THE ECONOMICS AND ETHICS OF SMALL-SCALE HOUSEHOLD SOLAR POWER FOR REMOTE RURAL VILLAGES IN BANGLADESH

Md Rumi Shammin¹
Assistant Professor of Environmental Studies, Oberlin College, USA

A.K. Enamul Haque
Professor of Economics, United International University, Bangladesh
Executive Director, Economics Research Group (ERG), Bangladesh

¹ Corresponding author.
122 Elm Street, Oberlin, OH 44074
Tel: 440/775-5316, Fax: 440/775-8946
Email: Rumi.Shammin@oberlin.edu
Web Site: http://sites.google.com/a/oberlin.edu/shammin/
ABSTRACT

Household solar power is considered to be a clean, carbon-free solution for remote rural areas that are off the regular electricity distribution grid. This is particularly attractive in less developed countries (LDCs) where household power needs in remote rural villages are minimal and can be supported by small scale solar installations. In Bangladesh, about 70% of the rural population is currently living off the grid – using biomass for cooking and kerosene lamps and candles for lighting. Small scale solar solutions thus offer a cost-effective solution for the government controlled power sector to begin to deliver electric power to this population through non-governmental enterprises. Under an initiative by the Government of Bangladesh with grants from the World Bank, Global Environment Facility, Asian Development Bank and other donors, about 650,000 solar home systems have already been installed in off-grid areas between 2003 and 2010 with a goal to finance 1 million homes by the end of year 2012. In addition to power generation, these types of projects are attractive as climate change mitigation initiatives in LDCs, including Bangladesh, that are currently primarily focused on adaptation programs. However, from a consumer perspective, solar power is still expensive on a per kilowatt-hour basis - even when compared to other off-grid solutions such as small generators. Using technical analysis, key informant interviews and field surveys, this paper investigates the economics of selected household solar projects in Bangladesh in comparison with other available off-grid solutions. Specific attention is given to equity analysis of the financing of solar power and final cost to consumers. While the wider benefits of solar power in reducing the external cost of power generation and combating global climate change are well known, this paper explores the question of whether such benefits are being equitably paid for and proposes alternative solutions that are economically and environmentally sustainable and at the same time ethically just.
1. INTRODUCTION

In the quest for development on a global level, rural electrification is an important challenge – particularly in terms of providing opportunities for a better quality of life for the world’s poor. More than 1.6 billion people around the world are still without electric power – most of them in off-grid rural areas in developing and less developed countries (LDCs). About 40% of rural population worldwide is without power. Regions that are lagging behind the most are South Asia with about 70% and Sub-Saharan Africa with about 90% of the rural population living off-grid (Zerriffi, 2011). According to Chakrabarty et al (2011), another 2 billion people in the world are underserviced despite having access to grid electricity. In Bangladesh, about 70% of the rural population is living in areas without electricity supply (Urmee et al., 2009; Chakrabarty et al., 2011) – more than 50% of them being landless and marginal farmers (Biswas et al., 2004). Currently, these people are primarily using kerosene lamps and candles for lighting. Two aspects of these rural households are noteworthy: 1) these households are generally more widely dispersed over the landscape and located in remote areas often separated by a river or some other natural barrier from the nearest electricity grid; and 2) these households have very low power needs (and affordability) per household. These make it difficult to incorporate them with the electricity grid – requiring expensive financial investment in infrastructure such as power stations, substations, long transmission lines across unfavorable terrains, etc. (Zerriffi, 2011; Komatsu et al., 2011). Therefore, a small-scale, distributed solution of power generation is needed to deliver electricity in a convenient and cost-effective manner to these households.

In the quest for development to be sustainable, it is also important to the global community that, to the extent possible, new power generation is based on renewable, carbon-free sources. This is not only because of the chain of land, water and air pollution over the life cycle of most conventional fossil fuel sources of electricity, but also because energy-related carbon emissions are the primary contributor to global climate change. Grid expansion means continued dependence on fossil fuels and potentially incremental emissions of greenhouse gases (Komatsu et al., 2011). This challenge presents a dilemma for the off-grid rural population in LDCs. On the one hand, they have near-zero contribution to the current causes of climate change and, therefore, are least obligated to make compromises to mitigate greenhouse gas (GHG) emissions. On the other hand, most of these rural communities are located in coastal or flood-prone areas that are also highly vulnerable to rising sea levels and the effect of extreme weather events on crop production caused by global climate change. Any initiative, local or global, that reduces the impact of climate change would be beneficial to them. The cumulative GHG emission from least developed countries is less than 1%, while the cumulative emission from OECD countries is more than 50% of global GHG emissions. However, the LDCs are expected to experience rapid growth in energy use in the coming decades and total CO₂ emission is expected to increase more than 10-fold during 2005-2035 (Mondal et al., 2010).

Solar home systems (SHSs) offer a possible win-win solution to the two challenges described above. Small-scale solar systems can be installed in individual households with the desired capacity that would meet their needs, create a pollution-free indoor environment, and at the same time contribute towards mitigation of climate change. This paper investigates the evolution of SHSs – particularly in Bangladesh – and explores whether a government-supported nationwide deployment of SHSs in Bangladesh is: delivering the perceived benefits of electrification; maintaining quality of service and reliability; being cost-effective for the end users; and achieving equitable distribution in terms of financing schemes and access to this technology. The equity aspect of the SHS solution to electrification is further analyzed in the context of global initiatives and financing for reducing greenhouse gas emissions to verify whether the
extra burden of mitigation is being unfairly borne by the poorest and least responsible people of the world.

1.1 Evolution of SHSs

Solar home systems have been evolving worldwide since the late 70’s and early 80’s. In developed countries, these have often been pioneered by visionary individuals motivated to conserve energy, increase the share of locally sourced electricity and energy independence, and reduce environmental impacts through personal actions. Over the years, varying degrees of federal and state level support have made adoption of solar home systems more affordable in North America, many European countries, and in some Asian countries. However, household energy demand is significantly higher in transitional economies and developed countries than developing and least developed countries. Electrification rate in transitional economies and OECD countries is nearly 100% for urban population and about 98% for rural population (Zerriffi, 2011) with the typical sizes of solar home systems ranging from 1.6kW to about 6kW. In the world’s first solar electric neighborhood in Gardner, Massachusetts, 30 solar homes are each fitted with a 2kW grid connected system. Pal Town Solar City in Japan has 550 homes - each outfitted with a 4kW system (Kamal, 2011). Trail Magic, a positive energy, climate neutral home in Oberlin, Ohio built by Professor Carl McDaniel, is powered by two solar arrays totaling 5.2kW (see figure 1).

![Figure 1: Trail magic in Oberlin, Ohio, USA with 5.2kW solar system](Photo by Md Rumi Shammin)

The demand for electricity in rural areas in LDCs is much less than the above examples – where typical solar home systems range between 20W and 100W. The number of small-scale SHS projects has been steadily increasing in the developing countries of Asia, South America, and Africa since the 90’s with nearly a million SHSs installed by the year 2000. This growth has accelerated in the new millennium with significant momentum documented in several South Asian countries including Sri Lanka, India, and Bangladesh (Komatsu et al., 2011).

1.2 Layout of a Typical Small-scale SHS System

There are few important differences between the larger solar home systems installed in developed countries and the small-scale solar home systems in LDCs. First, almost all SHSs in developed countries use an inverter to convert the DC power generated by the solar panels to AC power used by household electrical equipment. Contrarily, most SHSs in LDCs use DC powered equipment without needing an inverter – thus reducing both capital and maintenance costs. Second, SHSs in developed countries often
have the option of installing grid connected systems that do not require the use of a battery (even though some people prefer to install a battery back-up system while being grid connected) and taking full advantage of the power generated by the solar panels by receiving payments for net positive contribution to the grid (provided the utility company has a net-metering policy). Almost all the SHSs installed in LDCs use a battery to store power during the day in order to have access to electricity after hours. Especially in rural off-grid locations, there is no alternative to using batteries. Figure 2 shows the picture of a solar home system on the roof of an off-grid rural home in the south-western region of Bangladesh.

![Figure 2: SHS on the roof of rural off-grid homes in Batiaghata, Khulna, Bangladesh.](Photo by Md Rumi Shammin)

Typical SHSs installed in rural off-grid communities include solar panels mounted on the roof or poles to convert sunlight into useful electrical energy, an industrial grade battery to enable deep cycling, a charge controller to regulate the charging and discharging of the battery, connection wires and switches, and DC powered lights, fans, and appliances (see figure 3).

![Figure 3: Typical solar home system components (Mondal, 2010).]
One concern often raised regarding SHSs in rural households in LDCs is whether the technology is compatible with these communities in terms of performance and maintenance. It is, therefore, important to evaluate the warranty on the equipment and accessories and post-installation support by the public, non-governmental organization (NGO) or private company that install these systems.

1.3 Potential Benefits of SHSs in LDCs

The benefits of extending electric power to the off-grid population are well documented in the literature. SHS connected lighting provides better illumination and longer hours of availability without health risks from on-site pollution from kerosene or candles. This allows for increased and more efficient studying/reading opportunities for children. After hour access to adequate lighting makes way for new income-generation opportunities such as tutoring, mobile phone charging service, etc. The ability to have more time to attend to household chores after hours makes it possible for women to dedicate more time to productive activities during the day. Electric power also opens up the possibility of installing fans for comfort on hot days and provides rural population access to modern amenities such as radio, television, mobile phones, etc. In general, many of the benefits of the SHSs are skewed towards women and children. (Barnes, 2007; Biswas, 2002; Komatsu et al, 2011).

1.4 Lessons from Early Adopters of SHSs

Martinot et al. (2001) reported lessons from twelve projects funded by the World Bank and Global Environmental Facility that provided energy services to off-grid rural households in developing countries in the 90's. The following lessons were documented from these early experiences:

- solar home system delivery firms face a myriad of difficulties operating in rural areas;
- credit risk is a serious concern of both financiers and dealers and makes credit sales particularly challenging;
- technical performance of systems is becoming well-proven;
- customers desire a range of component options and service levels and can benefit from even small systems;
- projects must recognize the link between rural electric-grid extension and solar home system demand; and
- marketing campaigns can be extremely costly and time consuming in rural areas.

The authors argue that the challenges are to demonstrate sustainable and replicable business models, develop regulatory models for energy service concessions, and integrate rural electrification policy with solar home system delivery.

1.5 Economics of SHS in Rural Off-grid Communities

The economics of SHSs in rural off-grid communities involve careful consideration of costs and benefits against the level of affordability of the households. The first question is: do the SHSs cost more than what these households previously spent on traditional sources of energy for services that are now provided by electricity? If the answer is no, then the SHSs are definitely cost effective for these households – particularly since they now have access to additional benefits as mentioned in section 1.3. If the answer is yes, then the subsequent question is: do the additional benefits (monetary and social) measure up to the extra cost of obtaining SHSs? The answer to this question is more complicated since many of the social
benefits are difficult to quantify and monetize. One way to address this complexity is to conduct field surveys to assess whether the households perceive the benefits to be worth the extra cost.

Another aspect of the cost of the SHSs is that it involves both capital cost and potential maintenance costs. If maintenance costs are embodied in the financing mechanism of the SHSs or handled via warranty and customer service, then it is possible to assess the total cost over the life of the SHSs.

Finally, in terms of development goals of the Government of Bangladesh to provide electric power to all by 2020 (Mondal and Islam, 2011), the cost of delivering electricity via SHSs would be compared with grid expansion, locally distributed generation by small centralized plants, or even the less likely option of small-scale diesel generators. This aspect of SHS cost-effectiveness will not be addressed directly in this paper.

1.6 Equity Concerns related to SHS

Equity concerns related to SHSs arise in both local and global contexts. At the local level, SHSs may not be available to the relatively poorer households in rural communities. This is especially applicable if the financing mechanism involves significant upfront costs. At the global level, if one benefit of expanding SHSs in off-grid rural communities is to help mitigate climate change, then should the countries that are historically more responsible for GHG emissions partially subsidize these ventures? This is particularly relevant if the households adopting SHSs are now spending more than what they previously spent on traditional sources of energy.

2. SHS INITIATIVES IN BANGLADESH

Bangladesh is blessed with an abundance of solar radiation that can be used to harness solar energy. The average daily solar radiation varies between 3 and 6.5 kWh/m² - with a maximum during the months of March-April and a minimum during the months of December-January (Islam et al., 2006; Chakrabarty et al., 2011). Coupled with the fact that nearly 70 million people live in off-grid, often remote rural areas, small-scale SHSs appear to be an attractive method of delivering electricity to the rural population.

Historically, Bangladesh Atomic Energy Commission (BAEC) initiated several pilot solar photovoltaic systems in the 90's. The first significant rural solar initiative was the Norshingdi project implemented with financial support from France. The project involved installation of several battery charging stations with about 30kW total capacity and a few individual solar home systems (SHS) with a total capacity of about 33 kW. The systems were owned by Bangladesh Rural Electrification Board (REB) and the households under the program paid a monthly fee for the services. The penetration of SHSs began to increase in late 90’s – with Grameen Shakti, an affiliate of the Grameen Bank, leading the charge along with Bangladesh Rural Advancement Committee BRAC and a few other NGOs following suit. (Islam et al., 2006)

In order to bridge the financing gap for developing medium and large-scale infrastructure and renewable energy projects in Bangladesh, the Infrastructure Development Company Limited (IDCOL) was established on 14 May 1997 by the Government of Bangladesh (GOB). The Company was licensed by Bangladesh Bank as a non-bank financial institution (NBFI). The company now stands as the market leader in private sector energy and infrastructure financing in Bangladesh. IDCOL is managed by a seven-member independent Board of Directors comprising four senior government officials, three prominent entrepreneurs from the private sector and a full time Executive Director and Chief Executive Officer. It has a small and multi-skilled work force comprising economists, financial and market analysts, engineers,
lawyers, IT experts and accountants. IDCOL’s stakeholders include the government, private sector, NGOs, multilateral institutions, academics and the people of Bangladesh at large. (IDCOL: http://www.idcol.org/index.php)

IDCOL promotes dissemination of solar home system (SHS) in the remote rural areas of Bangladesh through its Solar Energy Program with the financial support from the World Bank, Global Environment Facility, Kreditanstalt für Wiederaufbau (KfW), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Asian Development Bank and Islamic Development Bank. IDCOL started the program in January 2003 and its initial target was to finance 50,000 SHSs by the end of June 2008. The target was achieved in September 2005, 3 years ahead of schedule and US $ 2.0 million below estimated project cost. IDCOL then revised its target and decided to finance 200,000 SHSs by the end of 2009. This was also achieved by May 2009. Now IDCOL’s target is to finance 1 million SHSs by the end of year 2012 and is expected to achieve that target well ahead of schedule. Based on these numbers, IDCOL’s Solar Energy Program is one of the fastest growing renewable energy programs in the world.

IDCOL implements the Solar Energy program through 30 partner organizations (POs). IDCOL provides grants and refinance the SHSs. They also set the technical specifications for the solar equipment, help develop publicity materials, train POs for capacity building, and monitor the performance of POs. The POs on the other hand are responsible for identifying project sites and potential customers and offer micro-credit programs to the customers. They work in the front lines and are mandated with installing and maintaining the systems, supply spare parts, build awareness and understanding about SHSs in target communities, and provide user training. POs are free to develop their own research and development programs in order to reduce system cost and to improve system quality and reliability. (Urmee et al., 2009).

3. RESEARCH QUESTIONS

This paper will investigate three broad research questions by focusing on SHS initiatives in Bangladesh:  
1. Is small-scale Solar Home System (SHS) a cost-effective solution for off-grid rural households in LDCs?  
2. Who receives the subsidy on SHS and what ethical/equity issues are associated with this?  
3. How sensitive is the rate of adoption of SHS to different income group in rural areas? Is it possible to re-align the scheme to make it for effective for poor households?

The answers will inform the research community about the economics and ethics of SHSs as a solution to providing electric power to remote off-grid rural communities in LDCs.

4. METHODS

This paper is based on extensive literature review, secondary data collection, and field surveys. Since there is now more than a decade of SHS installations in Bangladesh, there are several research papers published in international journals that have investigated different aspects of the questions posed in this paper. This research reviews and summarizes the lessons learned to provide a holistic and coherent understanding about the economics and ethics of SHSs. One paper in particular (Komatsu et al., 2011) approached similar questions and conducted an earlier survey in 2009 focusing primarily on projects implemented by Grameen Shakti in the districts of Kishoreganj, Manikganj, and Comilla. This paper is based on a similar survey conducted in 2012 in the south-western districts of Khulna and Bagherhat implemented by a different PO. The prior research by Komatsu et al. (2011) is used in this research both as baseline and for comparison.
Secondary data collection involves contacting vendors, private companies and NGOs to document the costs and issues related to alternative sources of electricity – especially diesel generators. Some of this information is drawn from brochures and leaflets.

Finally, a comprehensive field survey was carried out in the districts of Khulna and Bagherhat in the south-western coastal region of Bangladesh to understand quality of service of SHSs, demographic composition of SHS users, and whether cost-effective alternative exists for these households or whether a policy-shift could have make this scheme more efficient. The SHSs projects surveyed were implemented by IDCOL’s 7th largest PO: Bangladesh Rural Integrated Development for Grub-Street Economy (BRIDGE). BRIDGE had 15,779 installations (as of November 31, 2011) in 7 districts. In the Khulna and Bagherhat districts, BRIDGE had about 7,000 SHS installations at the time of the survey.

Random samples were drawn from ten different BRIDGE project locations. The initial sampling involved a goal of 1000 surveys distributed over the ten branches. 50% of the surveys (n=500) were carried out with households currently using SHS and the remaining 50% (n=500) surveys were carried out with non-SHS users from the same general area. The purpose of surveying the two groups was to determine equity issues regarding access to SHS, have a control population to document changes achieved by SHS implementation, and carry out economic analysis of potential expansion of SHS market in response to cost reduction. In relation to the last purpose, a choice experiment system was developed where each subsequent household surveyed was given one of several choices regarding its interest in reduced pricing. This goal here is to estimate the price elasticity of demand for SHSs in these communities.

The SHS user survey includes questions to gather data on: demographics (name, age, income, occupation, family size, education, etc.), satisfaction, user-friendliness, cost, maintenance, past energy use, present energy use, quality of life (before/after), idea of alternatives, perception of opportunity cost , etc. The non-user survey includes questions to gather data on: demographics (same variables as before), present energy use, unmet energy needs, idea of alternatives, perception of opportunity costs, and willingness to pay for SHS. Both questionnaires include questions targeted to barriers, benefits, and ethics/equity.

The final sample count is shown in table 1 and a map of the study area is shown in figure 4. The survey questionnaires are attached in Appendix A.

Table 1: Sample count from field surveys.

<table>
<thead>
<tr>
<th>District</th>
<th>Branch</th>
<th>SHS User</th>
<th>Non-SHS user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagherhat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rampal-1</td>
<td>47</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Rampal-2</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Mongla-1</td>
<td>40</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Mongla-2</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Kachua</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Chitalmari</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Kasimpur</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>Khulna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dacope</td>
<td>64</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Batiaghata-1</td>
<td>89</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>Batiaghata-2</td>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>
5. RESULTS

This section includes results from the literature review that address the main research questions. The secondary data collection and field surveys were completed in the months of March and April of 2012. At the time of writing this paper, data entry work was underway. Results from secondary data and field surveys will be presented at the ISEE2012 conference and an updated paper will full results will be uploaded at that time. Below, lessons from past studies on various aspects of SHSs in Bangladesh with some preliminary observations from the field surveys are presented.

5.1 Performance and Maintenance of SHSs

Chowdhury et al. (2011) developed a matrix for analyzing the performance and maintenance of SHSs installed in Bangladesh (see table 2). Their research studied 60 SHSs (between 1 and 7 years old) randomly drawn from four different locations (Nalitabari, Haluaghat, Paikgacha, and Galachipa). Their research revealed various technical and organizational shortcomings. The design of the installed SHSs suffered from over or under-sizing of system components and underperformance of the components with respect to the approved guideline and specifications. There were issues found with the placement of solar...
panels. Some of the flooded-cell batteries used were sub-optimal and in some cases posed health and safety risks. At the upper-organizational level, they identified a need for updating specifications and guidelines in order to keep up with technological developments. The projects also needed to have a process of learning and adapting based on lessons learned from SHS projects in Bangladesh and elsewhere. At the grassroots level, they identified a need for better training of the field operatives. The field offices also lacked proper equipment and facilities to support operation and maintenance of the systems. The above findings suggest an overall need for better design, management, implementation and support for the SHS projects and do not necessarily indicate technical issues with the performance of the SHSs if they are properly installed and maintained. In fact, Biswas (2002) reports that SHS users clearly prefer the quality of light provided by the SHSs compared to the kerosene lamps they used before. They also like the ability to power television, radio and fan. Finally, they like the fact that solar systems do not suffer from load shedding – a common planned power outage that happens frequently in grid electricity delivery system in Bangladesh.

Table 2: Field tests and observations for SHSs (Chowdhury et al. 2011)

<table>
<thead>
<tr>
<th>Category</th>
<th>Tests and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar panel</td>
<td>Orientation, Physical characteristics, Shading, dirt and maintenance, Operating environment</td>
</tr>
<tr>
<td>Battery</td>
<td>Specific gravity, Nominal voltage, Low voltage disconnect, High voltage disconnect, Indicator functioning</td>
</tr>
<tr>
<td>Charge controller</td>
<td>Continuity, Voltage drop, Connectivity, Contact resistance</td>
</tr>
<tr>
<td>Wiring</td>
<td>Start up time, Black spots, Type, Rated load</td>
</tr>
<tr>
<td>Switches</td>
<td></td>
</tr>
<tr>
<td>Lamp-circuit (inverter)</td>
<td>Health and safety, Workmanship and maintenance</td>
</tr>
<tr>
<td>Connected loads</td>
<td></td>
</tr>
<tr>
<td>Installation quality</td>
<td></td>
</tr>
</tbody>
</table>

5.2 Benefits of SHSs

SHSs have been demonstrated to provide a range of benefits consistent with the ones described in section 1.3. Monetary benefits include savings from reduced kerosene use, access to new income generating activities (cell phone charging service, tutoring, more daytime work hours for women), savings in terms of reduced travel cost (or opportunity cost of time) to buy kerosene. Urmee (2009) reports that about 40% of the households with solar home systems use it for income generation – directly or indirectly. Komatsu et al. (2011) documented the benefits of lighting as perceived by the 304 SHS users surveyed and found an overwhelming majority of the sampled households experiencing multiple benefits from SHS powered lighting (see figure 5). Respondents who use SHS for television viewing also revealed that they now have access to news and entertainment and enjoy social interactions with neighbors who visit to watch television together. A significant percent of households reported the benefit of being able to charge mobile phones at home. Probably the first major technological intervention that permeated into even the most remote areas of Bangladesh was the expansion of the mobile phone network. However, without
electricity, households either couldn’t own mobile phones or had to travel and pay for the service of recharging their mobile phones.

During field surveys conducted as part of this paper, informal conversations with SHS users informed that they enjoy the pollution-free indoor environment. A divorced, self-employed woman reported doubling of income from tutoring kids after hours.

5.3 Economics and Equity of SHSs

Biswas et al. (2004) reports that solar electricity is significantly cheaper than diesel generators at the household level in rural off-grid areas of Bangladesh. This is due to poor economy of small scale, where a low electricity consumption is not worth the associated infrastructure costs (i.e., cables, generator). They also find that the substituting kerosene lamps with straight tube fluorescent lamps (SFLs) would be viable as well – yielding positive net benefits. Mondal (2010) conducted six case studies of off-grid SHS users and on average found short payback periods (less than 3 years), positive NPVs and large IRRs (over 39%) – thus indicating SHSs as attractive investments. Considering that many existing financing schemes are designed for three years, the SHS appears to be cost effective.

Mondal (2010) also found that for households not engaged in any kind of income generating activities, the payback period is longer. He argues that in such cases the social and environmental benefits need to be internalized in cost-benefit analysis. For example, two kerosene hurricanes produce 292 kg CO₂ per year if used at the rate of 4 hours per night. If per ton CO₂ reduction cost is about 240 Taka (US$ 3) in
Bangladesh, then this represent a climate mitigation benefit of 70 Taka per year. If the cost of reducing CO₂ emissions is calculated at the current rate in US or European markets, then the value of this benefit would be even higher. However, this is a global benefit and a good reason for channeling external grant support for SHSs in countries like Bangladesh. Also, note that over the life of the system (claimed to be more than 5 years for battery and more than 10 years for the panels), the yearly emission reduction would amount to a more significant number for an average 50W system replacing at least four kerosene lamps.

Currently, SHS users under the IDCOL program receive approximately 10% of the cost through grant money. POs may receive an even smaller percent support for institutional development. The households have to make a 15% down payment of the remaining 90% balance. The rest of the cost is micro-financed at rates between 6% and 12%. At 12% flat interest over a three year period the total interest paid amounts to about 27.5% of the original price before grant support. At 6% flat rate, the total interest paid amounts to about 13.75%. When compared to external grant support, even at the lowest interest rates observed in the field (6%), the total interest paid by the household over the three year life of the loan is greater than the amount of grant support offered to them. The focal point here is that even though the SHS projects in Bangladesh have been largely described as supported by external grants, in reality most of the costs are borne by the consumers through micro-credit programs.

Another consideration regarding cost is whether the households are spending more or less compared to their previous energy sources. Komatsu et al. (2011) reports that the monthly payment for SHSs are significantly higher than previous energy expenditure. This is not inconsistent with results reported earlier regarding replacing two kerosene lamps with two SFLs. In reality, the average solar panel supports more than two SFLs and provides more services. Hence the households are spending more overall, but enjoying more services and greater benefits. Unless the household is engaged in new income generating activities using SHSs, many of these remain as non-monetary benefits. An ethical argument can be made for more equitable provisions where these benefits are subsidized by national and international programs for sustainable development and climate change mitigation.

Finally, it has been observed during the field surveys and also documented in several studies cited earlier in this paper that access to SHSs is still restricted to the relatively more affluent households in these remote rural off-grid communities. This is due to the substantial down payment and larger monthly payments that are associated with SHSs. Komatsu et al. (2011) conducted a choice experiment to find that a 10% discount in price can expand the market of SHSs anywhere from 30% to 60%.

6. CONCLUSIONS

Based on the results reported in section 5, it is evident that SHSs deliver a range of benefits to rural off-grid population in LDCs that contribute to higher quality of life. The technology appears to be reliable and the receiving communities seem to be adapting well with this new technology. However, design, management and implementation related issues often result in lower performance and reliability. There are also shortcomings that have been identified in terms of the quality of maintenance and post-sale services to consumers. These can be addressed by organizational interventions at various levels and through targeted quality control and training programs. The overall system needs to be a learning system so that it can adapt to new advancements in technology.

The economics of SHSs are more complicated as it is intertwined with ethical and equity issues. The SHSs are costlier than prior energy expenditure by the households and can only be afforded by the relatively...
more affluent people in the receiving communities. However, they also provide a range of benefits that directly improve both economic and social well-being of the households. Many of these benefits are difficult to quantify and monetize. If some of the social benefits are subsidized by national development funds and if the more widely distributed benefits of reduced environmental pollution and mitigation of climate change are subsidized by international financing mechanisms, then the cost of the SHSs would go down. This will allow for more homes to be powered by SHSs in off-grid rural areas in LDCs – thus creating a positive cycle of human development and environmental stewardship.

7. ACKNOWLEDGMENTS

Partial funding for this research was provided by the H.H. Powers Travel Grant awarded to Md. Rumi Shammin and the remaining cost was supported by the research portfolio of Md Rumi Shammin at Oberlin College. The authors like to acknowledge the contributions of the following individuals: Mr. Zohurul Haque, Executive Director of BRIDGE, for logistical support; Mr. Akhtarujjaman Shohel for survey development and supervision; Eashan Ahmed and Abu Mosayeb – undergraduate research assistants at United International University, Bangladesh; Amanda Jacir and Savitri Sedlacek – undergraduate research assistants at Oberlin College, USA; and student assistants from local colleges in the Khulna/Bagherhat area who carried out the field surveys - Md. Tanvir Rahman, Md. Suez Khan, Md. Kamruzzaman, Md. Robiul Islam, and Md. Arif Hossain.

REFERENCES


APPENDIX A

Two questionnaire surveys are attached in the following pages – one designed for SHS users and the other designed for SHS non-users.
Informed Consent for Survey Participant

We invite you to participate in a research survey on the economics and equity of solar home systems (SHS) installed in your area by Bangladesh Rural Integrated Development for Grub-Street Economy (BRIDGE) as part of the Solar Energy Program funded by the Infrastructure Development Company Limited (IDCOL). Your name has been randomly drawn from a list of people who are either current SHS participants or live in a community where some households are participants in the SHS program. Researchers at Oberlin College (USA) and United International University (Bangladesh) are conducting this survey. The research is funded by faculty research portfolio of Oberlin College.

Your participation is voluntary. The identities of people who complete the survey will be kept confidential, and no one’s name will be listed in the report or linked with responses. Survey responses will be kept in a locked file and access will be limited to the surveyors, researchers, and the College’s review board responsible for protecting human participants. The survey takes about 20 minutes to complete. There are no foreseeable risks or direct benefits for completing this survey. You will not receive any type of compensation for completing this survey. You have the right to discontinue the survey at any time without penalty and have the right to skip questions. Participants will be given a copy of the consent form to keep for their records.

The results of this survey will only be shared with researchers, policy makers and other major stakeholders for the purpose of developing policies and programs for the development of solar home systems in Bangladesh and other less developed countries. We will summarize the findings from the survey in the form of reports, presentations, and journal/popular publications. These will not include any information that makes it possible to identify a participant.
জরিপে অংশগ্রহণকারীদের সমন্বিতকৃতে

Infrastructure Development Company Limited (MCDL) এর অংশান্তর সৌরবিজ্ঞান কর্মসূচির অংশীভূতে Bangladesh Rural Integrated Development for Grub Street Economy (BRIDGE), স্ব স্ব অর্থনীতিক এবং সৌরাঞ্জনা হোম সিস্টেমের (সৌরবিজ্ঞান পায়নী মলভুক্ত) এর সমন্বিতকৃত উপর একটি গবেষণা জরিপে অংশগ্রহণের জন্য আমরা আপনাকে আমন্ত্রণ জানাচ্ছি। আপনার নাম ঐসব লোকের একটি তালিকা হতে বিক্ষিপ্ত ভাবে দেওয়া হয়েছে যাতে বর্তমানে হয় সৌরাঞ্জনা হোম সিস্টেম এর ব্যবহারকারী অথবা এমন সমস্ত বসবাসকারী যেখানে কোন কোন পরিবার সৌরাঞ্জনা হোম সিস্টেম ব্যবহার করছে। OBERLIN কলেজ (মার্কিন যুক্তরাষ্ট্র) এবং ইউনাইটেড ইন্টার-স্কাইনাল ইনিয়ারিংসটি (বাংলাদেশ) এই জরিপটি পরিচালনা করছে। এই গবেষণার সকল ধরনের অর্থায়ন করা হয় OBERLIN কলেজের পিস্টোরিকালি বিভাগ।

এই জরিপে আপনার অংশগ্রহণের এলেক্টারী। জরিপ সম্পাদকের পরিচার সম্পূর্ণভাবে গোপন রাখা হবে এবং পাঠিয়ে দেওয়া প্রতিকৃতির সাথে যুক্ত করা নাই প্রতিষ্ঠানের তালিকাত্তুক করা হবে না। জরিপ হতে প্রায় সম্পূর্ণ সমূহ একটি গোপন ফাইলে সরবরাহের চাহিদা করে যার প্রয়োজনকরণ জরিপকারীদের মাধ্যমে সম্পর্ক থাকবে গবেষক এবং কলেজের এর রিটিও অংশগ্রহণকারীদের নির্দেশের জন্য দায়বদ্ধ থাকবে। জরিপটি সম্পূর্ণ করতে রিপ মিনিট সময় লাগবে। এই জরিপ সমন্বয় করার ফলে সকল অন্যান্য নীতি বা অন্য সম্পর্কে কোনো সূত্র দেই যে কেনো প্রকার অবদান দিতা হাটাইয়া আপনার জরিপ পুনরায় বক্তৃতা করার এবং নেই সাথে যোগাযোগ পদ্য তাদের বিশেষ সংগ্রাম রয়েছে এবং জরিপে অংশগ্রহণকারীদেরকে তাদের গবেষণার সমর্থন জন্য একটি নকল পাত্র দেওয়া হবে।

বাংলাদেশ এবং অন্যান্য সহযোগিতা সেলে এটাই বিশ্বের শিক্ষাবিদ্যা ও জ্ঞানসূচির উন্নয়নের জন্য পাঠদান ও কর্মসূচির উন্নয়নের উদ্দেশ্যে জরিপের ফলাফল কেবলমাত্র গবেষক, বীর্যনির্দিষ্ট এবং সম্পূর্ণ উত্তরাধিকার পর্যালোচনা করবেন। জরিপ হতে প্রাপ্ত তথ্যের আবার অভিগমন, মাধ্যমিক এবং পরিচয় অন্যান্য জটিল প্রশ্নের আচার আচার করব। সেখানে অংশগ্রহণ করার ক্ষেত্রে সকল কোনো তথ্য উদ্ধৃত থাকবে না।
If you have any questions, comments, or concerns about this survey or if you wish to exercise your right to withdraw from the research project or complete the survey, you can contact Dr. Md Rumi Shammin at Oberlin College (rumi.shammin@oberlin.edu, tel: +1-440-775-5316). If you have any concerns about your rights as a participant, you can contact Heather Hogan, Chair of the Oberlin College Institutional Review Board (heather.hogan@oberlin.edu, tel: +1-440-775-8410).

Given the above information, I have the following questions.

1. Is your age above 18? □ Yes =1 No=2
   আপনার বয়স কি ১৮ বছরের বেশী?
   ১া. If yes, are you willing to participate in this survey? □ Yes=1 No=2
   যা হলে, আপনি কি আমাদের এই জরীপে অংশগ্রহণ করতে চান?
   If No, thank you. INTERVIEW ENDS HERE.
   যা হলে, আপনাকে অনেক ধন্যবাদ।
   ১b. If Yes to questions 1a, then
   যা হলে, নিচে উল্লিখিত নাম লিখুন ও প্রশ্নগুলি নিচে যাপন করুন।

I certify that the respondent has agreed voluntarily to provide information and participate in this research.

নাম প্রদান করে যে, উল্লিখিত নামের এই জরীপে অংশ প্রদান করতে চাই।

Name of person administering the survey:__________

Signature [স্পন্দন]

Location of the household:

District _______ Thana _________ Village _________

Enumerators ID Code:

1=Tanvir Rahman 01726260062
2=Md. Sabeur Khan 01725714695
3=Md. Kamruzzaman 01719635219
4=Md. Robiul Islam 01731445445
5=Md. Arif Hossain 01721369776
SOLAR HOME IMPACT STUDY

Household questionnaire

Module 1 - Information on Respondent

Name ____________________________

Address ____________________________

ঠিকানা ____________________________

1.1 Age [একক জন্ম পূর্বায় একজন বয়স নামাজ]

বয়স ____________________________

1.2 Gender [code- 1=Male, 2=Female]

লিঙ্গ [কেন্দ্রীয় ১=পুরুষ, ২=পুরনী]

1.3 Marital Status [code- 1=Single, 2=Married, 3=Divorced/separated, 4=Widow/Widower]

বৈসাদিক অবস্থা ____________________________

[কেন্দ্রীয় ১=বিবাহিত, ২=বিবাহিত, ৩=বিবাহৰ না শিক্ষিত, ৪=বিবাহিত/বিবাহৰ]

Module 2 - Household Profile

A Household is a dwelling unit where one or more persons live and eat together under a common cooking arrangement. [একটি ঘরের বা HOUSEHOLD সদস্য তুলনা একজন শ্রমিকের সহায়তা যারা একত্র সদস্য করে এবং একটি ঘরের বাড়ি প্রতিনিধিত্ব করে]

2.1 Family Size: male, □ female □

পরিবারের সদস্য সংখ্যা পুরুষ ডাক

A family member is a person who depends on the family. (Include children)

�কটি পরিবারের সদস্য তারাই যা পরিবারের উপর নির্ভরশীল [পিতা সহ]

2.2 Number of children in household □ (aged 14 or below)

পরিবারের ১৪ বছরের নীচে বয়সের শিক্ষার প্রথম সংখ্যা

2.3 Household Status: □ প্রতিনিধিত্ব করেন

<table>
<thead>
<tr>
<th>serial</th>
<th>Status Code বিভাগ প্রস্তাব অবস্থা</th>
<th>Male সংখ্যা</th>
<th>Female সংখ্যা</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Child (not old enough for school) শিক্ষা</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Student পার্শার</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No job কৃষি করেন</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Looking for job কৃষি করেন</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Government/Non-government worker সক্রিয় করেন</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Industrial worker সক্রিয় করেন</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Farmer কৃষিকর</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Poultry/Livestock farming খামারকের</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Fishing/Fisherman লাঙ্গের</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Day laborer লাঙ্গের</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Rickshaw puller লাঙ্গের</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Shop business শিক্ষার</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Business শিক্ষার</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>House owner রাজকর</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Other অন্যান্য</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.4 Educational Qualification: [List educational attainment of family members who are currently not student and are 7+ year of age]

<table>
<thead>
<tr>
<th>Gender</th>
<th>Highest Educational Level</th>
<th>Lowest Educational Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(code- 1=illiterate, 2=Primary (Class 1-5), 3=High School (Class 6-10), 4=SSC/Dhakil/Equivalent, 5=HSC/Fazil/Equivalent, 6=Bachelor, 7=Masters, 8=Medical/Engineering, 9=Diploma/Polytechnic, 10=Others, 11=Postgraduate)

2.5 Number of earners in your family- ☐ male, ☐ female

An earner is a person who brings material return in cash or kind for services rendered and for the use of goods. Earners bring both family and market income.

2.6 What is the educational level of the head of the household? ☐

Note: Head of the household means a member of the household who is the decision-maker regarding the decision-making of the household. In this case, the head of the household is the person who makes decisions about the household's activities.

(code- 1=illiterate, 2=Primary (Class 1-5), 3=High School (Class 6-10), 4=SSC/Dhakil/Equivalent, 5=HSC/Fazil/Equivalent, 6=Bachelor, 7=Masters, 8=Medical/Engineering, 9=Diploma/Polytechnic, 10=Others, 11=Postgraduate)

2.7 What is the occupation of the head of the household? ☐

(code- 1=Student, 2=No job, 3=Looking for job, 4=GO/NGO worker, 5=Teacher, 6=Farming, 7=Service provider, 8=Poultry/Livestock Farming, 9=Fisheries, 10=Day laborer, 11=Rickshaw puller, 12=Shop business, 13=Business family, 14=House owner)

2.8 Household Income ☐ [code for income as given below] per ☐ [code for duration]

Note: Income means material return in cash or kind received in exchange of goods and services in a particular period. Paying of wage is not considered as income. In case of self-employed, the income is considered.

[code for income]: 1=No income, 2=1-300, 3=300-500, 4=500-700, 5=700-900, 6=900-1200, 7=1200-1500, 8=1500-1700, 9=1700-2000, 10=2000-2500, 11=2500-3000, 12=3000-3500, 13=3500-4000, 14=4000-5000, 15=5000-6000, 16=6000-7000, 17=7000-8000, 18=8000-10000, 19=10000+

[code for duration]: 1=week, 2=two week, 3=three week, 4=month)
2.9 Type of home  

[Code: 1=Pacca, 2=semi-Pacca, 3=Thatched, 4=Golpata, 5=Other]  

2.10 Location of home  

[Code: 1=Rural, 2=Rural town center, 3=Rural town periphery]  

2.11 Is your house inside a municipality area?  

[Code: 1=Yes, 2=No]  

2.12 If No, how far is the nearest municipal town?  

In KM  

PLEASE GO TO NEXT PAGE
Module 3: System Information [User]

3.1 Type of system (model number)

3.2 Size of system

3.3 Date received

3.4 Number of electrical devices in use:

<table>
<thead>
<tr>
<th>Lights</th>
<th>Fans</th>
<th>TV</th>
<th>Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charger Light</td>
<td>Mobile phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ ]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5 Which on have you used to pay for your SHS?

<table>
<thead>
<tr>
<th>Code</th>
<th>response for multiple systems, if any.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 year, 12 installments, 6% service charge</td>
</tr>
<tr>
<td>2</td>
<td>2 year, 24 installments, 6% service charge</td>
</tr>
<tr>
<td>3</td>
<td>3 years, 36 installments, 6% service charge</td>
</tr>
<tr>
<td>4</td>
<td>Full payment with discount</td>
</tr>
</tbody>
</table>

Module 4: Prior Energy Use [Users]

4.1 What source of energy for living did you use before getting this system?

4.1a How long did you use to use this energy?

4.2 Living cost per month

4.3 What were problems with that energy source?

4.4 Did it affect the education of any member in the household?

4.4a How?

4.5 Did solar system affect the occupation of any member in the household?

4.5a How?
4.6 Did it affect the convenience of any member in the household? [code: 1=Yes, 2=No]

Convenience means "ease of access; suitable, aordable or proper."

4.6a How? □ □ □

Module 5: Solar Energy Use [users]

5.1 Is solar power better than your prior source? [code: 1=Yes, 2=No]

5.1a If yes, how much? [code: 1=not much, 2=little, 3=moderate, 4=a lot, 5=extraordinary]

5.1b If no, why?

5.2 How long do you use solar power?

5.3 What aspect of your life is better now [due to SHS]?

5.4 What do you think are the problems with solar system?

5.5 How much does it cost?

5.6 Solar housing system has zero operating cost. Do you save this money? [code: 1=Yes, 2=No]

5.6a If yes, how do you use the extra money?

5.7 How satisfied are you with your system?

5.7a If dissatisfied, why?

[Code: 1=not satisfied, 2=so-so, 3=okay, 4=satisfied, 5=very satisfied]
5.8 Is solar power enough for you?

Yes [ ], No [ ]

5.8a If no, what are less?

- Lights [ ]
- Fans [ ]
- TV [ ]
- Radio [ ]
- Charger Light [ ]
- Mobile phone [ ]
- Other [ ]

5.9 Would you support initiatives to further expand solar projects in your area?

Yes [ ], No [ ], Maybe, Not sure [ ]

5.10 Who do you think benefited it the most?

- Farmers [ ]
- Manufacturers [ ]
- Service men [ ]
- Professionals [ ]
- Low income group people [ ]
- Average income group people [ ]
- High income group people [ ]
- Owners of shops and homes [ ]
- Other [ ]

5.11 Who do you think are negatively affected by it?

- Farmers [ ]
- Manufacturers [ ]
- Service men [ ]
- Professionals [ ]
- Low income group people [ ]
- Average income group people [ ]
- High income group people [ ]
- Owners [ ]
- Other [ ]

5.12 Who do you think is left behind?

- Farmers [ ]
- Manufacturers [ ]
- Service men [ ]
- Professionals [ ]
- Low income group people [ ]
- Average income group people [ ]
- High income group people [ ]
- Owners [ ]
- Other [ ]

5.13 Can you think of other alternatives that could be used if solar systems were not available?

Yes [ ], No [ ]

5.14 These alternatives in your opinion are:

- More cost effective [ ]
- More user friendly [ ]
- More convenient [ ]
- Easily maintainable [ ]
- Worse [ ]

5.15 Did you face any problem in maintaining SHS?

Yes [ ], No [ ]

5.15a If yes, what are they?

- Costly [ ]
- Takes too much time [ ]
- Dirty [ ]
- Confusing/difficult to understand [ ]
- Other [ ]

5.16 Do the community providers visit every month?

Yes [ ], No [ ]
5.17 If no, how often do they come? [in months, if they don’t come at all, use 0]
(0=never, 1=at most every 2 weeks, 2=every 2 weeks, 3=every 4 weeks, 4=every 8 weeks, 5=at least every month)

5.18 What do the community providers do?

5.19 Did you have to spend any extra money? [code: 1=Yes, 2=No]

Module 6: Choice experimental Ques. on [users]

6.1 You have purchased a _______ [Q3.2] unit SHS for your home already. If you are asked to buy an additional SHS unit of choice 20Wp, for which you have to pay Tk.1,452 as down payment and Tk.297 as monthly installment for 3 years,

6.2 If No, are you willing to purchase this unit as cash payment for Tk.9675? [code: 1=Yes, 2=No]

6.3 If Yes, why might you want to buy the extra unit? [max four]

6.4 If No, why? [max three]

(1=Because it will have a negative impact on my household, 2=It is costly, 3=I do not need it anymore, 4=I cannot afford it, 5=Others)
Informed Consent for Survey Participant

We invite you to participate in a research survey on the economics and equity of solar home systems (SHS) installed in your area by Bangladesh Rural Integrated Development for Grub-Street Economy (BRIDGE) as part of the Solar Energy Program funded by the Infrastructure Development Company Limited (IDCOL). Your name has been randomly drawn from a list of people who are either current SHS participants or live in a community where some households are participants in the SHS program. Researchers at Oberlin College (USA) and United International University (Bangladesh) are conducting this survey. The research is funded by faculty research portfolio of Oberlin College.

Your participation is voluntary. The identities of people who complete the survey will be kept confidential, and no one's name will be listed in the report or linked with responses. Survey responses will be kept in a locked file and access will be limited to the surveyors, researchers and the College's review board responsible for protecting human participants. The survey takes about 20 minutes to complete. There are no foreseeable risks or direct benefits for completing this survey. You will not receive any type of compensation for completing this survey. You have the right to discontinue the survey at any time without penalty and have the right to skip questions. Participants will be given a copy of the consent form to keep for their records.

The results of this survey will only be shared with researchers, policy makers and other major stakeholders for the purpose of developing policies and programs for the development of solar home systems in Bangladesh and other less developed countries. We will summarize the findings from the survey in the form of reports, presentations, and journal/popular publications. These will not include any information that makes it possible to identify a participant.
জরিপে অশ্রুশালকারীদের সমস্তিক্রমে

Infrastructure Development Company Limited (MCDL) এর অর্থায়নে দৌরবিদ্ধ কর্মসূচির অংশহিসাবে Bangladesh Rural Integrated Development for Grub Street Economy (BRIDGE). হিসিভিত অর্থনৈতিক এবং সোসার হোম সিস্টেমের (সোসার বিদ্যুৎ গৃহীত প্রক্রিয়া) এর সমন্বয়ের উপর একটি গবেষণা জরিপে অংশগ্রহণের জন্য আমরা আপনাকে অভিনন্দন জানাচ্ছি। আপনার নাম উল্লেখের একটি ভালোবাসা অথবা বন্ধুত্ব যেমন দেওয়া হয় তাতে বিভিন্ন ভাবে নেওয়া হচ্ছে যারা বর্তমানে হয় সোসার হোম সিস্টেম এর ব্যবহারকারী অথবা এমন সময়ে বসবাসকারী যেখানে কেন্দ্রীয় পরিষদের সোসার হোম প্রযুক্তি ব্যবহার করছে। OBERLIN কলেজ (মার্কিন যুক্তরাষ্ট্র) এবং ইউনাইটেড ইন্টার-ম্যানেজমেন্ট ইন্টারন্যাশনাল স্ট্যাটাস ইন্টারন্যাশনাল (বাংলাদেশ) এই জরিপটি পরিচালনা করছে। এই গবেষণার সকল ধারণার অস্বাভাবিক করছে OBERLIN কলেজের ফিল্ড ফোকালিও বিভাগ।

এই জরিপে আপনার অশ্রুশাল লেখা প্রদানি। জরিপ সম্পাদকদের পরিচয় সম্পূর্ণভাবে গোপন রাখা হবে। এবং প্রতিবেদন অথবা প্রতিক্রিয়ার সাথে যুক্ত করার নামই প্রতিক্রিয়া অবলম্বন করা হবে না। জরিপ হতে একটি মতামত সম্পূর্ণ একটি গোপন ফাইলে সংরক্ষিত থাকবে যার প্রবেশাধিকার জরিপকারীদের মধ্যেই নির্ধারণ থাকবে। গবেষণা এবং কলেজের এক দর্শন জরিপে অংশগ্রহণকারীদের নিজস্ব প্রদর্শনের জন্য দায়বদ্ধ থাকবে। জরিপটি সম্পূর্ণ করতে বিশ মিনিট সময় লাগবে। এই জরিপ সম্পন্ন করার কোনো ভেদ্য বেঁধে থাকতে নেই যেহেতু সরলতর কোনো সুবিধা নেই। যে কোনো বিদ্যালয় আবাসিক জরিপ পুনর্বতন বসন্ত করা এবং সেই সাথে যেকোনো একটি বাদ দেয়ার অধিকার রয়েছে। জরিপে অশ্রুশালকারীদেরকে তাদের সমস্ত সংক্রান্ত জন্য একটি নকল পাঠ দেয়া হবে।

বাংলাদেশ এবং অন্যান্য দেশাতেও সহযোগিতায় শহুরের SHS উন্নয়নের জন্য পদ্ধতি ও কর্মসূচির উন্নয়নের উদ্দেশ্যে জরিপের ফলাফল কেবলমাত্র গবেষণার, বিতর্কনীতির এবং সংস্কৃতি অন্তর্ভুক্ত ব্যাপােচারের পরিশ্রমীরা করবেন। জরিপ হতে বাঙালি অন্যরা প্রতিবেদন, প্রসারণ এবং প্রতিক্রিয়া অথবা জনগণ প্রকাশনার আকর্ষণ প্রতিষ্ঠান করবে। সেখানে অংশগ্রহণ করীদেরকে চিহ্নিত করতে সকল কোনো তথ্য উদ্দেশ্য থাকবে না।
If you have any questions, comments, or concerns about this survey or if you wish to exercise your right to withdraw from the research project after completing the survey, you can contact Dr. Md Rumi Shammin at Oberlin College (rumi.shammin@oberlin.edu, tel: +1-440-775-5316). If you have any concerns about your rights as a participant, you can contact Heather Hogan, Chair of the Oberlin College Institutional Review Board (heather.hogan@oberlin.edu, tel: +1-440-775-8410).

The following information must be completed.

1. Is your age above 18?  [ ] Yes = 1  No = 2
   आপনার বয়স কি ১৮ বছরের বেশী?

1a. If yes, are you willing to participate in this survey?  [ ] Yes = 1  No = 2
   হলে, আপনি কি আমাদের এই জরুরী অনুষ্ঠান করতে চান?

If No, thank you. INTERVIEW ENDS HERE.

না হলে, আপনকে ধন্যবাদ।

1b. If Yes to ques. on 1a, then
   হলে, নিচে উত্তরদাতার নাম লিখুন ও প্রশ্নাত্ত নিচে রাখুন করুন।

I certify that the respondent ___________________________________________ has agreed voluntarily to provide information and participate in this research.

নিচে প্রশ্নাত্ত করছি যে, উত্তরদাতার স্বাক্ষর এই জরুরী অনুষ্ঠান করতে স্বীকার করে।

Name of person administering the survey:

তথ্যসূত্রকর্মীর নাম

Date:

Signature [স্বাক্ষর]

Location of the household:

District _______  Thana _________  Village _________

Enumerators ID Code:

1= Tanvir Rahman 01726260062
2= Md. Saeed Khan 01725714695
3= Md. Kamruzzaman 01719635219
4= Md. Robiul Islam 01731445445
5= Md. Arif Hossain 01721369776
SOLAR HOME IMPACT STUDY

Household questionnaire

Module 1- Information on Respondent

Name __________________________

Address ________________________

1.1 Age [একেক জন গৃহীত একটি নাম্বার বসাও]
   বয়স
   1.2 Gender [code- 1=Male, 2=Female]
   লিঙ্গ [কোথা ১=পুরুষ, ২=ফেমাল]
1.3 Marital Status [code- 1=Single, 2=Married, 3=Divorced/separated, 4=Widow/Widower]
   বৈষম্যক বিবাহ
   [কোথা, ১=বিবাহিত, ২=বিবাহিত, ৩=ব্যবস্থাপত্তক বা ব্যবস্থাপত্তক, ৪=বিবা:বিবাহীত]

Module 2- Household Profile

A Household is a dwelling unit where one or more persons live and eat together under a common
cooking arrangement. [একটি মাজী বা HOUSEHOLD এরতে যেকোনো একজন লিখনিবেদনের সাথে যায় একজন সদস্য হয় এবং
এক মাজী বাসা বাসা প্রেরণ করেন]

2.1 Family Size: male, ___ female ___
   পরিবারের সদস্য সংখ্যা পুরুষ স্ত্রী
   A family member is a person who depends on the family. (Include children)
   একটি পরিবারের সদস্য জাতীয় যার পরিবারের উপর নির্ভর প্রতি প্রতি সত্ত্বা]
   2.2 Number of children in household ___ (aged 14 or below)
   পরিবারে ১৫ বছরের নিচের বয়সের পুরুষ/নিম্নের সংখ্যা

2.3 Household Status: প্রকাশিত অবস্থা:

<table>
<thead>
<tr>
<th>serial</th>
<th>Status Code</th>
<th>প্রকাশিত অবস্থা</th>
<th>Male সূচনা</th>
<th>Female সূচনা</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Child (not old enough for school) শিক্ষা</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Student শিক্ষা</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No job চাকুরী নাই</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Looking for job চাকুরী উদ্যোগ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Government/Non-government worker সরকারি/নাগরিক কর্মী</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Industrial worker শিল্পী কর্মী</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Farmer উদ্যোক্তা</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Poultry/Livestock farming বাসুন্ধরীন, পশুবাড়ি কর্ম</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Fishing/Fisherman পর্যায়ী, পালা পালন</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Day laborer দিনকালীন</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Rickshaw puller বিজয়</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Shop business শেখারপত্র বিকাশ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Business ব্যবসা</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>House owner জমিদার/বাটিকে গন্ধ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Other অন্য</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.4 Educational Qualification: [List educational attainment of family members who are currently not student and are 7+ year of age]

<table>
<thead>
<tr>
<th>Gender</th>
<th>Highest Educational Level</th>
<th>Lowest Educational Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>সর্বোচ্চ শিক্ষার যোগাযোগ</td>
<td>সর্বনিম্ন শিক্ষার যোগাযোগ</td>
</tr>
<tr>
<td>Female</td>
<td>সর্বোচ্চ শিক্ষার যোগাযোগ</td>
<td>সর্঵নিম্ন শিক্ষার যোগাযোগ</td>
</tr>
</tbody>
</table>

Note: (Code: 1=Illiterate, 2=Primary (Class 1-5), 3=High School (Class 6-10), 4=SSC/Oakhil/Equivalent, 5=HSC/Fazil/Equivalent, 6=Bachelor, 7=Masters, 8=Medical/Engineering, 9=Diploma/Polytechnic, 10=Others)

2.5 Number of earners in your family- ☐ male, ☐ female

An earner is a person who brings material return in cash or kind for services rendered and for the use of goods. বিভিন্ন উপায়ের অন্তর্ভুক্ত হতে পারে।

2.6 What is the educational level of the head of the household? ☐

Note: Head of the household means a member of the household who is the decision-maker regarding the different aspects of the household. পরিবারের ব্যাপারের সম্পর্কে নির্ণয়ের কর্তা হিসেবে পরিবারের প্রধান সদস্যকে বর্ণনা করা যেতে পারে।

2.7 What is the occupation of the head of the household? ☐

Note: Occupation means the main source of income or any other activity in which the person is engaged. পরিবারের প্রধান সদস্যের রাষ্ট্রীয় অর্থনৈতিক উৎসের সম্পর্কে বিবরণ দিয়ে যেতে পারে।

2.8 Household Income ☐ [code for income as given below] per ☐ [code for duration]

Note: Income means the total amount of money earned in exchange of goods and services in a particular period. পরিবারের আয় তথ্য  প্রদানের জন্য পরিবারের অর্থনৈতিক উৎসের তথ্য দিয়ে যেতে পারে।

[Code for Income]: 1=Income, 2=1-300, 3=300-500, 4=500-700, 5=700-900, 6=900-1200, 7=1200-1500, 8=1500-1700, 9=1700-2000, 10=2000-2500, 11=2500-3000, 12=3000-3500, 13=3500-4000, 14=4000-5000, 15=5000-6000, 16=6000-7000, 17=7000-8000, 18=8000-10000, 19=10000+]

[Code for duration]: 1=week, 2=two week, 3=three week, 4=month]
2.9 Type of home

[Code: 1=Pacca, 2=Semi-Pacca, 3=Tin/Taili roof, 4=Thatched, 5=Golpata, 6=Other______]

2.10 Location of home

[Code: 1=Rural, 2=Rural town center, 3=Rural town periphery]

2.11 Is your house inside a municipality area?

[Code: 1=Yes, 2=No]

2.12 If No, how far is the nearest municipal town?

In KM

INTENTIONALLY LEFT BLANK

PLEASE GO TO NEXT PAGE
Module 7 - Current Energy Use

7.1 What source of energy for lighting do you use? □ □ □
(নাম: এলাকা, ২=কেরামিক, ৩=মেটালিক, ৪=চালুক্য, ৫=সয়াপূর, ৬=হালকা, ৭=হালকা, ৮=শুরু, ৯=হালকা, ১০=লালাহ, ১১=হালকা, ১২=লালাহ)

7.2 How much does it cost? Tk. □□□□□
(সার্কিল করুন)

7.3 What are the problems with this energy source? □ □ □ (maximum three reasons)
(নিবন্ধন তিনটি করুন)
(নেক-১=জল দুর্বল, ২=জল জলজ, ৩=সূচনা, ৪=হালকা, ৫=হালকা, ৬=শুষ্ক, ৭=বাবার পাঁচোরা বারে না, ৮=আয়রন রসায়ন উপরে অক্ষ, ৯=অন্যান্ত)

7.4 How long do you use this energy? □□□□□
(নিবন্ধন তিনটি করুন)

7.5 Does your current energy source affect the education of any member in the household? [ ]
(নিবন্ধন তিনটি করুন)

7.6a Did solar system affect the education of any member in the household? [ ]
(নিবন্ধন তিনটি করুন)

7.6b How? □□□□□
(নিবন্ধন তিনটি করুন)

7.7 Did it affect the convenience of any member in the household? [ ]
(নিবন্ধন তিনটি করুন)

7.7a How? □□□□□
(নিবন্ধন তিনটি করুন)
Module 8- Interest in Solar Power

8.1 Do you know about solar power? [code- 1=Yes, 2=No] 
(কেউ: ১=হাজ, ২=না)

8.2 Are you interested in solar power? [code- 1=Yes, 2=No] 
(কেউ: ১=হাজ, ২=না)

8.3 Do you think solar power would be better than your current source? [code- 1=Yes, 2=No] 
(কেউ: ১=হাজ, ২=না)

8.3a If yes, how much? [code- 1=Little bit, 2=moderate, 3=alot, 4=extraordinary] 
(কেউ: ১=একটু, ২=মাত্র, ৩=অনেক, ৪=অতিশীল)

8.3b What aspects of your life would be better? (maximum three reasons) 
(কেউ: ১=শিখান, ২=শান্তি, ৩=নিরস্ত, ৪=সুস্থিত, ৫=নয়, ৬=একটু অন্য, ৭=অন্যান্য)

8.4 What are the barriers to getting the solar system? 
(কেউ: ১=স্বর্থ, ২=মাস্টার, ৩=স্বর্থ, ৪=স্বর্ণ, ৫=নয়, ৬=অন্যান্য)

8.5 If the cost was less, would you be able to afford it? [code- 1=Yes, 2=No] 
(কেউ: ১=হাজ, ২=না)

8.6 Would you support initiatives to further expand solar projects in your area? 
(কেউ: ১=Yes, 2=No, 3=Maybe, 4=Not sure)

8.7 Who do you think benefits from it the most? (max two reasons) 
(কেউ: ১=স্বর্থ, ২=মাস্টার, ৩=স্বর্ণ, ৪=স্বর্ণ, ৫=নয়, ৬=অন্যান্য)

8.8 Who do you think are negatively affected by it? 
(কেউ: ১=স্বর্থ, ২=মাস্টার, ৩=স্বর্ণ, ৪=স্বর্ণ, ৫=নয়, ৬=অন্যান্য)
8.9 Who do you think is less behind?

[Code: 1=Farmers, 2=Manufacturers, 3=Service men, 4=Professionals, 5=Low income group people, 6=Average income group people, 7=High income group people, 8=Owners, 9=Other]

8.10 Can you think of other alternatives that could be used if solar systems were not available?

[Code: 1=Kerosene light, 2=biogas, 3=generator, 4=others]

8.11 These alternatives in your opinion are (maximum three codes)

[Code: 1=be er, 2=more cost e ec ve, 3=more user friendly, 4=more convenient, 5=easily maintainable, 6=Worse, 7=Other]

Module 9: Choice experimental Questions on non-users

9.1 You know that Solar Home System is an alternative energy and you can use this for lighting, and also for viewing TV plus charging mobile and so on. You are currently spending an amount of Tk. ___________[7.2] per month only for lighting. If you are asked to purchase an SHS 20Wp for your home which you can use for 2 CFL lights, for which you have to pay Tk.1,452 as down payment and Tk.297 as monthly installment for 3 years.

9.2 Will you be willing to purchase this unit?

[Code: 1=Yes, 2=No] >>> skip 9.2, if yes.

9.3 If No, are you willing to purchase this unit as cash payment for Tk. 9675?

[Code: 1=Yes, 2=No]

9.4 If Yes, why?

[Code: 1=Because it will have a positive impact on my household, 2=Income will increase, 3=be better life at home, 4=for education of my child, 5=Cheaper than I thought, 6=Other]