond food/water and shelter/clothing, energy is a basic need often taken for granted in developed countries and all too often woefully inadequate in developing regions.

“Energy services are a crucial input to the primary development challenge of providing adequate food, shelter, clothing, water, sanitation, medical care, schooling, and access to information. Thus energy is one dimension or determinant of poverty and development, but it is vital. Energy supports the provision of basic … Conversely, lack of access to energy contributes to poverty and deprivation and can contribute to economic decline” (Bradbrook, 2005).

Energy poverty, described as “the minimum quantity of physical energy needed to perform such basic tasks as cooking and lighting” (Khandker et al, 2010), directly affects between 22% - 57% of the people in the world, and they are overwhelming poor and predominately rural (IEA, 2014). The devastating consequences are multi-dimensional, affecting the finances, health, education, and environments not only of the energy-impoverished but those of their broader communities, countries, and the entire world. “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 2.6 billion people are without clean cooking facilities” (IEA, 2014). In addition to basic energy needs at the household-level, there are energy requirements for services associated with health, education, and communications. Moreover, there are energy demands for agricultural and productive uses without which there would be no opportunities for income-generation.

Given the pervasive and insidious effects of energy poverty, many international and development organizations are actively engaged in campaigns to expand access to cleaner, safer, sustainable energy sources, notably the United Nations’ Development Programme’s Sustainable Energy for All (hereafter, SE4ALL), supported by the World Bank. SE4ALL has 3 primary goals, the first being universal access to clean cooking fuels and electricity (World Bank, 2015).

While there is no articulated Millennium Development Goal (MDG) for energy “energy poverty is one of the many manifestations of poverty and a prevailing feature of deprived rural and urban households in developing
countries” (Rehfuess, 2006). “With respect to household energy, dependence on polluting and inefficient fuels and appliances is both a cause and a result of poverty” (WHO, 2015). Table 2.1.1 aligns the positive impacts of energy poverty reduction with each of the eight MDGs:

**Table 2.1.1: The United Nations’ Millennium Development Goals and energy poverty**

<table>
<thead>
<tr>
<th>Goal 1: Eradicate extreme poverty and hunger</th>
<th>Decreased illness from indoor air pollution lowers health care expenses and raises earning capacities.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased fuel efficiency and reduced fuel purchases ease constraints on household budgets.</td>
</tr>
<tr>
<td></td>
<td>Improved household energy technologies enable household-based income generation activities.</td>
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<tr>
<td>Goal 2: Achieve universal primary education</td>
<td>Healthier children who are not burdened with collecting fuel are more likely to attend school and have more time for homework.</td>
</tr>
<tr>
<td></td>
<td>Improved lighting sources allow children to study after dark.</td>
</tr>
<tr>
<td>Goal 3: Promote gender equality and empower women</td>
<td>Recapturing time spent on fuel collection and reducing cooking time give women more time to engage in productive activities, education and child care.</td>
</tr>
<tr>
<td></td>
<td>Risks of physical assault and injury are reduced if women and girls don’t have to travel as far/as often to collect fuel.</td>
</tr>
<tr>
<td></td>
<td>Gender equality is promoted if women are involved in household energy decisions.</td>
</tr>
<tr>
<td>Goal 4: Reduce child mortality</td>
<td>Reduced indoor air pollution lowers child morbidity and mortality from pneumonia.</td>
</tr>
<tr>
<td></td>
<td>Stillbirth, prenatal mortality and low birth weights can be avoided if embryos are protected from indoor air pollution.</td>
</tr>
<tr>
<td></td>
<td>Absence of open fires and kerosene lamps prevents infants and toddlers from being burned.</td>
</tr>
<tr>
<td>Goal 5: Improve maternal health</td>
<td>Controlling indoor air pollution can reduce incidence of chronic respiratory problems in women, especially new mothers.</td>
</tr>
<tr>
<td></td>
<td>Risk of prolapsed is reduced if women don’t have to carry heavy loads of wood.</td>
</tr>
<tr>
<td>Goal 6: Combat HIV/AIDS, malaria and other diseases</td>
<td>Reduced indoor air pollution levels can help prevent 1.6 million annual deaths from tuberculosis.</td>
</tr>
<tr>
<td>Goal 7: Ensure environmental sustainability</td>
<td>Deforestation may be mitigated in areas where wood is scarce.</td>
</tr>
<tr>
<td></td>
<td>Improved fuel efficiency reduces greenhouse gas emissions.</td>
</tr>
<tr>
<td>Goal 8: Develop a global partnership for development</td>
<td>Energy is essential to development.</td>
</tr>
</tbody>
</table>


If the MDGs are to be achieved and energy poverty reduced, significant changes must occur. To better understand the relationship between energy poverty reduction and the MDGs, one must first understand current energy uses at the Base of the pyramid (BoP).
A World Resources Institute study of annual spending by 2.1 billion people across 34 countries, estimated the BoP household market for energy at US$ 228 billion (All dollar amounts in 2005 PPP) and calculated that an average of 9% of expenditures are on energy, but with rural households spending 44% less than their urban counterparts. (Hammond et al, 2007)

Approximately three billion people use solid fuels - biomass (wood, dung, and crop residues) and coal – for cooking, heating and boiling water (Rehfuess, 2006). 95% of staple foodstuffs require cooking before eating (Burlingham and Townsand, 2008).

**Figure 2.1.1: Population using solid fuels (%), 2013**

An estimated 1.3 billion people in unelectrified households typically rely on kerosene for lighting, and the number is even larger if under-electrified homes are taken into account. (Climate and Clean Air Coalition, 2014). As presented in Figure 2.1.2, only 25% of rural Africa is electrified what makes it least electrified region.

**Figure 2.1.2: Regional electrification rates**

Source: IFC analysis; IEA
Note: OECD Organization for Economic Co-Operation and Development
Because of the explosive growth in mobile phone ownership in developing countries, figures change rapidly. But the trend of adoption by lower-income populations continues. Statistics from 2013 indicate that 88 out of 100 inhabitants in developing countries had mobile-cellular subscriptions (ITU, 2015). The International Telecommunications Union (ITU), a UN agency, predicted that, by the end of 2014, two of the three billion internet users would be in developing countries. (ITU, 2014) Mobile access devices require charging and the unelectrified must travel to central charging stations. (Farrell et. al. 2009).

2.2. Energy Poverty Impact Analysis

Beyond actual cash outlays for energy, there are other costs associated with energy poverty. There are significant health impacts from using “dirty” fuels as well as opportunity costs associated with fuel gathering and poor health. In addition, there are environmental impacts at the local, regional and global levels. The following sections review the impacts of energy poverty.

2.2.1. Health Impacts

The smoke produced by burning solid biomass fuels (such as wood, charcoal, coal, crop residue, and dung) is a major source of air pollution, particularly indoors. Fires, burns, and poisoning from kerosene and candles are additional risks that the poor contend with. The focus has now shifted to interventions that reduce indoor air pollution, promoting healthier fuel choices and/or improved efficiency in biomass use. The latter involves improved cookstoves and better ventilation in indoor cooking areas (Heltberg, 2003).

2.2.1.1. Mortality

According to the World Health Organization (hereafter, WHO), 4.3 million people a year die prematurely from illnesses (Figure 2.2.1) attributable to household air pollution caused by the inefficient use of solid fuels (2012 data).

Figure 2.2.1: Causes of death attributable to indoor air pollution


Pneumonia, attributed to breathing soot caused by household air pollution, is the cause of 50% of premature deaths in children under 5 years of age (WHO, 2014).
While it is difficult to put a price on a life, WHO estimates that switching to cleaner cooking sources would avert deaths among children and adults at a value of US$ 38.73 billion annually (IEA, 2006).

2.2.1.2. Morbidity

Both children and adults are at increased risk of developing respiratory diseases from indoor air pollution. The incidence of lung cancer, heart disease, stroke and cataracts are also positively correlated with exposure to high levels of air pollution in the home. There is some evidence that suggests household air pollution may contribute to “adverse pregnancy outcomes, tuberculosis, upper aero-digestive tract, cervical and other cancers.” (WHO, 2015). In addition to the direct health outcomes, exposure to indoor air pollution also has negative effects on those with already-weakened immune systems. AIDS sufferers are especially vulnerable (Rehfuess, 2006).

2.2.2. Environmental Impacts

“A changing climate affects the poorest people in developing countries the most. Droughts or heavy rains that lead to floods are disastrous to people with no buffers or savings” (World Bank, 2014). While developing countries’ overall contribution to global emissions is less than their industrialized counterparts, there are significant environmental impacts caused by the use of inefficient lighting and cooking devices by BoP households. In addition to the aforementioned 190 megatons of CO2 emissions caused by fuel-based lighting, over one billion metric tons of CO2 from cooking fires is released into the atmosphere each year. (Lee et al, 2013). In rural areas with few cars and limited electricity, CO2 is not the biggest issue, black carbon (BC) is.

An estimated 3 billion people are living in areas identified as “regional hotspots of BC-induced atmospheric solar heating” (Ramanathan and Carmichael, 2008). In Africa and Asia, an estimated 60 - 80% of black carbon emissions are from residential solid fuels, such as coal and biomass (Bond et al, 2013) with diesel engines and coal plants contributing lower percentages (Rosenthal, 2009). “Compared to greenhouse gas reductions, slashing black carbon offers a much quicker and cheaper fix. While climate-altering carbon dioxide can remain in the atmosphere for many decades, solid soot generally falls from the sky in days or weeks” (Luoma, 2010).

2.3. Energy Needs

“Although energy itself is not a basic human need, it is critical for the fulfillment of all needs. Lack of access to diverse and affordable energy services means that the basic needs of many people are not being met” (Bradbrook, 2005).
How much energy does a poor household require and for what tasks? The answers are as varied as the culturally and geographically heterogeneous households. Factors include family size and composition, climate, food supply and preferences, cooking practices, etc. The modern world relies on energy in almost every aspect of life. This paper's scope is limited to poor off-grid residential energy requirements. Because almost half of the rural poor are also subsistence farmers, agricultural uses are also of interest as are those for public and social facilities. However, they remain out-of-scope in this paper's analysis, as do the poor’s energy requirements for productive activities and transportation (London and Anupindi, 2012).

Residential energy requirements can be divided into 5 categories: 1) lighting; 2) cooking and water heating; 3) space heating; 4) cooling; and 5) information and communication (Halff et al., 2014). Lighting, cooking, and communications are the most universal while heating and cooling vary substantially due to climate factors. A household may also require energy for transportation, income-producing activities and/or agriculture. However, these are not considered in the scope of this paper. In an effort to standardize household energy requirements, Practical Action, in collaboration with the SE4ALL initiative, developed standards and defines Total Energy Access as presented in Table 2.3.1.

Table 2.3.1: Minimum standards for energy services

<table>
<thead>
<tr>
<th>Energy Service</th>
<th>Minimum standard</th>
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<tbody>
<tr>
<td>Lighting</td>
<td>300 lm for a minimum of 4 hours per night at household level</td>
</tr>
<tr>
<td>Cooking and water heating</td>
<td>1 kg woodfuel or 0.3 kg charcoal or 0.04 kg LPG or 0.2 liters of kerosene or ethanol per person per day, taking less than 30 minutes per household per day to obtain</td>
</tr>
<tr>
<td></td>
<td>Minimum efficiency of improved solid fuel stoves to be 40% greater than a three-stone fire in terms of fuel use</td>
</tr>
<tr>
<td></td>
<td>Annual mean concentrations of particulate matter (PM2.5) &lt; 10 µg/m³ in households, with interim goals of 15 µg/m³, 25 µg/m³ and 35 µg/m³</td>
</tr>
<tr>
<td>Space Heating</td>
<td>Minimum daytime indoor air temperature of 18ºC</td>
</tr>
<tr>
<td>Cooling</td>
<td>Households can extend life of perishable products by a minimum of 50% over that allowed by ambient storage</td>
</tr>
<tr>
<td></td>
<td>Maximum apparent indoor air temperature of 30º C</td>
</tr>
<tr>
<td>Information and communications</td>
<td>People can communicate electronic information from their household</td>
</tr>
<tr>
<td></td>
<td>People can access electronic media relevant to their lives and livelihoods in their household</td>
</tr>
</tbody>
</table>

Source: https://energypedia.info/images/archive/2/2c/20120503130947/TEA_ESI_questionnaire.pdf

Using these standards is advantageous because they take into account family size for cooking and water heating, climate variables for space heating and cooling, and include some measures of health and opportunity costs. Taking
these as minimum energy consumption measures, this paper will examine estimates of how much the poor currently spend on meeting them.

### 2.4. Energy Expenditures

As noted in paragraph 2.1., the achievement of the Millennium Development Goals is inextricably linked with affordable access to energy. Affordability is the key – there is an equity issue involved in energy acquisition (DFID, 2002). Not only do the poor tend to spend more per useable kilowatt of energy (Mills, 2002), the poorest of them generally have virtually no access to modern energy services due to the costs of energy technologies available currently (Heltberg, 2003).

A family who relies on kerosene for lighting often spends between 25% - 30% of their income on kerosene (Pope, 2012). While this figure is significantly higher than the 9% average energy expenditure cited before (2.1. Context analysis), reliance on kerosene is not only a result of the absence of grid connection. It also is a factor of affordability, which has three major components: 1) total cost; 2) initial investment; and 3) payment flexibility (Pope, 2012).

Kerosene lamps represent a pay-as-you-go (PAYG) business model with a limited initial investment in the lamps themselves and a high degree of payment flexibility. However, the on-going fuel costs of kerosene can be significant, especially for the poor who make small volume purchases and even more so for the rural poor who rely on a limited number of rural village vendors. Because it is a petroleum derivative, kerosene has a volatile price structure which places an additional burden on those who rely on it as their primary source for lighting.

As income increases, the proportion of household budgets expended on energy decreases (Figure 2.4.1). The “double penalty of poverty” arises from the facts, among others, that the poor pay more per unit because they buy in small quantities and because they have limited access to products and services. (Boston Consulting Group, 2011)

**Figure 2.4.1: Average yearly expenditure on energy**

<table>
<thead>
<tr>
<th>Annual Income (BOP)</th>
<th>Daily Expenditure</th>
<th>% of Income Spent on Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOP1500</td>
<td>$379 USD a day</td>
<td>25%</td>
</tr>
<tr>
<td>BOP1000</td>
<td>$264 USD a day</td>
<td>26%</td>
</tr>
<tr>
<td>BOP500</td>
<td>$148 USD a day</td>
<td>30%</td>
</tr>
</tbody>
</table>

Note: BOP500, BOP1000 and BOP 1500 present annual income increments of $500 PPP within the base of the pyramid

A kilowatt-hour of electricity typically costs between US$ 0.08 and US$ 0.40 in developed countries, but it costs between US$ 5.00 - US$ 20.00 to produce one kilowatt-hour from a kerosene lamp (Global Off-Grid Lighting Association, 2013). The Lawrence Berkeley Lab estimated that, when measured in units of useful energy services, kerosene lighting users pay 150 times more than households using compact fluorescent lamps. The estimated aggregate cost of fuel-based lighting is a staggering US$ 38 billion per year, not to mention approximately 190 megatons of CO$_2$ emissions (Mills, 2005).

In addition to lighting, the dramatic increase in mobile phone ownership has additional implications. "Typical fees for mobile phone charging are on the order of US$ 0.20 - US$ 0.40 per charge, though the rate can be higher in some regions" (Tracy and Jacobsen, 2012). As mobile phone use explodes among the poor, their expenditures for recharging these devices represents another drain on limited resources. Using data from mid-2013, the Groupe Sociale Mobile Association (GSMA) Mobile Enabled Community Services program estimated that there are more than 643 million people covered by mobile networks who lack access to electricity, and more than 476 million of them live in rural areas (Nique and Smetnik, 2015). Simpa Networks, an SHS provider, estimates that low-income off-grid consumers spend US$ 10 billion annually charging mobile phones (Simpa Networks, 2015).

The use of solid biomass for cooking and heating, except for charcoal and coal which are sold as commodities and typically used in urban and peri-urban environments (Mwampamba et al, 2013), generally represents a non-monetary activity. However, there is some evidence that "free firewood" can become scarce in locales which suffer from a rainy season (Twidell et al, 1985).

With annual out-of-pocket expenditures approaching US$ 50 billion just for fuel-based lighting and cell phone charging, the repayment capacity of poor households is significant. The role of microfinance is to enable the transformation of energy expenditures into asset accumulation. These renewable energy assets have important on-going benefits in improving families’ cash flows and freeing up expenditures once the energy devices have been paid for.

2.5. Opportunity Costs

Energy poverty not only entails inequitable energy expenditures, it also imposes opportunity costs in terms of lost productivity due to illness and time spent on fuel gathering and cooking. Children, when they are neither sick nor collecting wood or dung, have a better chance of attending school. Adults, particularly women, can engage in income-producing activities rather than walking kilometers to gather fuel (International Center for Research on Women, 2005).

"While it often takes a significant amount of time to collect firewood, this
time or opportunity cost cannot be easily converted into cash, and therefore it is difficult to assume that it could be diverted to purchasing improved cooking devices or fuels” (IFC, 2012).

The WHO estimated, in 2006, that the time savings due to less time spent on fuel collection and cooking would translate into productivity gains valued at US$ 43.98 billion if even only half of the population using solid cooking fuels in 2015 converted to liquid petroleum gas. While liquefied petroleum gas (LPG) is not considered a renewable energy source, the significant opportunity costs of fuel collection and inefficient cooking times are evident.

In an attempt to measure the magnitude of the time spent collecting firewood rather than merely relying on anecdotal evidence, Heltberg (2003) extracted data from surveys conducted in South Africa and Nepal and showed that rural households in Nepal spend up to 13.8 hours weekly collecting wood, while in South Africa up to 12 hours (Figure 2.5.1).

Figure 2.5.1: Wood collection time (in hours, per week) in rural South Africa and rural Nepal (only for those households that reported to spend time collecting wood)

![Figure 2.5.1](image)


Health impacts also have opportunity costs. An estimated 254 million days of sick time would be avoided annually if kerosene lamps were replaced by solar lanterns and improved cooking solutions were adopted (IFC, 2012). Given the enormous costs, both financial and non-monetary, of inefficient and unhealthy energy consumption in poor rural households, this paper examines technological solutions that offer possibilities to reduce cash expenditures while lowering opportunity costs.

3. TECHNOLOGICAL SOLUTIONS

“In order to reach universal, affordable and sustainable access to energy by 2030 (as stated by the United Nations), there is a need to ... develop innovative ways to provide decentralized and sustainable energy to off grid populations” (Nique and Smertnik, 2015).

While there is a downward shift in renewable energy product costs at the global level, sales prices to end-users are influenced by three additional factors: 1) import duties; 2) value-added taxes; and 3) supply-chain distribution costs. If any combinations of these are burdensome, end-user adoption at the local level may be hampered. According to the IFC, Malawi imposes a 50% tariff duty on
solar panels, while Kenya levies an even higher amount on stove importers although it has lowered duties on solar lanterns. Meanwhile, on the other side of the world, finished solar lighting products are subject to a 35% import tax in Cambodia (IFC, 2012). An exhaustive investigation of the effects of tariffs and value-added taxes is out of the scope of this paper; nevertheless, they remain important considerations in making renewable energy products more affordable for rural BoP households.

While governments can change duties and taxes with the stroke of a pen, the costs associated with supply-chain distribution are intertwined with petroleum prices, transportation infrastructure, and wages. Getting renewable energy products into the homes of the rural poor faces enormous “last-mile supply chain” hurdles. Again, an analysis is out of scope here but many consumer products corporations have figured out solutions.

An online search for “renewable energy” returns over 58 million results; indicative of this topic’s is breadth and depth. With thousands of technological devices to choose from and many more in the development pipeline, this paper offers a high-level overview of just a handful but with market potential for poor off-grid rural households, with particular focus on products that have been deployed using microfinance or innovative consumer credit. The four renewable technologies considered in this paper are: 1) solar lanterns; 2) solar home systems; 3) improved biomass cookstoves; and 4) biogas digesters.

3.1. Alternative Cooking/Heating Technologies

Improved cookstoves and biogas digesters represent two alternative cooking/heating technologies appropriate for rural households. Each offers health and environmental improvements. The former are less costly while the latter offer additional advantages but require an adequate supply of inputs and water and only work in climates with certain temperature ranges.

3.1.1. Improved Cookstoves

The replacement of the traditional three-rock wood-fuelled cookstove has been the target of many development and humanitarian projects for the last several decades. Significant successes have been demonstrated with improved biomass stoves which offer increased fuel efficiency, with implied savings in opportunity costs, and, when coupled with improved ventilation systems, improved indoor and outdoor air quality as well, with implied health and environmental benefits. This paper reviews improved solid biomass cookstoves. This type of improved cookstove was chosen because it is a device that is based on traditional cooking practices that does not require fuel-switching but focuses on increased fuel efficiency and reduced indoor air pollution. Solar cooking devices are not considered because they require fuel-switching nor are LPG stoves as it is not considered a renewable energy source.
The Global Alliance for Clean Cookstoves (GACC), a public-private partnership sponsored by the United Nations Foundation, has five focus areas where improved cookstoves can have positive impacts (Table 3.1.1.):

Table 3.1.1: Area where improved cookstoves have positive impact

<table>
<thead>
<tr>
<th>Area</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Reduce black carbon emissions by 50-90%</td>
</tr>
<tr>
<td></td>
<td>Protect forests in vulnerable areas</td>
</tr>
<tr>
<td>Health</td>
<td>Reduce indoor air pollution and the resulting deaths and diseases</td>
</tr>
<tr>
<td>Humanitarian</td>
<td>Reduce fuel-gathering activities and the associated physical violence</td>
</tr>
<tr>
<td>Livelihoods</td>
<td>Save time associated with fuel-gathering and money spent on fuel purchases</td>
</tr>
<tr>
<td></td>
<td>Increase entrepreneurial activities in cookstove production, distribution and sales</td>
</tr>
<tr>
<td>Women &amp; Gender</td>
<td>Empower women economically and socially</td>
</tr>
</tbody>
</table>

Adapted from: [http://cleancookstoves.org/impact-areas/](http://cleancookstoves.org/impact-areas/)

Included in GACC’s network of over 1000 partners more than 400 are involved in cookstove design, manufacturing and assembly. One prominent member, the Aprovecho Research Center (ARC), has developed ten design principles to improve fuel efficiency and reduce indoor air pollution. ARC freely disseminates instructions on how to design, construct and test three models of wood-fueled improved cookstoves (Still and MacCarty, n.d.). Rocket stoves follow all ten design principles and are produced in many countries. StoveTec is the technology transfer arm of Aprovecho and claims its stoves offer 40% - 50% savings in wood fuel requirements plus 55% - 70% reductions in emissions (ARC, 2013). Rocket stoves can be mass-produced, as in the StoveTec business model, or manufactured locally using indigenous materials, as in the case for the Maendeleo Jiko stove used in Kenya. The latter alternative has the advantage of providing local jobs and involving end-users in the design, testing and feedback loops. Uptake of the Maendeleo Jiko has been low, about 4.8% but a successor, the rocket mud stove, reached 80% penetration in the Keumbu Division (Ingwe, 2007).

According to the Clean Cooking Catalog, global database of cookstove and fuel performance information, rocket stoves have a life-span of 3 - 5 years and range in price from less than US$1 for a self-constructed mud stove to many hundreds of dollars worth cookstoves.

### 3.1.2. Biogas Digesters

“Biogas is a value-added product of anaerobic digestion of organic compounds. Household digesters are cheap, easy to handle, and reduce the amount of organic household waste. The size of these digesters varies between 1 and 150 m³. The common designs include fixed dome, floating drum, and plug flow type. Biogas and fertilizer obtained at the end of anaerobic digestion could
be used for cooking, lighting, and electricity” (Rajendran et al, 2012). Biogas produced in household digester is mainly used for cooking. The amount of gas for cooking purposes on monthly basis is estimated to 30 – 45 m³ what would be, translated to kerosene needs, 15 – 20 liters of kerosene (Rajendran et al, 2012). Besides cooking, biogas is used for lightning and digestate left over from the digester is used as fertilizer.

Table 3.1.2: Social, environmental and economical benefits of usage of biogas digester

<table>
<thead>
<tr>
<th>Social Benefits</th>
<th>Environmental Benefits</th>
<th>Economical Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved health conditions</td>
<td>Reduce deforestation</td>
<td>Improved standard of living</td>
</tr>
<tr>
<td>Less time for cooking</td>
<td>Reduce chemical fertilizer</td>
<td>More job opportunities</td>
</tr>
<tr>
<td>Less air pollution</td>
<td>Less emission due to fossil fuel</td>
<td>Valuable byproduct (fertilizer) that can be sold</td>
</tr>
<tr>
<td></td>
<td>Clean Energy</td>
<td></td>
</tr>
</tbody>
</table>

Adopted from: Household biogas digesters—A review, (Rajendran et al, 2012)

When selecting type of biogas digester the graphical location, availability of substrate and climate conditions have to be taken in consideration (Rajendran et al, 2012). In different geographical locations the size will vary a lot. In Nepal the size is typically between 4 and 20 m³ (Gautam et al, 2009), between 6 and 10 m³ in China (Daxiong et al, 1990), between 1 and 150 m³ in India (Tomar, 1994) and in Nigeria the typical size is 6 m³ for family of 9 (Adeoti et al, 2000).

The total cost of biogas digester can be analyzed through three major categories: production cost (acquisition cost); operation and maintenance cost (running cost) and cost of capital (Kossmann et al, 1990). Production or acquisition cost assumes material and work necessary for erection of the biogas plant. “To gain a rough idea of the typical costs of a simple, unheated biogas plant, the following figures can be used: total cost for a biogas plant, including all essential installations but not including land, is between US$ 50 - 75 per m³ capacity“(Kossmann et al, 1990). The excavation work makes 15% of the acquisition cost; therefore savings can be achieved by user-labor. Running costs consist of operation and maintenance cost: acquisition of the substrate; feeding and operating the plant; maintenance and repair of the plant; storage of slurry, gas distribution and administration (Kossmann et al, 1990). Capital cost is the cost of depreciation of the plant and the interest rate at which the capital for acquisition cost was provided. “In calculating the depreciation, the economic life-span of plants can be taken as 15 years, provided maintenance and repairs are carried out regularly. Certain parts of the plant have to be replaced after 8 - 10 years, e.g. a steel gas holder“(Kossmann et al, 1990).

3.2. Alternative Electrical Technologies

As described in paragraph 3.1.2., one of the benefits of the biogas digesters is the ability to generate electricity from biogas. However, the most mature such devices are generally employed in commercial settings rather than
at the household level on which this paper focuses. Biogas digesters require an additional generator to produce electricity for lighting, adding yet another cost element to their implementation. Hence, biogas digesters are not covered as an alternative electrical technology for rural households in this paper. Solar lanterns and solar home systems are elaborated below.

### 3.2.1. Solar Lanterns

“Solar lanterns priced between US$ 20 and US$ 50 are often the most affordable way for poor customers to purchase improved lighting services” (IFC, 2012). There are many renewable energy lighting products that are appropriate for poor off-grid household use. Lighting Global, a joint initiative sponsored by the International Finance Corporation and the World Bank, has certified almost 50 solar lighting products that meet its quality standards and have undergone third-party testing to ensure each conforms to the International Electrotechnical Commission (IEC) Technical Specification 62257-9-5. In addition to technical considerations, Lighting Global considers Truth in Advertising to be a key aspect. Thirty-nine of the approved Global Lighting solar lighting products offer mobile-phone charging features (Lighting Global, 2015).

The Global Off-Grid Lighting Association (2009) reviewed 50 alternatives to kerosene lamps, calculating the average payback period for each lighting device. The payback periods were categorized into 4 tiers: A) up to 6 months; B) six to twelve months; C) over 12 months; and Z) not enough light produced to replace a kerosene lamp. Twelve of the 50 alternative technologies fell into the first two categories, suggesting that either cash purchases or microfinance credits could enable poor off-grid households to replace kerosene lamps.

### 3.2.2. Solar Home Systems

“Solar home systems (SHS) are small systems designed to meet the electricity demand of a single household. A Solar home system always consists of one or more photovoltaic (PV) modules, a battery, and a load consisting of lights, and one or more sockets for radio, television or other appliances. A battery charge regulator is usually added to control charging and discharging of the battery” (Vervaart and Nieuwenhout, 2000). Solar home systems provide more comprehensive energy services than solar lanterns (IFC, 2012). Up-front costs vary by country and capacity for the device and installation. In the investment costs of SHS, PV modules make approx 65% of the cost, batteries constitute 13% and battery charge controller another 5%. Reducing the cost of modules clearly reduces the initial cost of the investment (Vervaart and Nieuwenhout, 2000).

Different components of SHS have different life spans and costs (Table 3.2.1.). The PV module is a component has a life-span of 20 years while batteries last only 3 years. Reducing the cost of PVs will reduce the initial cost,
but in order to reduce the overall 20 year costs of SHS, it is essential to increase the life-span of batteries (Vervaart and Nieuwenhout, 2000).

Table 3.2.1: Typical costs and expected lifetime figures for a 40 Wp SHS

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost / USD</th>
<th>Lifetime / Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module (40 Wp)</td>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>Battery</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>Controller</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Light fixtures (2 pcs)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Fluorescent tubes (2 pcs)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mounting materials, cables</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>372</strong></td>
<td></td>
</tr>
</tbody>
</table>


3.3. Implementation Challenges

Given the availability of technical solutions for energy poverty, it is puzzling as to why their adoption has not been broader. This section examines some of the barriers and challenges that must be overcome in order to ensure that rural poor households have access to affordable renewable energy devices.

3.3.1. Market Barriers

The 4 Ps of consumer marketing - Place, Price, Product, and Promotion – apply to BoP markets as well. But the challenges of marketing to the bottom 4 billion present additional factors. C.K Prahalad proposed the 4As – Awareness, Access, Affordability, and Availability. (Prahalad, 2012) And, taking it a step further, Niti Bahn of the Emerging Futures Lab postulated the 5Ds – Development, Demand, Distribution, Demand and Dignity (Bahn, 2010). In an attempt to coalesce these parameters, this paper briefly examines six categories of market barriers (Chen et al, 2014) and the role MFIs might play in addressing them.

**Market Barrier #1 Access to Finance**

The MFI industry has a long track record of providing access to financial services to marginalized households. Yet, a significant number of BoP households still are excluded. MFIs may view energy loans as “mission drift”. And for more expensive devices such as SHS and biogas digesters, loan terms need to be longer (FINCA, 2010). Loan repayment amounts and terms need to be carefully calibrated with expected energy expenditure substitutions. For asset financing, down payments may still be a barrier if 100% financing is not available.

**Market Barrier #2 Distribution Challenges**

The rural poor represent extremely challenging distribution models. Geographic dispersion and poor transportation infrastructure make “last mile”
distribution difficult. Low-volume demand and logistics push costs up for the very market segment that is the most cost-conscious (The Practitioner Hub for Inclusive Business, n.d.). Existing distribution networks may not have the capacity to market products which require some technical understanding. Rather than establishing rural retail distribution channels on their own, some renewable energy product producers have partnered with MFIs, tapping into their substantial client bases and leveraging their knowledge of local communities.

**Market Barrier #3 Consumer Awareness**

Poor infrastructure is not limited to transportation systems. The rural poor often pay an "information penalty" because they are cut off from information resources which affects their ability to learn about alternative energy products and make informed purchasing decisions (Hammond et. al., 2007). Those MFIs with an educational outreach can address this barrier by promoting the benefits of renewable energy and helping their energy loan clients get transparent product information.

**Market Barrier #4 Poor Product Quality**

Many early improved cookstove dissemination projects failed because of the poor quality of the devices (World Bank, 2011). Poor quality products erode consumer confidence (Ray, Clifford and Jewitt, 2014). Devices which cease to function while loans are still outstanding are one reason for default. And when such devices are used as collateral, the problem extends to both the customer and the financial institution (FINCA, 2010). MFIs can build capacity, either in-house or through partnerships with renewable energy device producers, to ensure that any product financed has gone through rigorous quality-assurance testing.

**Market Barrier #5 Policy Challenges**

Government subsidies for kerosene can hamper the adoption of solar lighting devices (OECD, 2010). The same may be true for fertilizer subsidies and biogas plants. Non-harmonized import tariffs and/or value-added taxes and their impact on affordability can make or break an industry, help or hurt producers, and open up or strangle markets. As MFIs expand their political clout, their ability to influence government policy increases.

**Market Barrier #6 After-Sales Service**

Even with improvements in design and production processes, a need for post-sales support exists. This is especially true for more complex systems such as SHS and biogas digesters. MFIs, which typically establish on-going relationships with clients, can protect their investments by partnering with renewable energy device producers that have strong after-sales service programs. Alternatively, there are business models in which microcredit recipients establish sales and/or maintenance enterprises to provide after-sales service.
3.3.2. Socio-Cultural Barriers

For thousands of years, people have cooked over open flames. Changing practices associated with something so intrinsically tied to food is a huge challenge. Completely free stoves were rejected by more than 30% of households in a Bangladesh project, headed by Yale development economist Ahmed Mushfiq Mobarak, because of a “lack of perceived value-added” (Luoma, 2010). Because the rural poor attribute little monetary value to the firewood they collect, with most of the labor provided by women and girls, there is scant incentive to reduce firewood consumption (Ingwe, 2007).

Holdren et al (2000) advocate rural energy development planning to be a decentralized, customer-centric process, with special emphasis on engaging women who bear the brunt of traditional energy systems and are most likely to benefit from improved systems. The best source of information on energy demand and the available supply of biomass resources are the local end-users.

3.3.3. Climate Barriers

Biogas digesters need water, temperatures above 15 degrees Celsius and “The site where the biogas is to be used must not be more than 150 m apart from the biodigester, because, beyond this distance, gas pressure decreases” (MEbA project, 2014).

4. FINANCING ALTERNATIVE TECHNOLOGY ADOPTION

If the financial costs of renewable energy services (including devices, distribution, taxes, maintenance, and financing) can be absorbed by cost savings, credit providers are in a win-win situation, and the elusive triple-bottom-line can become a reality. Moreover, the social mission of MFIs can be strengthened as the adoption of cleaner energy sources has positive health impacts as well the potential to help lift families out of poverty and address gender inequalities.

Affordability is a key question in regards to energy services. Holdren et al (2000) found “no rigorous quantification of this concept”. Instead, they offer a proxy – current energy expenditures, noting that some consumers are willing to increase their costs for safer and/or more convenient energy sources. In addition to championing policy reform as a catalyst in making capital resources more readily available for rural households, they identified successful microfinance initiatives and view the poor as customers with assets, not beneficiaries receiving hand-outs from governments and donors.
4.1. Repayment Capacity

The IFC estimates annual BoP energy expenditures at $317 billion (Combined total in 2005 purchasing power parity dollar terms for lowest and low consumption segments in 92 sample countries) including $137 billion on electricity (IFC, 2012b). Because this paper focuses on households not currently purchasing electricity, a revised estimate is $180 billion. Assuming a 50/50% rural/urban ratio (World Bank, 2013) and the tendency of the rural poor to spend 44% less on energy (Hammond et al., 2007) a more granular estimate for rural energy expenditures is US$ 59.4 billion.

Translating the overall expenditures into estimates at the household-level, the IFC states that “more than 90 percent of households without access to clean lighting and cooking solutions could afford improved products and services, since they already spend more on traditional energy than the commercial cost of superior, more modern energy. “Based on current spending patterns and the cost of modern alternatives, some 256 million households could afford improved “lighting plus” and 394 million could afford cleaner cooking solutions. … These households spend more than $1.25 each month on “lighting plus” and over $1.30 each month on wood and charcoal for cooking” (IFC, 2012). Because this paper focuses on rural households whose expenditures on cooking fuels are significantly lower than those for urban households, the expenditures for wood and charcoal for cooking may be overstated for rural families. However, it is clear that repayment capacity exists for hundreds of millions of BoP households.

Figure 2.4.1 in section 2.4. Energy Expenditures shows that people in BoP spend yearly between US$ 148 – US$ 379 on energy what translates to US$ 12 – US$ 31 monthly. Analysis done by IFC (Table 4.1.1.) shows that levelized monthly costs of various renewable energy technologies (SHS, solar lantern..) to the end-user on monthly basis are between US$ 0.8 for charcoal stove and US$ 8.5 for solar home system, what demonstrates that there is repayment capacity at the BoP.

Table 4.1.1: Commercial price of modern energy alternatives

<table>
<thead>
<tr>
<th>Commercial price of modern energy alternatives</th>
<th>Capital cost, USD</th>
<th>Operating cost per month, USD</th>
<th>Levelized monthly cost to the end-user, USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop SHS</td>
<td>250-500</td>
<td>2 - 4</td>
<td>8.5</td>
</tr>
<tr>
<td>Solar lantern</td>
<td>20 - 40</td>
<td>0.5 - 1</td>
<td>1.25</td>
</tr>
<tr>
<td>Rechargeable lanterns</td>
<td>6 - 20</td>
<td>0.5 - 1</td>
<td>1.25</td>
</tr>
<tr>
<td>Improved charcoal stove</td>
<td>5 - 25</td>
<td>0 - 7.1</td>
<td>0.8 - 8</td>
</tr>
</tbody>
</table>

Adopted from: IFC analysis based on Demographic and Health Surveys, IFC Macro, various years; IEA 2009; IFC-WRI 2007; UN2011; and UNDP/WHO 2009

“Customer education on the benefits of modern technologies, valued extra features (like phone charging), product performance guarantees, and social
recognition can all increase willingness to pay. The growth of mobile telephone sales across the developing world has shown that the poor can often find a way to pay for something with perceived value, or something that they simply desire” (IFC, 2012).

The BoP is not “a market that allows for the traditional pursuit of high margins; instead, profits are driven by volume and capital efficiency.” Although they were referring to opportunities for multinational corporations, the idea proposed by Prahalad and Hart applies to microfinancing as well. Unit sales, whether the product is a widget or a microcredit, are where profitability lies at the bottom of the pyramid. Managing transaction costs and, for MFIs, operational costs are a challenge. But recent innovations in mobile banking offer hope. “Creating buying power, shaping aspirations, improving access, and tailoring local solutions – the four elements of the commercial infrastructure for the bottom of the pyramid are intertwined” (Prahalad and Hart, 2002). MFIs and Non-Governmental Organizations (NGOs) are experienced in all four of these elements.

“Limited access to tailor-made financing for end-users” was ranked by 25% of respondents as one of the largest barriers to the development of the stand-alone renewable energy sector at the 2014 International Off-Grid Renewable Energy Conference (International Renewable Energy Agency, 2015). Another take-away from the conference was the importance of forming strategic partnerships with local institutions to reduce risk. For developers moving into new markets, local NGOs and community organizations are “the best partners to electrify that village.” For example, partnering with a local NGO trusted in the community can lower security risks and the costs of customer relationship management.

As the microfinance industry has matured, MFIs have diversified offerings and increased their ability to respond to demand-driven markets.

4.2. Willingness to Pay

Repayment capacity and willingness to pay (WTP) are a two-headed coin. BoP consumers with little cash and uneven income streams “cannot afford to take risks on unproven products” (Ashley and Sinha, 2014). With so many unmet needs competing for any available cash, it is not surprising that the adoption of renewable energy products by BoP households has been slow. “An unmet need does not constitute a market. A market exists only to the extent that there are buyers willing and able to a price higher than the total costs, including the opportunity cost of capital, of the sellers. The perceived consumer value must exceed the price; and the buyers have to be willing and able to pay this price” (Garrette and Karnani, 2010).
Te Creemos, a regulated MFI in Mexico, commissioned a study of energy consumption habits in Mexico. One of the findings was that clients are reluctant to invest in energy technology until more pressing home improvements are completed (IADB, 2013).

As previously discussed in 3.3.2, when cooking fuel is gathered for “free” by women and girls, there is no economic incentive to invest in more efficient cookstoves (Ingwe, 2007).

Given these and other disincentives, the Inclusive Business Hub proposes five strategies to overcome WTP barriers and this paper adds some suggested tactics described in Table 4.2.1 (Ashley and Sinha, 2014).

**Table 4.2.1: Five strategies to overcome WTP barriers**

<table>
<thead>
<tr>
<th>Build consumer trust</th>
<th>“Adapt ‘high-touch’ marketing strategies to build confidence and demand.” Engage local residents as agents. Implement public awareness campaigns. Encourage “word-of-mouth” advertising.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage partners’ brand names and networks</td>
<td>Harness existing distribution infrastructure Recognize the value of trusted brand name for large-ticket items</td>
</tr>
<tr>
<td>Increase the value proposition of the product</td>
<td>Focus on the quality of the product. Provide sufficient after-sales service. Bundle the product with other products and/or services. Price the product competitively.</td>
</tr>
<tr>
<td>Charge part of the price to others</td>
<td>Affordability is key, especially at the BoP. Reducing renewable energy product costs through government subsidies and/or carbon credits are discussed in sections 4.3.3. and 4.3.4.</td>
</tr>
<tr>
<td>Offer consumer financing</td>
<td>Partner with an MFI. Adopt a Pay As You Go business model.</td>
</tr>
</tbody>
</table>


Employing these strategies will increase demand and WTP, but financing remains an important issue to BoP households. The next section discusses microfinancing methodologies used in purchasing renewable energy devices.

If clients have to pay all or most of the cost for renewable energy products up-front, the market becomes smaller. The reductions of the up-front costs are important in order to increase the size of the market (IFC, 2012). Figure 4.2.1 demonstrates sensitivity analysis of upfront payments on the addressable market.
According to research of IFC (Figure 4.2.1) if clients don't have upfront costs for solar lamps the market would be 112 millions of households; if they have to pay 10% of the cost upfront 13 million households less would be willing to buy the product and market would constitute 99 million households. Willingness to buy renewable energy products increases with a reduction in upfront costs; hence MFIs have the ability to play an important role in the adoption of renewable energy products.

4.3. Financing Methodologies

MFIs, which have established context-responsive relationships with millions of energy poor beneficiaries, can expand their product offerings and leverage their existing operations to fill gaps in the rural energy value chain by engaging in consumer education, marketing, and even sales. As MFIs build capacity in renewable energy lending, their social mission is strengthened as their clients’ quality of life improves.

In the following sections, different lending methodologies are identified and selected case studies employing each methodology are briefly discussed. The case studies were selected based on the Ashden Awards, a program that has recognized over 170 ground-breaking sustainable energy projects since 2001 (Ashden, 2015). A second criteria for case study selection was an award-winning project’s use of microfinance and/or innovative credit provision. This paper’s case studies were selected from the pool of Ashden Award winners who demonstrated creative use of microfinance credit provision.

The Ashden Awards, which have been given annually to over 170 winners since 2001, recognize ground-breaking work in the sustainable energy sector. Ashden evaluates organisations’ uses of innovative end-user financial mechanism and business models, including those which incorporate carbon finance, for their potential to increase access to sustainable energy products or services to marginalized populations. Enterprises or programmes which provide
sustainable energy to women and girls are eligible for an award that recognizes the role of clean energy in transforming their lives.

4.3.1. Individual Lending

Barefoot Power, an Australian-based social for-profit company, won an Ashden Award in 2012. Its product offerings include a portable solar lamp and an expandable solar kit, both of which have phone charging capabilities. In 2012 product prices in the Ugandan market ranged from US$ 28 to US$ 137 for a mid-capacity solar kit. To finance purchases, Barefoot has partnered with Savings and Credit Co-operatives (SACCO) and FINCA Uganda. FINCA Uganda offers six-to-twelve month loans with an interest rate of 3.5% per month (Ashden, 2012). In addition to its microfinance partnering, Barefoot Power provides business support services to its affiliates throughout the supply chain. It offers a “Business in a Box” micro-franchise program, which includes supplier credit. In an effort to streamline distribution costs, it makes innovative use of the public bus system to deliver products to retailers in rural areas (Ashden, 2012).

FINCA Uganda, having learned valuable lessons from a 2004 launch of microenergy loan product which did not reach anticipated scale, identified three implementation challenges: 1) supply chain delays; 2) ineffective marketing; and 3) lack of training. FINCA Uganda refocused its efforts in 2008 with its Micro-Energy Loan Program, a pilot funded by USAID. An important design revision is the inclusion of Energy Officers who work alongside Loan Officers. Energy Officers are responsible for marketing and product demonstration, client education, client’s energy needs assessment, and post-sales support and maintenance (FINCA, 2010). FINCA Uganda’s risk mitigation strategies include using the SHS as 50% of required loan collateral, and consumer subsidies reduce average system sales prices by 27% (FINCA, 2010). For MFIs, operational efficiency is a crucial factor. FINCA Uganda’s 2004 project used a separate loan product tailored to energy asset purchases. The 2008 pilot, in an attempt to increase operational efficiency, bundles energy loans with business loans for existing customers. While the loans at targeted at households, 42% of customers interviewed reported using their SHS for business purposes. Nevertheless, household benefits occupied the top 7 positions in client household impact survey (FINCA, 2010).

4.3.2. Group Lending

Shri Kshethra Dharmasthala Rural Development Project (SKDRDP) is a not-for-profit organization that developed a network of 169,000 self-help groups operating in rural Karnataka, India; a 2012 Ashden Award winner. The program helps each group member to makes a five-year household plan and commits to saving a fixed amount each week. Members of groups are typically farmers and small traders, 70% of whom earn less than US$ 2/day. Loan amounts, for domestic consumption and agricultural uses, graduate as a member establishes
a good repayment record. After two years, a group in good standing is eligible for energy loans.

SKDRDP maintains a list of approved renewable energy suppliers who offer reliable technology, after-sales service and pass along any applicable government subsidies (Ashden, 2012). SKDRDP has developed two renewable energy loan products which cover 100% of the purchase price financed at 18% annual interest rate. The first, repaid over 150 weeks, is for SHS which typically cost US$ 400 (including wiring and labor). The second provides loans up to US$ 300 for the full cost of constructing biogas plant subsidies (Ashden, 2012).

### 4.3.3. Asset Finance

While renewable energy products represent the potential for household expenditures to be redirected to food, education, healthcare, and/or savings, the initial investment is often out of the reach of those living in extreme poverty. And providing microcredits for “consumption” purposes is often out-of-scope for MFIs. Consumer credit, readily available to the middle-class, is one option to remedy this roadblock. Credit provided by the manufacturers and distributors of renewable energy products to finance the purchase of their products represents a win-win situation. The manufacturers gain market share and poor households gain access to renewable energy.

An innovative form of consumer credit is pay-as-you-go (PAYG), which is very popular in the mobile phone industry. Customers purchase a device and then make small payments to keep it functioning. Greenlight Planet offers PAYG financing utilizing a mobile payment platform. The company’s solar lantern products are available in 33 countries and in use in 1,500,000 households (Greenlight Planet, 2015). For one of the models in its product line, the consumer’s initial investment limited to a deposit of approximately 21% of the total cost, with a weekly repayment of US$ 1.00 required for a period of ten weeks. (Lighting Africa, 2015) If the weekly repayments fall into arrears, the lantern’s embedded chip disables it until payments are current. After the total cost of the lantern has been paid, the chip is deactivated and the customer has no further financial obligations, other than maintenance.

“Most of our customers earn less than $2 a day and have very little disposable income. Some are dependent on daily wages that are used to purchase necessities including kerosene, mobile phone airtime and food in small increments. We needed to find an alternative to up-front payments that fit this purchasing pattern,” says Anish Thakkar, CEO and co-founder of Greenlight Planet (Lighting Africa, 2015).

Another strategy for expanding consumer credit to the poor is through partial product cost subsidization. Rather than giving away the product through social delivery programs, which potentially leads to market distortion (GVEP,
2009), a manufacturer applies available subsidies to reduce the end-user’s cost. One such form of subsidy is carbon credits.

Toyola (2011 Ashden Award winner) offers two months credit for improved charcoal cookstove purchases; household models range between US$ 6.60 - 8.00, after carbon subsidies are applied. The average savings on charcoal is US$ 27.00 which translates to a three-to-four month return on investment. Toyola offers an innovative “money box” system. One-third of its credit customers “deposit” their savings on charcoal expenditures and use the funds to make their credit payments (Ashden, 2011).

As the distributed solar devices and improved cookstove markets develop, new consumer financing mechanisms will likely come into play, increasing the adoption of innovative energy poverty solutions.

4.3.4. Government Subsidies

Controversy generally surrounds government subsidies, and energy subsidies are no exception. Critics claim that subsidies contribute to market distortion and exacerbate inefficiencies, while proponents argue the private sector needs to be incentivized to provide services to the rural poor (Reiche et al, 2000).

Grameen Shakti, a sustainable energy devices provider in Bangladesh, combines credit with government subsidies for one of its lines of biogas digesters. Each IDCOL biogas plant, regardless of size, is eligible for a BDT 5000 subsidy, which is applied against the financed loan balance. Customers are required to make a 15% down payment and loan repayment is spread out over 2 years, at 6% flat rate interest (Grameen Shakti, 2009). The subsidy effectively makes the device more affordable, especially for those who buy the smallest capacity, as it represents almost 20% of the BDT 26,000 pricetag for the lowest-cost system but less than 10% of the BDT 52,000 maximum-capacity system.

“The Grameen Shakti renewable energy program includes: solar energy through their Solar Home System; biogas for use as cooking fuel, electricity production and organic fertilizer; and improved cooking stoves. The model also includes a social business component that: creates employment; fosters entrepreneurship; empowers women, youth and communities; breaks the cycle of energy poverty; and contributes to the United Nations’ Millennium Development Goals. The Grameen Shakti model is expanding rapidly in Bangladesh and has begun to be replicated outside the country” (Amin and Langendoen, 2012).

These case studies demonstrate the role that innovative financing plays in stimulating the adoption of renewable energy devices at the BoP household level.
5. CONCLUSIONS

Financing is a major barrier to the adoption of renewable energy by poor off-grid rural households. Microfinance can be the bridge between its impoverished clients and modern energy sources, breaking the vicious cycle that traps the poor and stymies development.

The dimensions of energy poverty are significant and impact many facets of existence – health, education, gender equality, and the environment. Microfinance is not merely about financial inclusion. In its purest form, it has the ability to transform lives – the lives of the half-million children who die from pneumonia every year; the lives of students whose families’ futures depend on their education; the lives of women and girls who are burdened with gathering fuel and spend hours cooking over smoky fires; and the lives and livelihoods of farmers who already live at subsistence levels.

Energy poverty imposes a double penalty. The poor can and do pay for energy but they pay proportionally more for lower quality services. The price they pay is not only monetary but there are considerable health impacts and opportunity costs.

Microfinance can transform these expenditures into asset-building investments whose dividends include healthier homes with more productive families. A twenty-dollar investment in a solar lamp not only pays for itself in terms of reduced kerosene consumption, it provides better light for children to study after dark and reduces health risks and the attendant medical costs. An investment in an improved cookstove is an investment in women’s productivity and girls’ education. Investing in a biogas digester not only provides cooking fuel, it gives farmers’ a renewable source of organic fertilizer to improve their yields.

These technological innovations provide cleaner, safer and more efficient forms of energy for cooking, lighting and communications. But the key issues are affordability, in terms that BoP households can manage, and low market demand. Although renewable energy may be less expensive in terms of the total cost of ownership, upfront costs are a major barrier.

This paper has demonstrated the hypothesis that microfinance can be an enabling mechanism. The case studies cited prove that by providing microcredits tailored to the needs of individual households, both in terms of the technology intervention and the repayment terms, MFIs and consumer credit providers can help minimize the energy poverty trap. Once a household has acquired a more efficient renewable energy source, energy expenditures can shift from purchases to loan repayment. Once the loan is repaid, the household has accumulated an asset that will continue to reduce constraints on limited budgets and improve the quality of life in many dimensions.
For many MFIs, energy loans are an unfamiliar paradigm. By focusing on internal capacity building and developing strategic partnerships with energy service providers, MFIs can expand their service offerings. Individual lending methodologies are appropriate for asset acquisition while group lending’s focus on social capital can play an important role in influencing technology adoption uptake. It may not be business-as-usual but it is a valuable business proposition that allows MFIs to increase their outreach.

Finance providers and renewable energy device producers face many barriers and need to develop marketing strategies that promote the value proposition of renewable energy devices for BoP households and increase consumer awareness of the myriad of benefits. Centuries-old cultural practices cannot be displaced overnight. Top-down design rarely ensures bottom-up acceptance. Engaging poor rural households as stakeholders is paramount.

The world is witnessing a boom in renewable energy development. However, for poor rural off-grid households to benefit, microfinance needs to develop innovative mechanisms as well. MFIs have made great strides in reaching poor rural households. Leveraging these established networks is a plausible path for expanding the adoption of renewable energy at the household level. By making context-specific microcredits available for energy asset acquisitions, the stranglehold that energy poverty imposes may finally be eradicated.


Greenlight Planet (2015): “On a mission to deliver energy everyone can afford”, in: http://greenlightplanet.com/about


Still, D. & MacCarty, N. (n.d.): “Cooking with less Fuel: Breathing Less Smoke”, Aprovecho Research Center, World Food Programme, School Feeding Service (PDPF); Partnership for Clean Indoor Air (PCIA); Shell Foundation, in: http://www.aprovecho.org/lab/pubs/arcpubs


